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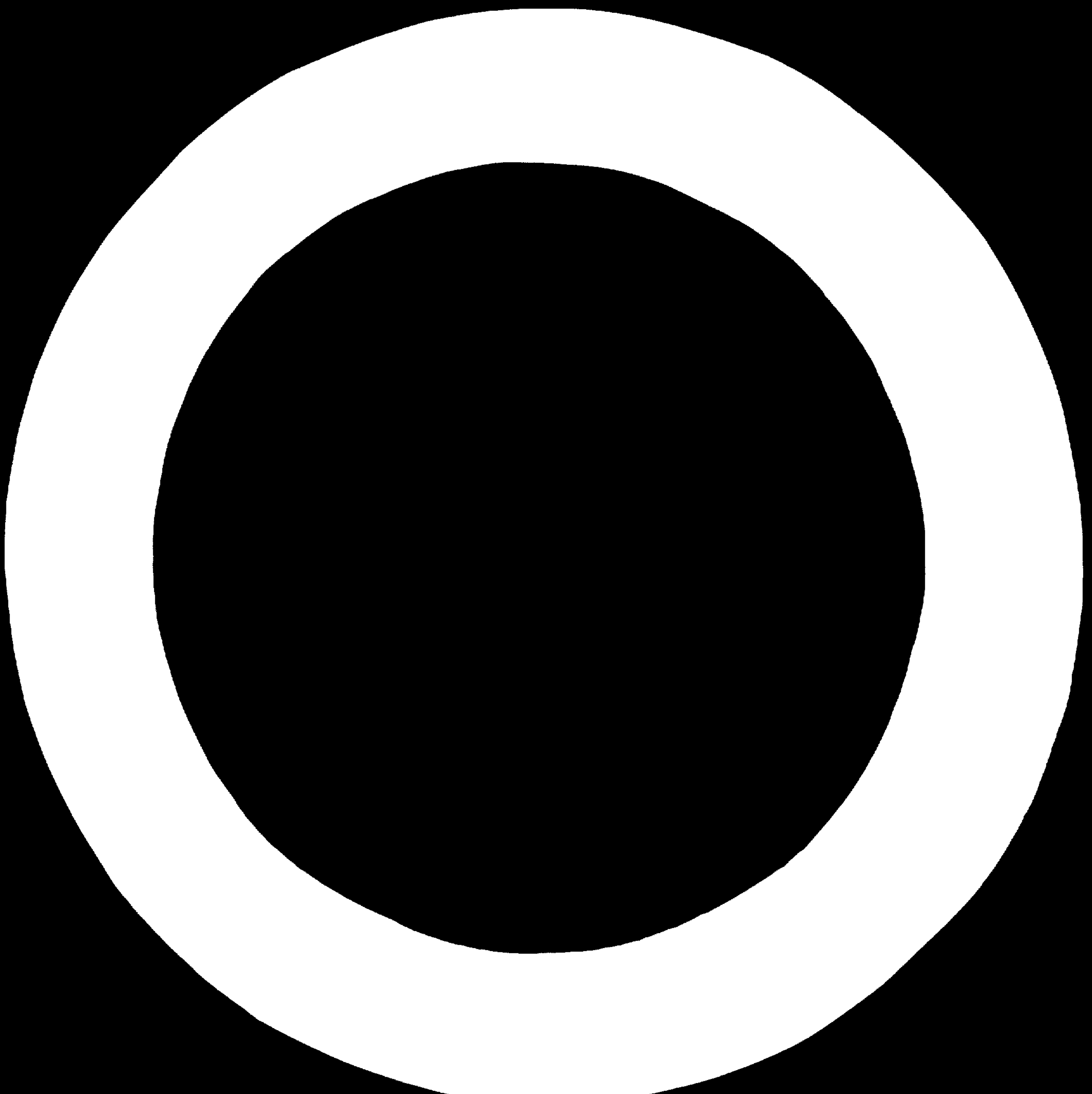
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

Industrial Planning and Programming Series No. 3

Planning for Advanced Skills and Technologies

UNITED NATIONS



TED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, VIENNA

DUSTRIAL PLANNING AND PROGRAMMING SERIES No. 3

PLANNING FOR ADVANCED SKILLS AND TECHNOLOGIES

Studies presented at the Ad Hoc Meeting of Experts on the Role of Advanced Skills and Technologies in Industrial Development, New York, 22 – 30 May 1967

UNITED NATIONS

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PREFACE

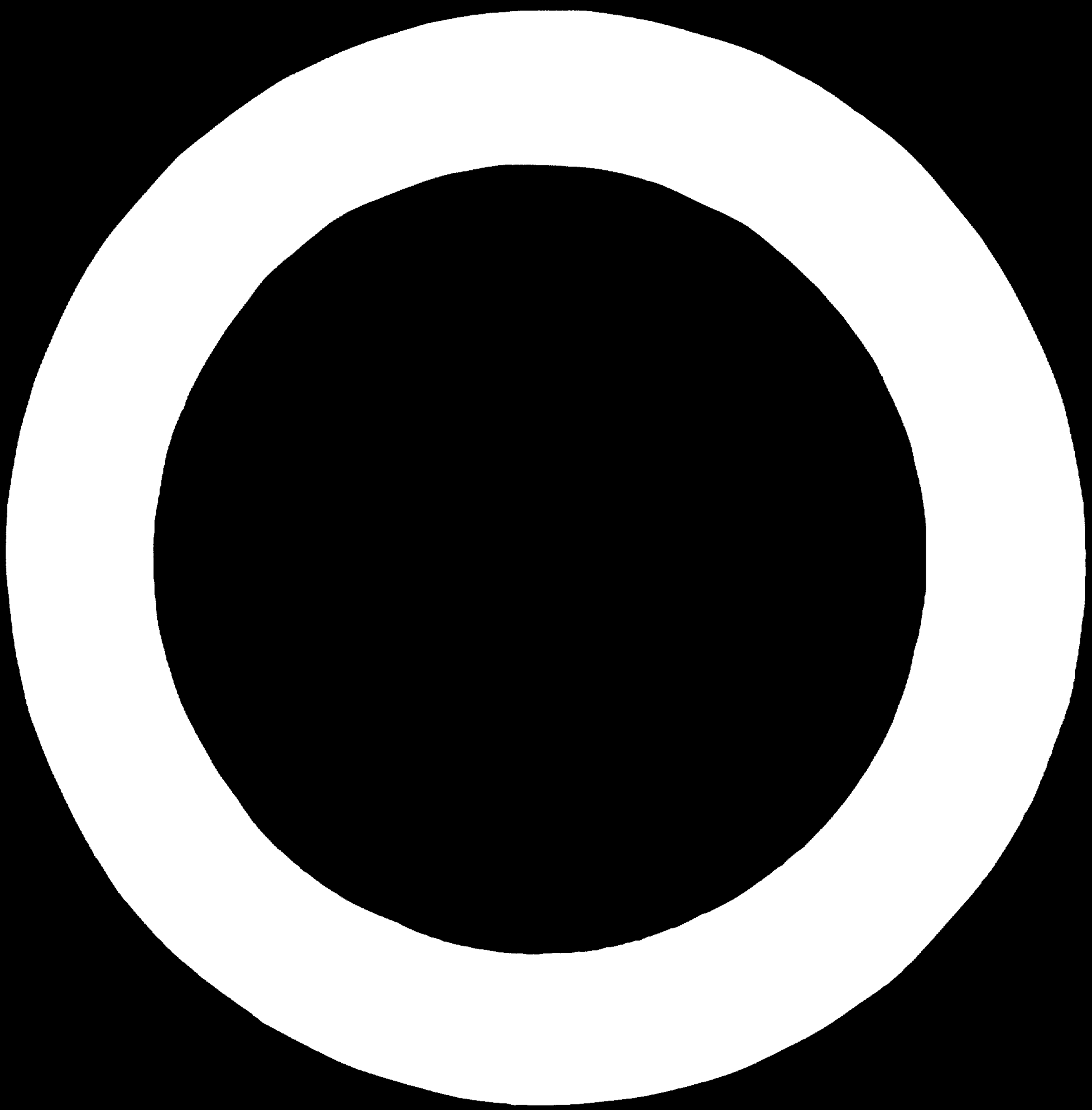
This volume is No. 3 of the Industrial Planning and Programming Series of UNIDO.[1] It is the aim of this series to present studies prepared either by staff members of the Industrial Programming Section of UNIDO or by expert consultants, as well as contributions made in this field by seminars or *ad hoc* groups of experts. It is envisaged that studies to be published will cover the spectrum of industrial planning and programming including programming data, planning methodology and programming techniques, as well as organizational aspects of industrial planning and programming. It is hoped that the series will reach planning and programming officials and technical assistance experts working in developing countries and be helpful to them in their daily endeavours.[2]

Opinions expressed in the articles comprising the present publication are those of the authors and do not necessarily reflect the views of the United Nations Industrial Development Organization.

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the United Nations Industrial Development Organization concerning the legal status of any country or territory or of its authorities, or concerning the delimitation of its frontiers.

[1] Other numbers in the series are as follows: No. 1, *Techniques of Sectoral Economic Planning: The Chemical Industries*, Sales No. 66.II.B.17; No. 2: *International Comparisons of Interindustry Data*. Proceedings of the Meeting of the First Ad Hoc Group of Experts on Industrial Programming Data, held in New York, November 1966 and No. 4: *Profiles of Manufacturing Establishments*, Vol. I, Sales No. E.67.II.B.17.

[2] For reference to other studies in the field of industrial planning and programming prepared by UNIDO, and its predecessor the Centre for Industrial Development, see the *Preface* to *Techniques of Sectoral Economic Planning*, No. 1 of the series, Sales No. 66.II.B.17.



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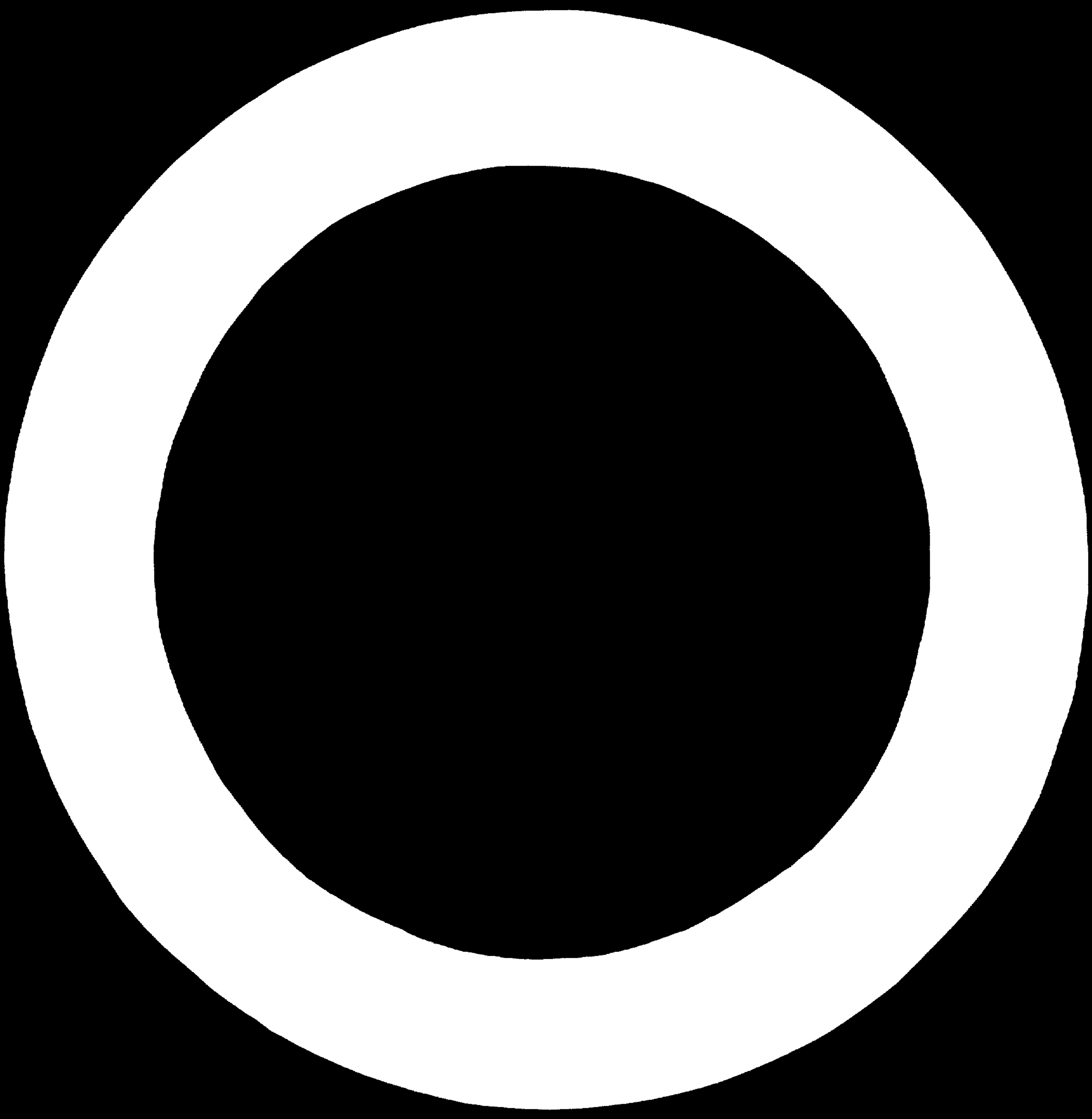

INTRODUCTION

The present volume contains papers prepared for the *Ad Hoc* Meeting of Experts on the Role of Advanced Skills and Technologies in Industrial Development held at United Nations Headquarters in New York from 22 to 29 May, 1967.[1] By and large the contents and the style of the original texts, as presented to the Meeting, have been preserved. However, certain corrections have been incorporated and some editorial changes have been made by the UNIDO secretariat. Bibliographical and other references have been verified, whenever possible, and some references have been printed as footnotes. The deliberations following the presentation of the papers as well as the conclusions and recommendations reached at the Meeting are the subject of other publications, and are not included in the present volume.[2]

THE PROGRAMME OF WORK OF UNIDO

UNIDO has been entrusted with the primary function of meeting the urgent needs of the developing countries in accelerating their industrial development through promotional and operational activities supported by relevant research. The operational activities of UNIDO are undertaken at the request of governments of developing countries to assist them, *inter alia*, in carrying out surveys of industrial development possibilities, in formulating industrial development plans and programmes and in determining the priorities, policies and instruments for their implementation, in preparing pre-investment studies of specific industrial possibilities and in evaluating specific projects, in executing economic feasibility studies and in achieving the most efficient utilization of new and existing industrial capacity.

Most of the research activities of UNIDO are also addressed to the aim of achieving greater efficiency in operational activities. Other research activities of UNIDO which do not necessarily have an immediate and direct supporting role in relation to operational activities nevertheless serve useful long range development needs, such as aiding in the formulation of alternative industrial development strategies.[3] It is in this last group that the present publication should be considered.

In commenting on the future orientation of the work programme of UNIDO, A. K. Sen had occasion to say:[4]

> "UNIDO's work presumably must relate ultimately to action, but action is often best induced by disseminating information and creating a proper body of opinion. Because of its responsibility to the world body of nations and because of its orientation towards industrial development, the UNIDO can provide seeds of thought that may germinate into massive action in the future. This it will not be able to do if it concentrates only on immediate action, when the basic framework of thought is deficient and there is a lack of an informed body of opinion that can guide purposive action towards the realization of the aspirations of the developing nations..."

One of UNIDO's main areas of work is that of industrial planning and programming. In response to the increasing concern of developing countries with problems of industrial planning and programming, UNIDO has developed supporting services at the planning, sectoral programming, and project level; included in the latter are the phases of formulation, evaluation, implementation and follow-up of industrial projects.

THE PROBLEM

While previous studies of development planning have concentrated largely on optimizing the use of capital, recently there has been a trend towards emphasizing shortages of skills and the role played by technical progress in economic growth. Leadership in this direction certainly came from the industrialized countries which have pioneered in the field of human resources development and scientific and technological planning.

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[1] The Meeting was attended by the following international experts, acting in their individual capacity: Prof. L. B. Cohen, Department of Industrial Engineering, Columbia University (USA); Dr. George Cukor, Institute of Economics (Hungary); Prof. Kazimierz Laski, Central School of Planning and Statistics (Poland); Dr. Jiri Nekola, Institute for Science Planning (Czechoslovakia); Dr. L. Riha, Institute for Science Planning (Czechoslovakia); Mr. Carl Riskin, East Asian Institute, Columbia University (USA); Prof. A. K. Sen, Delhi School of Economics (India); Prof. Karl Shell, Massachusetts Institute of Technology (USA); Mr. Zygmunt Slawinski, ECLA; Prof. John Vaizey, Brunel University (UK); Prof. Alexander Woroniak, Catholic University of America (USA); Prof. Manuel Zymelman, Harvard University (USA).

[2] An article presenting the conclusions and recommendations of the Meeting is included in the *Industrialization and Productivity* Bulletin No. 12. The report of the Meeting, together with a summary of the discussion, will be published as a separate United Nations publication.

[3] See Resolution Adopted by the Industrial Development Board on the Future Programme of Work and Activities of the UNIDO at its first session, Document ID/B/RES/1 (I), May 1967.

[4] Statement of the Chairman of the *Ad Hoc* Meeting of Experts on the Role of Advanced Skills and Technologies in Industrial Development, New York, May 1967, made at the closing session on 29 May 1967.

While in recent years the industrialized countries have been very concerned with analysing the contribution to economic growth originating in technical progress, and with developing and employing the advanced skills necessary for the application of modern industrial technology, the developing countries have seen a widening of the technological gap that separates them from the industrialized countries.

Although increasing recognition is being given to the fact that industrialization involves the adoption of advanced technologies, this adoption poses several problems for the developing countries. Not only do these technologies originate largely in the industrialized countries, but they evolve within the framework of a resource endowment pattern which, though common to the developed countries, is alien to the developing countries. Moreover, steps have to be taken to transfer these technologies from the advanced to the less developed countries. In this respect it is important to note that the manufacturing industries sector plays a major role in the introduction of advanced technologies in the developing countries and in the use and formation of technical and scientific skills.

A crucial problem for the developing countries is to take into account their present and likely future pattern of skills and to plan ahead for the changes in skill requirements which will result from the inception of new industrial programmes using advanced technology. Developing countries must pay special attention to the selection of such a sequence of investment decisions that would be most conducive to rapid and sustained growth on the basis of the optimal utilization of their present available skills and facilities for the formation of new skills. Once due consideration is given to these factors, developing countries will perhaps shift some of the emphasis from education as a general "infrastructure" type of requirement to the demand for skills emanating from the productive side.

The Meeting for which these studies were prepared was convened, therefore, for the purpose of assessing the role of the introduction of advanced skills and technologies in developing countries through their industrial programmes.[5] At this Meeting, it was expected that recommendations be made on UNIDO's work in the field of technological planning, human resources development and manpower planning and in particular on how UNIDO should make available to developing countries its technical and advisory services in the area of planning and programming for the introduction of advanced skills and technologies in industrial development, as well as in the manpower planning techniques necessary to meet skill requirements and productivity changes implicit in the adoption of modern industrial technology.[6]

SUMMARY OF THE CONTENTS

Part One—Technology and Skills

In keeping with the above purposes, the Meeting attempted to deal with issues at three different levels: theory, planning and policy. This is reflected in the organization of the present volume which contains in Part One papers concerned with presenting the problem of the interrelationship between advanced technologies and skill requirements. These papers present a discussion on questions of definition, measurement and classification of skills.

J. Vaizey argues in his paper against educational planning and research which appear to be based on a systematic overevaluation of formal education and on an underevaluation of learning-by-doing and on-the-job training—two methods of skill formation which investigations have shown to be both common and efficient. The recent trend towards exaggerating the amount of education required by a given growth target also manifests itself in a tendency to exaggerate the extent to which education has to precede the introduction or spread of industries and trades requiring skills. In addition, it tends to disregard some genuine problems in educating and training "high level manpower", especially the managerial and government strata in societies where education is very traditionalistic.

Vaizey puts forward many provocative questions, for example, whether it is better to train for specific skills, or to provide a high level general education. Is there (in any serious sense) a skill bottleneck in developing countries, or is it rather a managerial bottleneck? How far is it possible to predict technological change, and how far is very high level scientific and technological manpower necessary for the development of advanced technological sectors? How many skills should be produced, at what cost and how far in advance of assessed needs? Is it not likely that, if in a develop-

[5] From the Statement of the Executive Director of UNIDO, Dr. I. H. Abdel-Rahman, to the opening session of the Meeting.

[6] From the statement made by Mr. E. Salamon, Chief, Industrial Programming Section of UNIDO. For the conclusions and recommendations of the Meeting see *Industrialization and Productivity Bulletin* No. 12.

ing economy skills are produced in advance, pressures to emigrate and social unrest will arise as a result of white collar unemployment?

Such questions are fundamental in relation to the analysis of future requirements for skills. In his work on educational requirements of the British economy, Vaizey has considered five separate sectors with five different characteristics: *(i)* capital intensive industries which use limited skill and limited research, e.g. railways; *(ii)* skill intensive industries, with limited capital and limited research, e.g. education; *(iii)* skill and research intensive industries, e.g. pharmaceuticals; *(iv)* skill intensive, capital intensive and research intensive industries, e.g. aerospace; *(v)* industries that require limited skill, limited capital and limited research, e.g. retail trade.

While Vaizey argues that there is no necessary correlation between the skill structures of two countries and their industrial structures, *J. Timar* attempts to show that some necessary correlation does exist between the skill structures, although his work is based mainly on comparisons between Hungary and a few industrially advanced countries. Taking all the various aspects into account, diversion between these two views may not be so great as it might seem, due to the ambiguity of the term "skill structure". The general point of departure for Timar's paper is that there is a given structure of labour force corresponding to a given level of economic development. With economic growth there is a shift in the distribution of labour. The proportion of the agricultural labour force falls, that of the tertiary sector (services) increases, and there is a constant increase within both white collar and blue collar occupations in the requirements for more highly qualified persons in all sectors.

The most important characteristics of manpower employed in industry are its educational level, the share of technical specialists (engineers, scientists, technicians) and of skilled workers in the total labour force and the occupational composition of the qualified labour force. The manpower of individual industries has a characteristic structure of educational levels and occupational composition. This structure is determined primarily by the industrial technology used in the sector, and more precisely by the homogeneous or heterogeneous character of the products and production processes, the diversity of the product mix and the rate of change of the products, the batch size of production, the amount of work necessary for product development and by the mechanical or chemical character of the technology in the main production process.

Timar suggests that the average complexity (educational level) of labour can be measured appropriately by a system of coefficients that takes into account the direct and indirect costs of education and training in addition to the length of time necessary to attain the different levels. This method makes perceptible the importance of the more highly qualified labour force. The complexity of labour thus measured is higher in countries with more developed industries. Differences in the complexity of labour in individual industrial sectors are characteristic of the sectors, showing the same pattern in countries at very dissimilar levels of development. This fact can be traced back to the influence of technology on the composition of labour in the industrial sectors.

The purpose of *L. B. Cohen*'s paper "Job Evaluation as a Source of Information about Skill Requirements" is to show the type of information which is collected about skills in job evaluation, so that the usefulness of this information in determining skill requirements may be assessed. The technique of job evaluation, which is a method of wage scale determination, employs information about the skills of jobs being evaluated. Different systems of job evaluation such as ranking, grading, point system and factor comparison are discussed from the point of view of the assessment of skill requirements. The author points out that information about skill requirements is contained in the job analysis, description and specification.

The skill concept in job evaluation considers: *(i)* general education, *(ii)* application of training, and *(iii)* personal traits and subfactors pertaining to them. Skills arising from general education concern language and mathematics. For skills arising from occupational training and experience, the source of the given skill rather than its content can be specified (formal schooling, trade and professional schooling, training programmes within a particular company, prior job experience, particular skills such as the ability to use certain tools).

Cohen concludes that, through a competent job evaluation, relevant information can be obtained about the skill requirements of the establishment in which such an evaluation is made. He also presents methods by which the available information can be summarized so as to depict the skill requirements of the enterprise as a whole. These results are applicable to the particular establishment from which the skill data derive. The extent to which data on the skill requirements of any particular establishment may be generalized so as to be applicable to other establishments in the same culture or in other cultures requires further study.

Part Two—Choice of Technology and Other Theoretical Issues

Part Two includes studies on: the problem of choice of techniques; a model of growth of a centrally planned economy with surplus labour under possible changing capital-output ratio; and models of optimal growth, including such features as a technological gap and educational activity, leading to models which include an economic choice between different types of technological change, and the production of knowledge through allocation of economic resources.

In his paper *A. K. Sen* summarizes the debate in economic literature on the choice of technique. He classifies the major positions according to their implicit treatments of a general formula in which the real cost of labour is equalled to the marginal product of labour. These positions are shown to differ essentially in their views of the savings rate as optimal or sub-optimal, and in their assumptions with regard to the relative proportions of wages and profits consumed—a question affected by the efficacy of available fiscal machinery. Thus stated, the differences involve both questions of a political-ethical nature (how should consumption in the future be valued relative to that at present?) and questions of fact, which admit testing (what are the proportions saved out of wages and profits respectively?). As to the latter question, Sen thinks there is evidence that the proportion of profits that can be recovered for further investment is substantially higher than that of wages, especially for public enterprises. As to the former, his opinion is that in the developing countries the savings rate tends to be inoptimally low.

K. Laski discusses in his paper the problem of investment allocation in developing countries with emphasis on the optimal degree of capital intensity. He deals with the dilemma between choosing an income-maximizing or a surplus-maximizing technique. He argues that the existence of an "independent" investment fund, in addition to the "dependent" one tied to the level of mechanization currently being chosen, and the existence of technical progress both tend to lengthen the amount of time required for the surplus-maximizing technique to overtake the income-maximizing one in total consumption generated, and thus both lead to favouring more labour-intensive techniques than would otherwise be chosen. Thus he proposes to reduce the marginal capital-output ratio wherever possible in order to accelerate growth for a given rate of investment. He underlines the fact that bottlenecks and difficulties in foreign trade limit sharply the growth of national income and therefore the role of the investment rate. He thinks that contradictions between consumption in the short and long run, tied with the level of mechanization, do not occur in economies where major disparities in the social distribution of national income exist and where it is possible to raise the investment rate at the expense of the consumption of non-essential goods.

As a prologue to the theory of endogenous technical change, *K. Shell* presents first models of stylized enterprise economies and planning models in which there is exogenous technical change; then, three different models of education and technological change. The models draw inspiration from the work of Uzawa, and Nelson and Phelps. The first model of education specifies that changes in labour force efficiency are dependent upon the fraction of the labour force engaged in educational activity. The second model specifies that changes in labour force efficiency are dependent upon the gap between exogenously determined "available technology" and "technology in practice" and upon the "educational attainment" of the society. The two views are then integrated with the specification that changes in educational attainment are dependent upon the fraction of the labour force employed in the educational sectors. The rigid assumption that technical change affects the production function in a pre-specified way that is not subject to economic calculation is relaxed, and a planning model is examined in which the bias of technical change is open to choice by the planning authority. The difficulties inherent in extending the analysis to enterprise economies are discussed.

Shell questions the commonly used specifications of how the volume of inventions, education of labour, or the learning-by-doing of entrepreneurs affects production functions as a rigid carry-over from capital theory. He asserts that, if there is an economic choice as to how much technological change a society should seek, there must be an economic choice between different types of technological change. Roughly, a planner or an entrepreneur must be faced with a choice between "labour saving" and "capital saving" technological change. This choice is crucial both for explaining the direction of progress in market economies and for planning research and development, educational policy etc. in centrally planned economies. The paper ends by pointing to the need for future research on the various possibilities of accelerating technological progress by way of devoting economic resources to inventive activity.

Part Three — Industrial Manpower Planning

Part Three contains a paper discussing the planning for changes in productivity and to meet skill requirements in manufacturing industries; a study on manpower planning including empirical research on the skill and educational requirements of the different industries and the relationship between the skill composition and productivity; and finally, a report dealing with the planning of science and technological research in a centrally planned economy.

Manpower planning has a static aspect, concerning accounting identities, and a dynamic aspect dealing with qualitative changes; in his paper *G. Cukor* deals mainly with this latter aspect, in particular with changes in productivity, and with change in the quality of the labour force—usually measured by the skill composition of manpower.

For planning purposes, labour productivity can be considered as a set of technical coefficients establishing links between the output of different industrial branches and labour—the most general and important input. A plan of skill requirements contains special coefficients reflecting not the total requirements of labour but rather those of particular skills, depending on the volume of output and on the change in the pattern of production. Productivity could, in principle, be directly planned by planning production and labour requirements independently. However, this is not feasible for longer periods and for larger industrial branches or for the industrial sector as a whole. What can be planned is the change in productivity, assuming that some of the factors affecting productivity will remain unchanged or change only slightly. The main factors, or rather groups of factors, influencing productivity are: *(i)* the quantity and quality of capital equipment; *(ii)* the use made of available capacities; *(iii)* the skills of the workers (quality of the labour force); *(iv)* welfare and social factors; and *(v)* natural factors. Cukor discusses in some detail the problems of planning productivity with regard to these factors.

The planning of industrial skills is discussed within the framework of planning for a certain number of important skill categories; *(a)* engineers, scientists and technicians, and *(b)* skilled workers. Some tendencies in manpower development, such as shifts between major economic branches, the increase of general education and skill levels etc., are also discussed in the paper. It is pointed out that the planning of high level technical manpower (engineers, scientists and technicians) has to be done centrally, within the framework of long-term planning (about 15 years). Planning of skilled workers, on the other hand, should be done decentrally (i.e. according to the requirements of individual factories), within the framework of medium-term plans (for about 3 to 5 years), central planning performing only additional tasks such as providing for the requirements of factories not yet in existence at the time of planning.

The paper by *M. Zymelman* deals with the relationships between occupational structures and productivity of industries. One of the conclusions from this research is that there is a systematic relationship between the productivity (value added per employee) of a given industry and the occupational structure of the same industry. These relationships, arrived at by a detailed analysis of a three digit occupational breakdown by a two digit industry classification, may be helpful in the formulation of planning models incorporating manpower variables, including models relating targets of employment and productivity to the educational system to supply the needed skills.

A basic contention of this study is that the direct linking of productivity to formal education ignores important variables in the causality process between productivity and "human resources". A higher educational level does not automatically produce a higher level of output, unless this higher level of education is the result of a "higher" occupational mix, such as more professionals and less labourers. It is therefore of little use for planning purposes to link directly productivity or income *per capita* to formal education.

The necessity of research on the different paths of skill acquisition at the blue collar skilled worker level and the need to acquire better data on the "human functions" involved in production are also put forward in Zymelman's paper. There is a need to determine the different combinations of knowledge, ability and practice that go into every skilled blue collar occupation independently of traditional ways and obsolete customs. Regretfully, little is known about this because educators are mostly interested in formal education, while a large proportion of those employed in skilled occupations acquire the training for their job informally. Yet, according to Prof. Zymelman, it is in this area that the developing countries will have to concentrate their efforts and develop imaginative programmes adapted to their own needs rather than follow unquestioningly the traditional ways of advanced countries.

The paper by *Chvátal et al.* outlines some problems of planning basic research in relation to industrial growth and surveys Czechoslovakia's State Five-Year Plan of basic research until 1970. The main goal of planning and programming in research is to create appropriate conditions for the utilization of the scientific capacities of the country. This task is quite complicated in small countries such as Czechoslovakia which have to adapt their scientific programmes to their financial possibilities and apply appropriate priorities.

The methods of elaborating basic research plans dealing with the five-year basic research plan, the operational plan of basic research and the financial aspects of research programmes are outlined. A description is given of the programme of basic research in relation to the prospective development of industry. The method of planning and programming is based on the elaboration of studies and conceptions; a "study" is defined as an analysis of basic trends of the development of science and technology leading to an evaluation of the most efficient ways to be followed; a "conception" is defined as an elaborated projection of the subsequent development based on the analysis carried out in the study.

The studies and conceptions are aimed at determining: *(i)* the requirements of society in the future (particularly standards of living); *(ii)* the development of productive forces; and *(iii)* the development of scientific and technological progress. The maximal period of time for which, from the point of view of scientific and technological developments, long-term forecasts can be effectively worked out seems to be approximatively 25 years.

In the natural and engineering sciences three types of basic research projects are established, namely programmes oriented to *(i)* prospective needs of the national economy to create new theoretical knowledge without fully specific goals, *(ii)* individual branches of science aiming at the development of science itself, and *(iii)* the solution of problems required by concrete realization targets.

The final part of this paper contains basic data on research and development activities in Czechoslovakia, particularly from the point of view of manpower and financial resources.

Part Four - Policies for the Adoption of Advanced Technologies

In Part Four, the papers deal with some policy aspects pertaining to the adoption of advanced technologies. One paper discusses the pattern of dualistic industrial development in recent years in Mainland China where large-scale industry coexisted with so-called "local" industry; this local industry was based on the utilization of resources upon which there was no competitive claim from the large-scale, centrally planned industry. Organizational and control aspects in the adoption of advanced technology in the context of recent experience in the Union of Soviet Socialist Republics are discussed in another paper, and the last contribution examines the pattern of industrial development in Latin America in connexion with the training and educational requirements demanded by the industrial development process.

In his paper *C. Riskin* seeks to explain the recourse to technological dualism in the recent industrial development of Mainland China by means of a model of the Dobb-Sen-type, modified to take account of the multiplicity of factors of production required by the production of any given commodity, the different rates at which these factors become inelastic in supply as their scale of use expands, and the different proportions in which they are required by different techniques. Raw material shortages, transport bottlenecks and seasonal labour requirements in agriculture are given as typical bottlenecks in the expansion of the large-scale sector of industry which the development of "local" industry was designed to circumvent. Local industry was often based on the utilization of surplus and waste agricultural raw materials and, in general, on the utilization of resources upon which there was no competitive claim from the large-scale, centrally planned industry that was always accorded the highest priority.

In *A. Woroniak*'s opinion, recent Soviet experience supports the hypothesis of the importance of business organization and management in shaping the peculiarities of technological transfer. Emphasis on technological progress by the Soviet planners as almost the sole moving force of growth resulted in routinization of innovation and of capital investments which were not only considered as propellants of rapid growth, but as the conveyors of technology into the economy. Simultaneously, adequate manpower was created by strictly adhering to the principle of "using all educated people, and to educate only for use". Aiming education at the minimum technical requirements, stripping the training to its bare essentials, and concentrating until very recently on "learning-by-doing", Soviet leaders secured a constant supply of skilled workers.

However, problems exist, at least in some sectors, which are the cause of serious concern. In view of the adequacy of capital investment and manpower, the source of these problems is sought in the institutional set-up, particularly in business organization and management. Undoubtedly, similar problems existed before, but they may have been exaggerated by the increasing complexity of the Soviet socio-economic system, and to some extent by the high level of sophistication of Soviet technology that limits borrowing innovations from abroad. Illustrative cases and statistical data are presented which indicate the existence of problems of co-ordination, lack of proper use of incentives, and waste of resources due to erroneous directives at various levels of administration and management. This seems to be confirmed by the fact that the Soviet managerial apparatus has recently been searching intensively for effective organizational forms and rational managerial structures of incentives and control.

Z. Slawinski's paper presents a manpower survey of Latin America and an analysis of the pattern of industrial development as related to skilled manpower requirements. With regard to the pattern of industrial development, he mentions the influence of aspects such as: diversification, technology, administration and organization, the size of market problem, employment policy etc. According to Slawinski, economic progress depends as much on the development of measuring instruments as on technological progress in general. Industry, being the sector with the highest complexity, requires sophisticated methods of analysis and measurement. The main tools in this respect are the improved techniques of industrial process analysis, the improved methods of skilled manpower analysis and the improved apparatus for collecting and tabulating socio-economic information—the relevant classifications forming an integral part of the system.

In Slawinski's opinion, the developing countries pass through five common stages in the process of industrialization: *(i)* the pre-factory stage; *(ii)* development of traditional consumer goods industries—basic goods for consumption; *(iii)* development of basic steel production, simple machinery and construction materials (many developing countries are entering into this stage); *(iv)* high grade industries stage; and *(v)* higher grade industries stage. While Africa is still in the second stage (with some countries entering the third stage), some Latin American countries and a few of the relatively advanced developing countries, though not yet having completed the third stage, are already entering the fourth stage. Slawinski argues that the more complex skill requirements problem starts with the fourth stage and subsequently increases immensely.

The role of advanced skills and technologies is a subject on which the current body of knowledge is so deficient that policy conclusions must, of necessity, be largely tentative. Perhaps the biggest gap in this important area is the lack of empirical research in fields closely related to policy.[7] If it is admittedly difficult to tackle new problems coherently, it is even more difficult to throw light on a set of old problems arranged under a new common denominator. In trying to do so, the UNIDO *Ad Hoc* Meeting of Experts on the Role of Advanced Skills and Technologies in Industrial Development put many questions in an appropriate perspective so that the answers might, perhaps, be more readily found.

> "What is an advanced technology? What is really at stake in the problem of choice of techniques? What are the inter-relationships between market size, efficient scale of production and market structure in advanced technologies in which economies of scale obtain? What quality of skills and in what quantity are they demanded in using advanced technologies? How could these skills be efficiently formed? What are the present observable imbalances of supply and demand of skills? How should planning for skilled manpower proceed? What are the needs of data to permit efficient planning of skilled manpower? What are the observed and necessary relationships between formal education and other forms of skill formations? etc."[8]

The present volume may have been more successful in raising questions than in providing answers. It is to be hoped, however, that these questions will provide stimulus for further research in this field.

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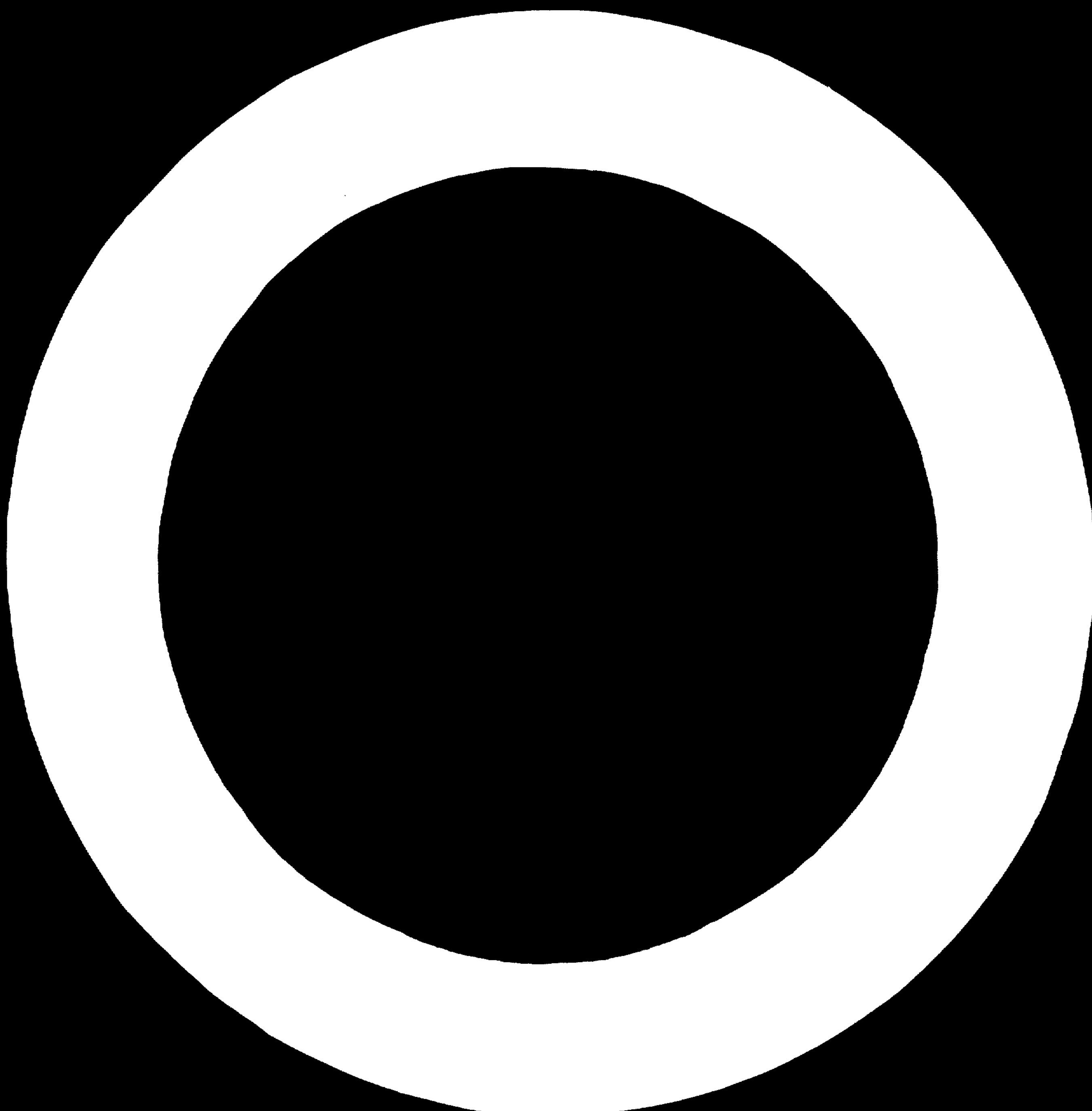
[7] A. K. Sen, op. cit.

[8] From the statement by Mr. S. Teitel, Secretary of the Meeting, made at its closing session on 29 May 1967.

Part One

TECHNOLOGY AND SKILLS



TECHNOLOGY AND SKILL

John Vaizey, Brunel University, London, United Kingdom

THIS PAPER is an attempt to develop certain lines of work that are currently being pursued, and to formulate certain questions, four in number

(i) What is the complementarity between the development of education, the progress of technology, and innovation embodied in new investment in plant and equipment?

(ii) In the light of this analysis, what kind of skills are required by advanced technologies? Specifically, do they precede technological innovation and capital investment, in optimal conditions, and if so, how many and what skills should be provided in advance?

(iii) How should such skills be measured and classified?

(iv) What is the role of the manufacturing sector in introducing advanced technologies in developing countries? Is it a reservoir of skills which may later be used to develop skills in other sectors or are its skills specific to its own technological circumstances?

In the preparation of this paper it has not been possible to do more than classify some of the evidence and arguments that might be brought to bear on this series of questions. A significant programme of research ought to be undertaken before even a preliminary paper is presented, but I am here drawing on certain work in progress, and crave indulgence in advance for any inadequacies. In order to approach this series of questions we have to ask some other, preliminary questions.

1 EDUCATION AND TECHNOLOGY

Where are the skilled people in an advanced economy? Let us begin by identifying "skill" with "education". Table 1 suggests an outline of where they were to be found in the United Kingdom in 1951. Of these educated people, the great majority are non technically, non scientifically oriented. We can abstract, therefore, most teachers, most arts graduates etc from the picture. There are difficult categories, e.g. nurses, who are complementary to doctors, and the content of whose work becomes increasingly technologically based, or a number of arts graduates (managers and teachers) who are employed in technically oriented managerial roles because their jobs arise in technologically advanced economies. In other words there are *prima facie* reasons for supposing that the group of more highly educated people does not necessarily include the total of technically qualified personnel, and that education is primarily non technical in its orientation. Such data as are available from the developing nations tend to suggest that education there is even less technically oriented. If "on the job" acquired skills were studied, it would be seen that the picture is different. This, in turn, suggests that skill acquisition follows investment, rather than the other way.

The next question is, how has the allocation of these educated people changed during the course of time? If we compared 1900 with 1965 what would we see? In the absence of statistics of the "education/occupation" mix in 1900, we have to exercise judgement. The general conclusion, borne out by table 2, seems to be that the distribution has shifted towards industry and business, but not to any great extent. In other words, there is not much reason to suppose that the growth of gross national product (in the United Kingdom, at least) has in any significant sense led to, or been connected with, a shift in the education/occupation mix.

If we look at the capital stock (assuming that the assessment and measurement of capital is meaningful), industry by industry, we can see whether there is any proved connexion between occupation mix, skill mix, and capital intensity. And if we compare the rate of gross investment we are looking at the potential rate of incorporation of new technology into plant and equipment. Suppose, to take a simple example, that a new industry is started. Its capital stock in year 1 is equal to I of that year, and is all potentially new technology. Another industry, with a capital stock K, and a gross investment I, equal to $K/10$, is potentially able to have one tenth of its capital in a "new" technology. The rate of incorporation will depend upon the expansion of the stock of capital and the rate of scrapping. But, as we all know, productivity gradually rises even without the

TABLE 1. OCCUPATIONAL CLASS DISTRIBUTION BY INDUSTRY, ENGLAND AND WALES, 1961

Industry	Occupational class*								
	1A	*1B*	*2*	*3*	*4*	*5*	*6*	*7*	*All*
Agriculture etc.	0.03	0.00	28.61	0.72	1.83	7.67	60.81	0.24	100
Mining	0.65	0.30	0.91	3.13	5.65	30.52	47.64	2.11	100
Ceramics etc.	0.51	1.35	4.06	6.76	2.97	37.93	19.30	27.04	100
Chemicals	3.83	4.96	7.08	16.02	3.58	15.33	27.00	22.24	100
Metal manufacture	1.23	1.86	2.74	8.86	5.37	30.40	18.56	22.80	100
Engineering and shipbuilding	1.63	4.01	4.13	11.37	6.49	41.17	15.96	12.20	100
Vehicles	0.86	2.50	4.77	9.88	6.18	47.74	16.85	11.19	100
Metal goods	0.40	0.40	4.86	8.67	5.26	37.17	20.71	14.45	100
Precision instruments	0.92	2.34	5.96	10.96	4.80	52.52	15.18	7.32	100
Textiles	0.33	0.77	3.22	5.14	3.07	50.40	23.19	13.79	100
Leather etc.	0.30	0.49	6.86	6.05	2.86	66.21	4.48	12.67	100
Clothing	0.04	0.17	4.34	4.79	2.08	36.03	48.10	3.90	100
Food, drink and tobacco	0.56	0.72	6.94	10.77	3.32	25.97	30.80	20.00	100
Manufactures of wood and cork	0.13	0.00	4.98	5.63	3.02	63.40	8.77	13.31	100
Paper and printing	3.52	1.30	6.87	12.43	2.78	44.85	13.91	14.38	100
Other manufactured goods	0.86	2.70	6.42	11.10	3.47	42.08	15.02	18.36	100
Building and contracting	1.22	0.40	3.98	3.91	3.76	57.64	4.36	24.00	100
Gas, electricity and water	3.06	1.63	4.88	15.87	2.32	27.61	18.24	26.06	100
Transport and communication	0.38	1.75	4.53	13.05	3.60	19.63	41.81	15.41	100
Distributive trades	0.15	1.04	30.13	12.36	0.80	5.55	43.43	6.85	100
Finance	1.31	0.16	18.97	66.83	0.22	2.26	3.06	6.34	100
Public administration	5.09	2.97	7.90	18.25	1.18	10.25	30.63	14.08	100
Professional services	12.73	44.95	2.80	13.92	0.14	2.06	17.96	4.77	100
Miscellaneous services	0.26	3.00	13.06	4.06	0.12	8.45	65.06	5.20	100
All	1.06	4.07	9.95	10.06	2.00	25.37	32.04	11.67	100

Source: G. ROUTH, *Occupation and Pay in Great Britain 1906–1960*, Cambridge University Press, 1965, p. 30.

* Occupational class: *1A* higher professional; *1B* lower professional; *2* employers, administrators, managers; *3* clerical workers; *4* foremen, inspectors, supervisors; *5* skilled workers; *6* semi-skilled workers; *7* unskilled workers.

incorporation of a new technology. As Z. Slawinski has pointed out in his paper "Requirements and Training of Highly Skilled Manpower for Latin American Industrial Development", a distinction must be made between the factory as a whole, and parts of the productive process. In other words, small adaptations, whether of equipment or procedure, may have cumulative effects on technology which are more significant than a single big innovation embodied in a wholly new productive outfit.

The same conditions apply to the labour force. The rate of retirement and the rate of additional recruitment affect the total stock of people with new ideas and new skills incorporated in the labour force. At the same time "learning on the job" and "learning by doing" are cumulatively even more important than new entrants with new skills acquired before employment.

Three further considerations may therefore be adduced. The new capital (or manpower) may be introduced as part of an existing system, limiting the potentiality of innovation. This capital may not have innovating characteristics: it may be of the same design as that which is being scrapped. In addition, "learning on the job" appears to yield a steadily increasing product (the Horndal effect) to both labour and capital. I can see no way in which these questions may be dealt with except by the most detailed investigation of particular instances, and even then the element of judgement as to what has occurred is irreducibly subjective, as the studies by Jewkes *et al.* and Carter and Williams have suggested.[1]

In research proper, certain clear distinctions have generally been made. There is research directly sponsored by a specific sector of the economy (e.g. atomic energy, space or oil), and there is research which goes on under its own steam and may later have an economic application (e.g. the effects of biochemistry on drug therapy, and consequently on the development of the pharmaceutical firms). Clearly the latter has, so to speak, a series of minor logics of its own. It is accidental, one supposes, whether or not the developments of capital, of labour and of research happen to coincide, and it is impossible to say, except by the investigation of many case histories, which comes

[1] JOHN JEWKES, DAVID SAWYERS and RICHARD STILLERMAN, *The Sources of Invention*, London 1958; C. F. CARTER and B. WILLIAMS, *Industry and Technical Progress*, Oxford University Press, 1957.

TABLE 2. DISTRIBUTION OF OCCUPIED POPULATION IN ENGLAND AND WALES (INCLUDING EMPLOYERS, SELF-EMPLOYED AND UNEMPLOYED) BY INDUSTRY, CENSUS YEARS, 1911–1951 AND 1959

Industry	*1911*		*1921*		*1931*		*1951*		*1959*	
	('000s)	*Per cent*	*('000s)*	*Per cent*	*('000s)*	*Per cent*	*('000s)*	*Per cent*	*('000s)*	*Per cent*
Agriculture etc.	1,499	*8.4*	1,372	*7.3*	1,257	*6.1*	1,142	*5.0*	969	*4.1*
Mining etc.	1,128	*6.3*	1,305	*6.9*	1,166	*5.7*	861	*3.8*	844	*3.6*
Ceramics, glass etc.	201	*1.1*	214	*1.1*	265	*1.3*	318	*1.4*	326	*1.4*
Chemicals	147	*0.8*	215	*1.1*	239	*1.2*	442	*2.0*	543	*2.3*
Metal manufacture	509	*2.8*	562	*3.0*	524	*2.6*	579	*2.6*	558	*2.3*
Engineering and ship-building	878	*4.9*	1,203	*6.4*	1,090	*5.3*	1,801	*8.0*	2,121	*8.9*
Vehicles	291	*1.6*	375	*2.0*	402	*2.0*	1,009	*4.5*	1,246	*5.2*
Metal goods n.e.s. / Precision instruments, jewellery etc.	321	*1.8*	424	*2.2*	450	*2.2*	636	*2.8*	676	*2.8*
Textiles	1,359	*7.6*	1,306	*6.9*	1,338	*6.5*	997	*4.4*	865	*3.6*
Leather etc.	93	*0.5*	87	*0.5*	92	*0.4*	79	*0.4*	67	*0.3*
Clothing	1,159	*6.5*	873	*4.6*	880	*4.3*	729	*3.2*	646	*2.7*
Food, drink and tobacco	554	*3.1*	623	*3.3*	709	*3.5*	756	*3.4*	920	*3.9*
Wood	276	*1.5*	304	*1.6*	321	*1.6*	333	*1.5*	310	*1.3*
Paper and printing	334	*1.9*	403	*2.1*	497	*2.4*	520	*2.3*	589	*2.5*
Other manufactures	96	*0.5*	205	*1.1*	235	*1.1*	267	*1.2*	288	*1.2*
Building	950	*5.3*	795	*4.2*	1,122	*5.5*	1,431	*6.4*	1,543	*6.5*
Gas, electricity and water	116	*0.6*	179	*0.9*	246	*1.2*	361	*1.6*	380	*1.6*
Transport and communication	1,416	*7.9*	1,570	*8.3*	1,671	*8.2*	1,734	*7.7*	1,700	*7.2*
Distributive trades	2,133	*11.9*	2,230	*11.9*	2,697	*13.2*	2,712	*12.1*	2,988	*12.6*
Finance	199	*1.1*	311	*1.6*	366	*1.8*	439	*2.0*	543	*2.3*
Public administration and defence	701	*3.9*	1,007	*5.3*	999*	*4.9*	1,726	*7.7*	1,898	*8.0*
Professional services	798	*4.4*	886	*4.7*	1,067	*5.2*	1,543	*6.9*	1,984	*8.3*
Miscellaneous services	2,783	*15.5*	2,398	*12.7*	2,865	*14.0*	2,086	*9.3*	1,763	*7.4*
Total:	17,941	*100.0*	18,855	*100.0*	20,498	*100.0*	22,501	*100.0*	23,767	*100.0*

Source: G. ROUTH, *Occupation and Pay in Great Britain 1906–1960*, Cambridge University Press, 1965, p. 40.
* Local authority "institutions" distinguished in 1931, and posted to "Professional services". In 1921, only nurses, attendants and medical occupations extracted from "Public administration and defence" and posted "Professional services".

first: gross investment, new skills, or research breakthroughs. It is sufficient to say that there are several extreme positions:

- *(a)* capital-intensive industries using little skill and little research (railways);
- *(b)* skill-intensive industries using little capital and little research (education);
- *(c)* skill- and research-intensive industries (pharmaceuticals);
- *(d)* skill- and capital- and research intensive industries (aerospace);
- *(e)* labour-intensive industries requiring little skill, capital or research (small retailing).

It is fairly clear that categories *(c)* and *(d)* are the pace-setters, and that over the last half-century there has been a relative decline of category *(e)* and a rise in category *(b)*

What are the implications of looking at the subject in this way? First, research will point to far more skill-intensive techniques and usually to more capital-intensive techniques as well. Second, the nature and direction of investment will generally determine the size and nature of the demands of the skills, rather than the other way round, though some writers[1] have agreed that the existence of a pool of skilled labour will attract labour. The experience of the Boston-Cambridge complex is also illuminating. Nevertheless, the general case holds, because there skills have usually been acquired on the job. The projection of the nature, size and direction of these investments is therefore a fundamental part of the task of the manpower planner. Third, the availability of skills will partly determine the choice of capital equipment, but (historically) the nature of the capital equipment has generally determined the nature of the skills required. This is because technology has more often been concerned with machines than with people, and because (contrary to what is generally

[1] Cf. G. C. ALLEN, *Industrial Development of Birmingham and the Black Country, 1860–1927*. London, Cass, 1966.

assumed in many cultures) skills are fairly easily acquired, and people learn "on the job" surprisingly well despite the lack of formal education.

The work done so far on choice of technologies has been predominantly concerned with capital. Where there has been a discussion of factor proportions, the factors have usually been assumed to be homogeneous; and when heterogeneity has been assumed, it has been wholly (so far as I am aware) of capital. In W. A. Lewis's work[3] the question has been one of choosing simple, cheap machines rather than complex expensive machines—e.g. spades rather than earth-moving machines. The question of the appropriate supply of skills, though it has been considered by Lewis[4] has been essentially a subsidiary one. In later, more sophisticated work, like that of W. Galenson and H. Leibenstein[5], and of A. K. Sen[6], there has been an explicit assumption (as I understand it) of the homogeneity of the input labour.

It is clearly not inherent in their work that this should be the case. Just as "capital" can be broken up into many discrete pieces of equipment so, with C. Riskin in his paper on "Local Industry and Choice of Techniques in Planning of Industrial Development in Mainland China" (pp. 171 to 180), we can assume a multiplicity of specific inputs required for the production of any given commodity; an uneven rate at which these inputs become scarce as the scale of production expands; and different proportions in which the inputs are required by different techniques. It must inevitably follow that the labour force can be so divided into many specific inputs.

We have then—as I understand it—to evaluate the different kinds of skill, and to determine the degree of specificity of skills prevailing in specific techniques. The subsequent question is, what kind of education and training is required to produce these skills. I shall comment later on the work of J. Tinbergen, H. C. Bos and H. Correa[7], who have used a physical capital model as an analogy for the labour force, and on the consequent implications for education (which is equivalent in their work, I would argue, to a capital-goods producing industry). At this stage I might simply say that the analogy seems to me unconvincing. It breaks down on the issue of specificity, as well as on other grounds, as I argue in the Annex.

2. Skill requirements of advanced technology

M. Zymelman in his paper on "Productivity, Skills and Education in Manufacturing Industries" (pp. 103 to 138) suggests that there exists a high degree of complementarity between a certain type of production method and the kind of labour force it requires. In other words, a certain level of technology, and hence a certain level of productivity, are represented by a specific kind of organization and by a specific kind of capital equipment that is made to work by a labour force whose occupational composition is well defined. The question that immediately arises is, which is the chicken and which is the egg? Generally, it is clear, machines are developed or imported first, and then skill requirements arise. In certain cases, however, the development of skills precedes the development of technique—the instance that springs to mind is the need for training organizers of the labour brigades in Morocco and Ghana; but in these instances the question is nearly always one of management rather than of technical skill.

It certainly seems that the physical capital structure to a great extent dictates the requirements for skills; the constraints of the shortage of skills and the shortage of managerial ability are real, but they seem to be fairly quickly overcome.

It is a general impression that the analogy of the physical model has been most unfortunate in its intellectual and policy consequences. As I suggested above, it seems that what Tinbergen, Bos and Correa have done is to develop a model for labour which is derived directly from models of capital in economic growth. The result is a series of assumptions about the nature of skills, and their relation to education, which are pragmatically invalid. Skills are not (by and large) as discrete and specific as pieces of capital equipment are. Many people can do, more or less well, a wide

[3] W. A. Lewis, "Economic Development with Unlimited Supplies of Labour", in *Manchester School of Economic and Social Studies*, Vol. 22, No. 2, May 1954.

[4] W. A. Lewis, *The Theory of Economic Growth*, London, Allen and Unwin, 1955.

[5] W. Galenson and H. Leibenstein, "Investment Criteria, Productivity and Economic Development", *Quarterly Journal of Economics*, August 1955.

[6] A. K. Sen, *Choice of Techniques*, Oxford 1960. [Editor's note: additional bibliographical references to research work done with the model of a labour surplus economy are given at the end of the article by A. K. Sen, pp. 45 to 57 in this volume.]

[7] J. Tinbergen and H. C. Bos, "A Planning Model for the Educational Requirements of Economic Development", in *The Residual Factor and Economic Growth*, OECD, Paris 1964, 147ff.; J. Tinbergen and H. C. Bos, "An Appraisal of the Model and the Results of Its Application", in *Econometric Models of Education—Some Apparatus*, OECD, Paris 1965, 95ff.; H. Correa and J. Tinbergen, "Quantitative Adoption of Education to Accelerated Growth", *Kyklos*, Vol. 15, 1962, 776ff.

variety of jobs: there is an element of improvization, of "make do and mend", about labour which is impressive. There are, of course, two extreme instances where this is not the case: in highly developed skills, like surgery or piloting aircraft, where specific skills are reinforced by legal constraints on who may exercise them; and in poor countries where roles in production are culturally assigned and nobody may perform another role. But in the bulk of economies the majority of skilled and semi-skilled jobs fall somewhere between these two extremes; and this is the case above all in the manufacturing industry. Thus the models of Tinbergen, Bos, and Correa tend to exaggerate the likelihood of skill bottlenecks because they underestimate the substitutability of skills. Further, they take for granted that the educational and training background which prevails in advanced countries is a necessary background for the exercise of those skills. This argument seems to me to be self-evidently a dangerous one. After the Russian Revolution of 1917 many taxi-drivers in Paris were ex-Czarist generals: but it did not follow that to be a good taxi-driver one needed to have gone to the St. Petersburg Military Academy. While nobody would deny that to get a really productive economy functioning normally, like that of California, it may be an advantage, or even essential, to have the Californian educational system (though many of California's skills are imported), the bulk of the evidence tends to suggest the proposition that a great many skills—including some that are highly complex—can be more rapidly acquired than is generally supposed.

There has been a tendency to argue that very high levels of education, and a massive expansion of the education system at all levels, are necessary for economic growth. It is certainly possible to argue the contrary case, especially when the nature of the education system is considered. In the developing countries, generally speaking, education is anti-technological in its bias.

3. Skill classification

This leads us to the question of the measurement and classification of skills. There are two main methods. One is to take the occupational distribution as the basis for measurement and classification—a work of enormous complexity—but giving a very high degree of specificity. It is then possible to take specific requirements for specific skills and train specifically for them (as Z. Slawinski argues). This is the approach of "education for use" employed in the socialist countries. The second approach is to measure skill by educational background. This approach is widely advocated, and is used in almost all the work of the Organization for Economic Co-operation and Development (OECD). But I agree with M. Zymelman that the linking of productivity to formal education ignores variables in the causality process between productivity and human resources. A high educational level does not automatically produce a higher level of output unless this higher level of education is a result of a "higher" occupational mix, such as more professionals and fewer labourers. It is therefore of little use for planning purposes to link productivity or income *per capita* directly with formal education. This points to the necessity of (further) research in a vital area, i.e. that of inquiring into the different ways or paths of skill acquisition (especially at the level of the blue-collar skilled worker), and that of obtaining better data on the human functions involved in production. It would follow, therefore, that the educational background of various skills is almost a matter of accident. Certainly the relationship between skill and educational background is immensely complex and not easily classified by such simple criteria as "educational level".

On the other hand, where the adjustment between educational background and skill formation is (more or less) adequate, there may be a strong argument for simplifying the skill classification by approximating it to educational background. It is argued, for example by J. Timar in his paper on "Classification and Analysis of Industries Based on Know-how and Skills" (pp. 11 to 31), that such a step is possible in Hungary. He says that the average complexity (educational level) of labour can be appropriately measured by a system of coefficients, which takes into account the length of time necessary to attain the different levels but also the direct and indirect costs of education and training. This method makes evident the importance of the more highly qualified labour force. The complexity of labour as measured by this or by any other method is higher in countries with better developed industries. That is, it is possible in his view to relate productivity to the skill-mix, and the skill-mix to educational background, and to weight the skill-mix by the costs of education.

As G. Cukor points out in his paper "Planning Methods for Skill Requirements and Productivity Change" (pp. 93 to 102), it is very useful in practice to measure the costs of education. These costs are borne partly by families (individual persons) and partly by the society (central or local governments). In most countries the investment costs and, at least partly, the operating costs of educational institutions are borne by society; the living costs of students are borne mainly by the families (but also by society) in the form of grants, scholarships etc. There is an additional "opportunity cost" in the earnings of the individual and the national income foregone by the society because of the delay in entering the working population. This is certainly true, but "opportunity cost" is an ambiguous concept and statistically elusive. I would argue that this method of measurement of costs does not give the arithmetic ratios of skill intensity that would be necessary for the planning model to give unambiguous answers. In other words, there is a real difficulty in the measurement and classification of skills, and hence in assigning a significant place in the strategy of economic growth to skill formation and, by implication, to the role of the education system, since there are at least two major weaknesses in the chain of logic linking productivity with education. It is this dual weakness (ably analysed by R. C. Hollister in his critique of the OECD methodology[8]) which has led to certain policy conclusions which are at least questionable.

The assumption that there is a fixed technical coefficient between skills and capital, and between both and output, means that it is held to be possible to postulate a rate of economic growth for any economy which requires a given distribution and size of the capital stock, and of the labour force. It is then possible to argue back to physical investment levels and to educational output levels, after making due allowance (in the case of physical capital) for the withdrawal of obsolete and worn-out capital, or (in the case of the labour force) for the death or retirement of the workers.

Since there are fairly fixed relationships (in the short run at least) within the educational system—such as the inputs at primary level necessary to produce a given quantity of graduates—it follows that the analysis of the relationship between the growth of gross national product, productivity and skill requirements leads to a national model of the education system (to which has to be added the requirements for education arising from the so-called "social demand for education", or "education as a consumption", referred to by G. Cukor in his paper).

The results of this type of analysis are two-fold. First, astronomic levels of education appear to be needed for economic growth. The results of this in terms of the fiscal burden are the diversion of a large number of talented people into the teaching profession and the raising in the community of educational aspirations which cannot easily be satisfied (and for which jobs are not likely to be available), as well as a certain amount of social unrest. All these things reinforce the doubts which many people have expressed about the possibility of restructuring traditional education in such a way that it becomes growth-inducing rather than growth-retarding, as so much education (especially in the developing nations) is at present. On the basis of the need for blue-collar skills, countries are producing masses of white-collar mandarins.

The second result of the analysis along these lines appears to be a systematic overvaluation of formal education, and a systematic undervaluation of learning by doing and learning on the job—two methods of acquiring skill which many investigations have shown to be both common and efficient (in terms of time and resources devoted to training, in relation to output). In other words, the analysis tends to exaggerate the amount of education required by a given target for growth, and the extent to which this education has to precede the introduction, or spread, of industries and trades requiring skills. In addition, it tends to remove from consideration the genuine problems in educating and training high level manpower—especially the managerial and governing classes—in societies where education is extremely traditionalist.

4. Training for skills in developing countries

On this basis, if we consider a developing country with a small enclave of an advanced sector (including modern manufacturing industry) and a traditional sector or sectors around it, we may be able to say a little about the place of skill development in the manufacturing sector in modernizing the economy as a whole. In the first place, the spread of traditional education (as has been argued above) is likely to lead mainly to social unrest, drift to the towns, "educated unemployed" etc. rather than to the creation of a reservoir of skills. Second, experience suggests that many skills necessary in the manufacturing industry are fairly easily acquired, and that immigrants from the rural areas will acquire them with minimal formal education and training. Third, advanced managerial skills and professional skills will often be provided by immigrants, or by nationals trained

[8] R. C. Hollister, *A Technical Evaluation of the MRP*. OECD, Paris 1966.

abroad. (This is where the political and social problems associated with dependence, and especially technological dependence, are chiefly felt.) It is perhaps fair to say that there is a tendency to identify the need for these kinds of skills—skills of a very high degree at the managerial and scientific level—with the need for lower-level skills. A number of countries appear to be training manpower of high levels to fill jobs of the middle levels.

We may conclude by asking certain questions. Is it correct to train for specific skills, or to educate generally to a high level? Is there (in any serious sense) a skill bottleneck? Is there not rather a managerial bottleneck? Further, how far is it possible to predict technological change, and how far is very high-level scientific and technological manpower necessary for the development of advanced technological sectors? This takes us straight back to the classical problem in development economics as to whether a developing economy can or should make a technological leap into the very latest modes of production. It is quite clear that, as far as manpower is concerned, it is feasible to a greater extent than it is for physical capital, since advanced education and training (if confined to a narrow class, who are not permitted to emigrate) is far cheaper than the physical capital which the advanced skills complement. Suppose the view is taken that such a leap should be made. Then a number of important questions arise. How many skills should be produced at what cost and how far in advance of assessed needs? Is it not likely that, if the skills are produced in advance in a developing economy, pressures to emigrate and social unrest will arise, as a result of white-collar unemployment?

At a lower level also a number of problems arise: what is the appropriate relationship between high-level and middle-level manpower, in circumstances where the relationships are not technologically determined, but where there is some degree of flexibility? And how far is learning-on-the-job susceptible to high-level advance planning? It is obvious that this paper is an attempt to broach a problem that has hitherto received scant attention. It has therefore seemed to me more important at this stage to seek to pose important issues than to attempt a systematic review of the literature and of the evidence so far available.[a]

[a] This has been ably dealt with in OECD, *The Residual Factor and Economic Growth*, Paris, 1964.

ANNEX

MANPOWER FORECASTING MODELS OF EDUCATION

THE GENERAL method of forecasting is as follows:

(i) The gross national product is projected ahead for—say—20 years. The rates of GNP increase are usually fairly high, and this exaggerates the quantity of various inputs required.

(ii) The sectoral distribution of the GNP in year $(n+20)$ is then assumed to resemble the sectoral distribution of an economy in year (n) which has a GNP similar in *per capita* levels to that expected in the country under investigation in year $(n+20)$. This, of course, is a very dubious assumption, for a variety of reasons.

(iii) A manpower survey, based on census material, is taken for the country for year (n) and the occupational mix for each industry, trade or service is accepted as given, or optional. This is fallacious, and disregards the "chicken and egg" problem of which comes first, education or the demand for skills. (If the whole population had Ph.Ds, all bus drivers would have Ph.Ds.) This manpower mix is then projected for year $(n+20)$. Sometimes a general trend towards skill-intensification is assumed, but the objections to the procedure remain even in this case.

(iv) Skill-levels are then approximated to educational levels. This is extremely dangerous in view of the fact that many skilled people picked up their skills 'on the job', and their educational background may not be a relevant factor.

(v) Retirement rates from the labour force for years (n to $n + 20$) are then calculated, using mortality and morbidity tables, and calculations of drop-outs from the labour force for other reasons. These calculations are highly vulnerable, the rate of job turnover is extremely high, and such social factors as emigration, age of retirement etc. remain largely uninvestigated.

(vi) The desired output from education is then taken to be the manpower targets, derived from the occupational mix for year ($n + 20$), minus the retirements from the labour force, and an assumed annual increment to the stock of skills.

(vii) This desired output then gives an educational structure, since the relationships between different levels of education are assumed to be fixed technical coefficients. This assumption is not unreasonable. But it leaves entirely on one side two questions:

(a) whether the existing educational structure is desirable in itself (whether it is anti-growth, anti-scientific etc.);

(b) whether the educational structure is essential to produce the skills.

(viii) In addition, the so-called social demand for education is calculated, by projecting population, and assuming steadily rising enrolment ratios for each age-cohort. This is added to the calculations referred to in *(i)* above.

(ix) The usual consequence of these calculations is an almost infinite expansion of the existing inadequate education system, with a number of bad consequences:

(a) the education system is put under intolerable strain, and begins to break down;

(b) the demand for teachers becomes the biggest single factor in determining the size of higher education, and about half or more of the graduates become teachers;

(c) the fiscal burden is gigantic;

(d) white-collar unemployment begins to accelerate;

(e) on-the-job training and other informal procedures (which are the true sources of skill formation) are neglected; and

(f) the upgrading of existing workers is neglected.

(x) The errors in the calculations all the way along the line tend to be cumulative in an upward direction, and there is no serious correction for this.

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CLASSIFICATION AND ANALYSIS OF INDUSTRIES BASED ON KNOW-HOW AND SKILLS

János Timar, National Planning Office, Hungary

INDUSTRIAL GROWTH is at the centre of modern economic development. The development of up-to-date large-scale industrial production requires considerable time and investment. Several years ago it seemed that the modern machinery, equipment and factory buildings of the industrially developed countries constituted the basic difference between their industry and that of the developing countries. Further investigation and practical experience, however, have proved that, although scarcity of capital for the creation of the material basis is a barrier to rapid growth, the lack of engineers, technicians, skilled workers and other qualified personnel able to use modern technical methods is an even greater hindrance. Machinery, equipment and, for a certain length of time, even key workers and instructors can be imported, but the mass of productive manpower must be drawn from a country's nationals. It is imperative in the national interest, therefore, that nationals be trained and employed both as general labourers and as leading specialists.

The training and education of industrial manpower takes considerable time. Due to the rapidity of scientific and technical development, new problems continuously arise, even in developed countries. Such problems are even more acute in less advanced countries despite the great efforts made by their respective governments to further education for industrial as well as for social and cultural purposes. In this endeavour they are given appreciable help by the United Nations, UNESCO and other international organizations as well as by the more developed countries.

Both the preparation of the labour force for industrial development and the acceleration of industrialization require a clear conception of the structural changes in the labour force, changes which are a precondition as well as a consequence of industrial development. Such a conception is particularly important for developing countries which can import industrial machinery, equipment and technologies, but cannot fully adopt them without changes in the structure of the labour force or in the system of education and training.

The aim of the present study is to investigate: *(i)* the structural changes in the labour force which occur in the course of industrial development; *(ii)* the possibilities of drawing up a classification of industries based on the quality, structure and changes of the labour force; and *(iii)*, what main conclusions can be drawn from the analysis of changing manpower structures.

1. INDUSTRIAL DEVELOPMENT AND STRUCTURAL CHANGE IN THE LABOUR FORCE

Industry is at the heart of contemporary social and economic development. All the developed countries in Europe, North America and elsewhere have advanced industries. The rest of the world and, in particular, the former colonial countries are just beginning to build up modern industries which are considered essential to economic and social development. It is generally admitted that one of the crucial problems of industrialization—perhaps even the most crucial—is the development of industrial manpower. This development occurs within the framework of the over-all structural change of the entire working population.

Industrial development can be accelerated if the interrelationships between industrialization and the structural change of the labour force are recognized. The basic aspects of these interrelationships are well known (and have been developed in detail in studies by Colin Clark, Jean Fourastié and others). A brief survey of the whole development, however, seems useful here in order to place some particular manpower problems of industry in their proper perspective.

At the beginning of the era of modern economic development, or perhaps more exactly at the beginning of the (first) industrial revolution, 80 to 90 per cent of the total working population of what are now the industrially developed countries was occupied in agriculture. Only 10 per cent of the labour force was engaged in industry (including construction) and in the services. Small-scale enterprises having a family type of work organization were predominant. This type of production, generally employing simple technologies, was mainly manual. The rate of illiteracy was very high and skills had to be acquired by practical experience.

Industrial development and its impact on the labour force had initially three main features:

(i) The productivity of agriculture increased faster than agricultural production. Employment in that sector therefore decreased and unemployed and underemployed persons migrated to non-agricultural sectors.

(ii) Large-scale enterprises based on the use of machinery and mechanical equipment sprang up and indeed became predominant in the industrial sector. The share of small-scale and domestic industry in total industrial production decreased but continued unabated and even to some extent increased in the service sector. Industrial production grew rapidly, due mainly to a long period of expansion of industrial employment. Towards the end of this period of extensive industrial development, the share of industry in total employment had increased to about 30 to 40 per cent, while that of agriculture had fallen to about 25 to 30 per cent. At the same time the rapid advance in agricultural and industrial production also promoted the development of transport, trade, and other service-type sectors; employment in these comprised about 30 to 40 per cent of the total.

(iii) Industrial development caused a structural change in total employment: manpower shifted from agriculture to industry and services. The sex composition of the labour force (or more exactly of the labour force in non-family-type enterprises) also changed, for women were leaving their households and taking jobs. The increase in female manpower, together with the growth of the population, were the main causes of the increase in total employment. The educational level of the labour force rose substantially, a process necessitated mainly by the technological development of production. The spread of general primary educa-

TABLE 1. STRUCTURE OF EMPLOYMENT IN THE MAIN ECONOMIC SECTORS IN PERCENTAGE OF TOTAL EMPLOYMENT IN SELECTED COUNTRIES

Country	*Year*				*Agriculture*				*Industry and construction*				*Services*			
	I	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*
Annual per capita national income (above $ 1,000)																
1. United States	1870	1910	1940	1964	53	32	19	7	22	31	35	34	25	37	46	59
2. Canada	1901	1931	1941	1965	40	32	30	9	32	27	31	34	28	41	39	57
3. Sweden	—	1910	1930	1960	—	48	36	14	—	27	32	45	—	25	32	41
4. New Zealand	1911	1921	1936	1961	27	28	26	14	29	26	28	37	44	46	46	49
5. Australia	1901	1921	1933	1961	25	23	22	11	35	34	35	40	40	43	43	49
6. United Kingdom	1881	1901	1931	1961	13	9	6	4	50	47	47	49	37	44	47	47
7. Denmark	1911	1930	1940	1960	42	36	29	18	24	26	31	37	34	38	40	45
8. Germany (Fed. Rep)	1882	1925	1939	1964	43	31	26	11	37	42	42	49	20	27	32	40
Annual per capita national income ($ 500 to $1,000)																
9. Belgium	1910	1920	1930	1963	22	19	17	6	46	47	48	46	32	34	35	48
10. Switzerland	1890	1910	1930	1960	38	27	21	12	41	45	44	49	21	28	35	39
11. Norway	1900	1920	1930	1960	42	37	35	20	29	29	26	37	29	34	39	43
12. France	1866	1921	1936	1962	51	41	36	20	26	31	31	38	23	28	33	42
13. Austria	—	1920	1934	1961	—	32	33	23	—	33	34	43	—	35	33	34
14. Eastern Germany	1882	1925	1939	1960	43	31	26	18	37	42	42	47	20	27	32	35
15. Czechoslovakia	—	1921	1930	1960	—	42	30	26	—	38	45	46	—	20	25	28
16. USSR	1913	1928	1937	1961	75	80	56	37	9	8	24	33	16	12	20	30
Annual per capita national income (below $ 500)																
17. Italy	1881	1911	1936	1964	57	55	48	25	26	27	29	41	17	18	23	34
18. Japan	1880	1910	1935	1963	82	63	48	24	6	15	19	32	12	22	33	44
19. Hungary	1900	1910	1941	1964	59	53	50	33	16	20	23	36	25	27	27	31
20. Poland	—	1931	1950	1960	—	71	58	48	—	15	23	28	—	14	19	24
21. Romania		1931	1950	1956		81	74	70	—	8	14	17	—	9	12	13
22. Bulgaria	—	1935	1937	1956	—	80	76	65	—	10	13	19	—	10	11	16
23. Spain	—	1920	1940	1960	—	59	52	44	—	22	23	29	—	19	15	27
24. Portugal	1910	1930	1940	1960	59	56	51	42	23	20	22	31	18	24	27	27

Source: J. TIMAR, *Planning the Labor Force in Hungary*, International Arts and Sciences Press, White Plains, New York, 1966.

tion resulted in the elimination of illiteracy. As will be seen later in more detail, the importance of all forms of schooling increased with the expansion of the labour force.

With the disappearance of the former abundance of manpower, industrial development of an extensive type came to an end. Less manpower became available from the traditional sources (agriculture and the family) and the service (tertiary) sectors absorbed a larger part of the total. As a consequence, growth in industrial production became more and more dependent on an increase in productivity rather than in employment. This characterizes a new stage of economic development.

TABLE 2. STRUCTURE OF THE ECONOMICALLY ACTIVE POPULATION: PERCENTAGE DISTRIBUTION BY MAIN ECONOMIC SECTORS, BY OCCUPATIONAL GROUPS AND BY STATUS

Country	*Year*	*Agriculture* ISIC 0	*Manufacturing and construction* ISIC 1–5	*Others* ISIC 6–9	*Highly qualified specialists* ISCO 0–1	*Clerical and sales workers* ISCO 2–3	*Non agricultural workers* ISCO 5–9	*Agricultural employment* ISCO 4	*Salaried employees and wage earners*: *Economy as a whole*	*Salaried employees and wage earners*: *Manufacturing*
United States	1964	7	34	59	20	22	52	6	83	97
Canada	1965	9	34	57	21	21	49	9	84	97
Sweden	1960	14	45	41	15	18	54	13	83	94
Switzerland	1960	12	49	39	10	21	58	11	81	90
United Kingdom	1961	4	49	47	—	—	—	—	—	—
Australia	1961	11	40	49	—	—	—	—	79	92
New Zealand	1961	14	37	49	15	21	49	15	84	94
France	1962	20	38	42	—	—	—	—	72	91
Germany (Fed. Rep.)	1964	11	49	40	—	—	—	—	84	93
Norway	1960	20	37	43	11	15	55	19	78	93
Belgium	1963	6	46	48	11	23	59	7	77	90
Venezuela	1961	34	22	44	7	18	40	35	60	68
Netherlands	1960	11	42	47	12	22	55	11	80	92
USSR	1961	37	33	30	—	—	—	—	60	98
Austria	1961	23	43	34	11	15	51	23	71	89
Czechoslovakia	1960	26	46	28	—	—	—	—	—	—
Eastern Germany	1960	18	47	35	—	—	—	—	—	—
Italy	1964	25	41	34	—	—	47	26	64	80
Hungary	1964	33	36	31	10	10	52	28	70	87
Poland	1960	48	28	24	—	—	—	—	52	89
Romania	1956	70	17	13	—	—	—	—	30	80
Bulgaria	1956	65	19	16	—	—	—	—	37	85
Cyprus	1960	45	25	30	5	11	43	41	—	—
Yugoslavia	1961	59	23	18	7	7	29	57	42	87
Ireland	1961	35	26	39	8	16	40	36	59	89
Spain	1960	44	29	27	4	16	45	35	61	80
Greece	1961	56	19	25	4	10	31	55	34	64
Portugal	1960	42	31	27	4	11	42	42	72	84
Trinidad and Tobago	1960	21	34	45	10	15	54	21	—	—
Jamaica	1960	40	25	35	4	14	49	36	55	47
Panama	1960	48	13	39	7	12	30	51	42	60
Mexico	1960	55	19	26	4	15	27	54	64	81
Chile	1960	30	30	40	7	15	48	30	73	76
Nicaragua	1963	60	16	24	3	10	28	59	56	60
Honduras	1961	70	11	19	3	7	20	70	40	58
Dominican Republic	1960	52	23	25	7	6	36	51	—	—
Philippines	1962	61	14	25	7	9	22	62	33	48
Ecuador	1962	57	19	24	4	10	29	57	48	43
Peru	1961	52	20	28	5	10	38	47	48	53
Syria	1964	51	20	29	5	13	31	51	28	54
Tunisia	1956	75	11	14	—	—	—	—	38	51
United Arab Republic	1960	58	12	30	4	12	29	55	49	77
Ghana	1960	62	15	23	3	15	21	61	20	23
Liberia	1962	82	9	9	2	4	14	80	—	—
Republic of Korea	1964	63	11	26	3	14	22	61	28	60
Niger '	1960	97	1	2	—	—	—	—	—	—
India	1961	73	13	14	3	5	14	78	13	35
Pakistan	1961	76	10	14	2	6	17	75	20	33
Thailand	1960	84	4	12	2	6	9	83	12	50

Source: *Yearbook of Labour Statistics*, International Labour Office, Geneva, 1965.

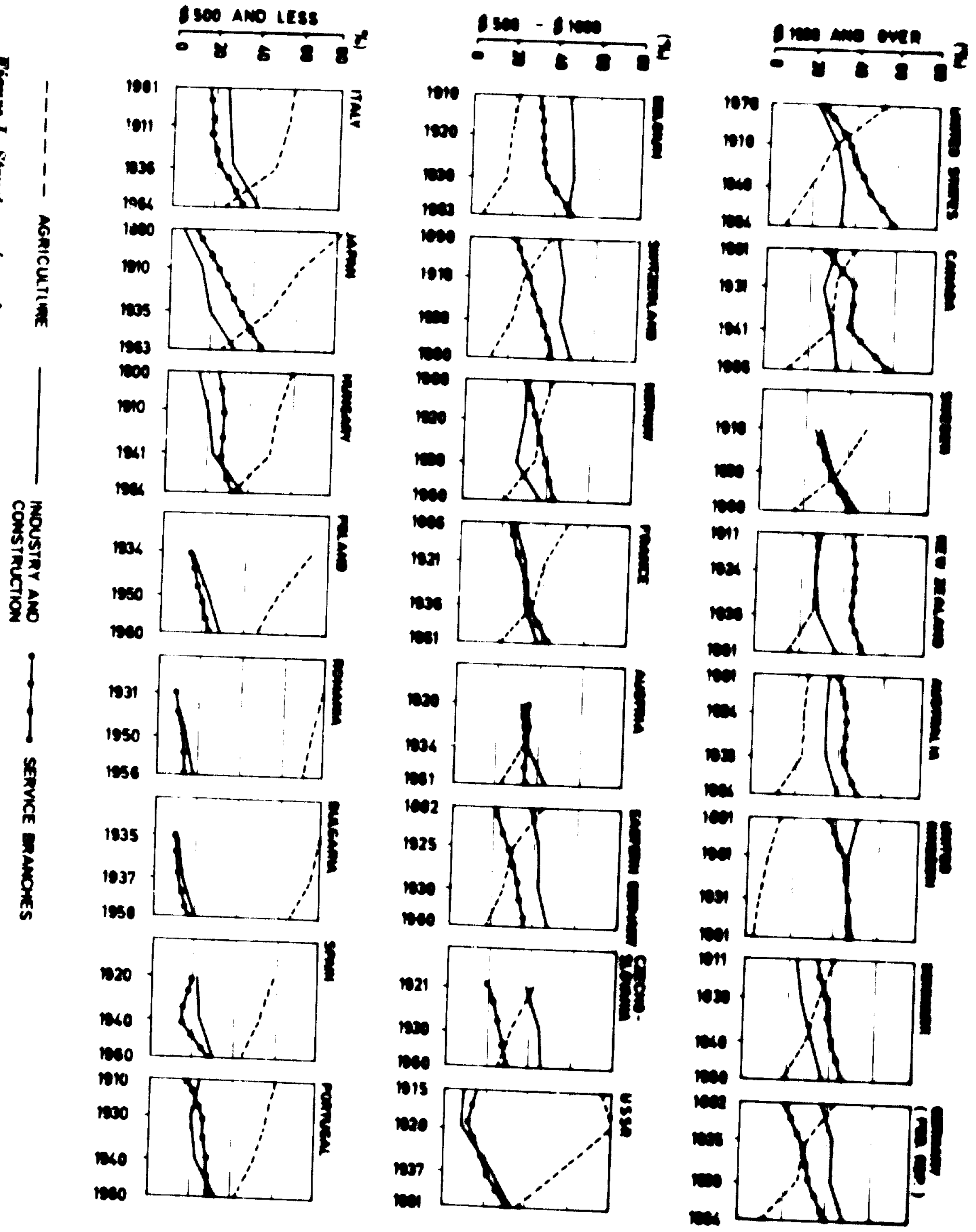


Figure 1. Structure of employment in the main economic sectors in percentage of total employment in selected countries

In this new period of intensive industrial development, machinery and new scientific production methods were also introduced into agriculture more rapidly than before. The share of agricultural employment continued to decrease and in the most developed countries represented only between 4 and 14 per cent of the total employment. In this period, with large-scale production predominant in industry, automation was already beginning. The role of domestic and small-scale industrial production was insignificant. The increase in the industrial labour force was determined by the population growth (except for the use of foreign labour force in some countries), and its share in total employment was already even decreasing in the most developed industrial countries. Employment in certain industrial sectors was stagnating or even regressing, and this provided one of the sources of fresh manpower for the dynamic, rapidly increasing industries.

The further increase of material goods production naturally also promoted the further development of transportation and trade. Up-to-date technical and organizational methods began playing a more important role in these sectors. Education, health services and public administration also absorbed an increasing share of the labour force. The number of persons employed in these sectors grew more rapidly and their share in total employment exceeded that of industrial employment; in the most developed countries, it exceeded even that of industry and agriculture taken together.

Modern technological methods became predominant in every field of human activity. Automation gradually expanded, and science appeared as a direct productive force. Organized formal education became a primary factor in the formation of the skills necessary for production. The interrelationship between education and the economy, hitherto not fully recognized, became even more apparent. It was gradually admitted that the rate of economic development was determined directly and to a large extent by the educational level of the labour force.

This structural change of the labour force within the three main economic sectors is shown in table 1 and figure I; the data cover 24 countries for the period from the end of the last or the beginning of this century up to the years 1960–1965. They clearly show the tendency of agriculture to decrease its share of employment and of services to increase.

Table 2 covers a larger number of countries, including the developing countries, and gives more recent figures. This distribution of the labour force is by main economic sectors; the low participation in industrial activities is a feature very characteristic of the developing countries. The distribution by occupational group shows that highly qualified specialists and clerical and sales workers comprise a larger share in countries at higher levels of development. The increased share of salaried employees and wage earners in the total labour force demonstrates the growing importance of large-scale enterprises in the more developed countries.

The development of the labour forces in individual industries—as regards both the number of employed and the level of skills—can be properly understood within this broad framework. However, in order to recognize the main causes of the differences in the skill pattern of the various industries, a brief survey of the technologies used in the various industrial sectors is necessary.

2 INDUSTRIAL TECHNOLOGIES AS THE BASIS OF SKILL REQUIREMENTS AND THEIR IMPACT ON THE OCCUPATIONAL STRUCTURE

The different technologies used in various industrial sectors obviously determine, to a large extent, the character of the manpower required. If considered in full detail these technologies appear very diverse; nevertheless, from a more general viewpoint their main characteristics can serve as criteria to classify industrial sectors. These characteristics are connected on the one hand with the product itself and on the other hand with particular production techniques, the latter being largely determined by the chemical, physical and other characteristics of the products.

Certain characteristics of industrial technologies of several industries are shown in table 3.

One part of the products serving either final consumption or further industrial use can be considered as homogeneous, having uniform physical and chemical properties. The majority of basic and auxiliary materials, the products of mining, chemical and metallurgical processes, and textiles—in general the products of most of the industrial sectors—belong to this group. The products of some industries and very important ones—are composed of parts having different physical and chemical properties. These products, which are put together in assembly processes, can be called heterogeneous. The most important of them, such as electrical machinery, vehicles, instruments etc., are manufactured by the engineering industries, but clothing, shoes and furniture also belong to this group. The above criterion, as well as the

TABLE 3. CHARACTERISTICS OF INDUSTRIAL TECHNOLOGY OF INDIVIDUAL INDUSTRIES

Industry	*Product*					*Production process*			
	Product type	*Product mix diversification*	*Product change*	*Product development*	*Production development*	*Production process basic principle*	*Production process batch size*	*Main process: Type of labour skills needed*	*Main process: Amount of preparatory work*
1. Mining	homogeneous	narrow	none	low	homogeneous	mechanical	mass	traditional	medium
2. Metallurgy	homogeneous	medium	slow	medium	homogeneous	mechanical-chemical	mass	traditional, scientific	medium
3. Engineering	heterogeneous	wide	rapid	high	heterogeneous	mechanical	individual; serial; mass	traditional; scientific	high
4. Electricity	homogeneous	narrow	none	low	homogeneous		mass	scientific	low
5. Building materials	homogeneous	narrow	none	low	homogeneous	mechanical-chemical	mass	traditional	low
6. Chemical and rubber	homogeneous	medium	slow	high	homogeneous	chemical	mass	scientific	medium
7. Wood processing and furniture	heterogeneous	wide	rapid	medium	heterogeneous	mechanical	serial	traditional	medium
8. Paper	homogeneous	medium	slow	medium	homogeneous	mechanical-chemical	mass	traditional	low
9. Printing	heterogeneous	wide	rapid	low	heterogeneous	mechanical	serial	traditional	medium
10. Textile	homogeneous	medium	slow	low	homogeneous	mechanical	mass	traditional	low
11. Leather and fur	homogeneous	medium	slow	low	homogeneous	mechanical	serial	traditional	low
12. Clothing	heterogeneous	wide	rapid	low	heterogeneous	mechanical	serial	traditional	medium
13. Food	homogeneous	narrow	slow	low	homogeneous	mechanical-chemical	mass	traditional	low

other criteria which will be discussed below do not permit an exact and unequivocal classification in every case. In printing, for example, it is difficult to decide whether the products books, papers and reviews should be considered homogeneous or heterogeneous. The material itself, namely paper, has of course the same qualities in each case. However, considering the diversification of the products and the assembly type operations in bookbinding, it seems appropriate to consider printing as an industry producing heterogeneous products.

The production process is determined by the diversification of the product mix of the industry in question or, more exactly, of a single plant belonging to the industry. There is a definite relation between technology and the extent of the variety of that which it produces. In the case of homogeneous products the diversification is generally narrower, and with heterogeneous products it is usually wider; this is only the general tendency, however, and not the absolute rule. If we disregard by-products and the less important products, we can say that a single product comes from (electrical) power plants, building material plants and (in most cases) food industry plants; the same is true of single mines, for the character of their products is homogeneous. A wide diversification of products characterizes the engineering and the clothing industries in general, although there are some plants in the former which make only a few products, or in certain cases, only one (e.g. radio receivers, television sets or passenger cars). There are some industries, however, such as the chemical and in particular the pharmaceutical industry, in which the variety of the products to be considered is moderately wide, though the product itself is homogeneous.

Diversification (i.e. variety of product) is important also because it largely determines to what extent and with what frequency the products manufactured are liable to change. This fact is closely connected with product development and therefore with the requirement of highly qualified technical manpower. It can be observed that there is no change (or only a very slow one) in industries where the product is homogeneous and the diversification rather narrow (e.g. electricity or building materials). In the case of heterogeneous products and wide product diversification — as in the clothing industry or in several sectors of the engineering industries — the change of products is very frequent. The rate of product change has an effect on the amount of work necessary for product development, but it is not the sole decisive factor. There are industries in which, despite their high frequency of change (for example the clothing and the furniture industries), the amount of work invested in development is insignificant because the new products are basically similar to the old, and changes are made to suit changing fashions. Furthermore, these products are not particularly complicated. Of course, an occasional change may require more development work, for example a new procedure of glueing (fastening) in the shoe industry. In these cases, however, the change affects primarily the production process and only secondarily the product itself. The most important changes affecting the product are primarily those connected with the material used (for example the introduction of synthetic fibres in the clothing industry or of artificial leather in the shoe industry); the actual development in such cases is centred in the industry producing the basic materials in question.

The characteristics of the products mentioned above largely determine the characteristics of the main technological processes. A "main process" may be defined as an operation that contributes to shaping the product itself; "auxiliary processes" include material handling, maintenance and the like. The main production processes can be divided, like the products, into homogeneous and heterogeneous. In the homogeneous processes the same operation is continuously performed by the same machinery or equipment; in the heterogeneous, operations change more or less frequently. There is a rather close connexion between the character of the products and the production processes. Industries having homogeneous products also have homogeneous technologies. For heterogeneous products resulting from assembly operations the main production processes are usually heterogeneous: for example the machine tools of the engineering industries usually serve to produce parts made of different materials and having different shapes.

It is appropriate to distinguish also the scientific-technological principles of the technological processes. A process may either change only the shape of the material by making use of mechanical technology or bring about chemical change by the application of chemical technology. The character of the technology influences the requirements for highly-qualified technical labour and, of course, also the basic knowledge necessary for manual workers. Chemical technologies are (obviously) utilized in the chemical industries; both chemical and mechanical technologies are utilized in metallurgy, in the building-materials industries and in some sectors of the food industries; and mainly mechanical technologies in the other industrial sectors. Technological processes and, in particular, their organization vary according to batch size. In this respect, distinction should be made between individual, serial and mass production. As a rule mass production is used for homogeneous and serial production for heterogeneous products and processes. In the engineering industries all three—individual, serial and mass production—can be found.

Skill requirements, as seen mainly from the viewpoint of skilled workers, can be traditional or scientific. The skills requiring primarily practical experience and know-how as well as those which, in the large-scale industries, are the organic continuation of the artisan skills can be considered traditional. In the scientific skills manual dexterity is of less importance: here the emphasis is on process control and regulation by means of instruments. Long practical experience is less important in the performance of these jobs than a higher educational level, a comprehension of the production processes and of written instructions, and an aptitude for making the required written reports. If we disregard cases of total automation (which are rather exceptional, even in the most developed countries) the traditional skills are predominant in light industries (except perhaps in paper production) and in food industries. Scientific skills are predominant in chemical industries and in electricity. The skills of the engineering industries and of metallurgy are partly traditional and partly scientific.

From the viewpoint of the relationship of the worker to the machinery or implements used, technological processes can be classified as follows:

(i) Manual work performed without tools or with the simplest tools.

(ii) Manual work performed with the aid of mechanical (power-driven) tools.

(iii) Work performed with the aid of machinery, but with a predominance of manual work

(e.g. the feeding of production machinery with material, the feeding of material-handling equipment).

(iv) Work performed with the aid of machinery and with a predominance of mechanical work, the operations performed concerning mostly (but not exclusively) the direct control and regulation of equipment.

(v) Control of more complex equipment, the whole process taking place in principle without intervention by the worker, whose main task is to effect corrections in the process or to deal with emergencies.

Jobs of types *(iii)* and *(iv)* are the most important in the majority of industries. Manual work is still necessary, of course, at least for maintenance. Automated processes coming under *(v)* are important mainly in certain chemical industries and in electricity production. If we consider the categories in the list above as successive steps of mechanization and automation, we find that the introduction of the higher technological stages is facilitated by increasing homogeneity of the product, increasing batch-size and decreasing frequency of product-change. The tendency of technical development is to extend the role played by the higher technological stages and to restrict the lower stages in the main technological processes and in material handling (the situation is different in the case of maintenance). These stages—excluding maintenance—require different types of skills. Lower skill levels, where unskilled or semi-skilled workers are employed, are required by manual work and by work on machinery where there is a predominance of manual operation. The typical skilled worker in large-scale industries, for example the turners in the engineering industries, perform tasks coming under *(iv)*. The control of more complex equipment mentioned under *(v)* requires a new type of skilled worker, in whom aptitudes such as attention, thoroughness and reliability, as well as the appropriate schooling, are more important than special professional skills. Such a skilled worker can therefore shift more easily from one industry to another in his particular field than can the more typical skilled worker in large-scale industry.

Material handling and maintenance, of course, form an integral part of the total technological process. The jobs connected with these are characterized by the fact that their skill requirements are not (or not exclusively) connected with the main technologies. To maintain buildings, the skills of the building industry are needed, and to maintain machinery mainly those skills which are typical of the engineering industries are required. The maintenance of textile-producing equipment or of machinery in the food industry also require special experience in the respective industries. Skill requirements in material handling are generally not very high and arise chiefly from the character of the material (for example, liquids or solids, large and heavy or small and light pieces etc.). The influence of these different technologies on manpower in individual industries will be discussed in more detail in the following sections.

3. Classification of industries by the quality of the labour force

Before the present era of large-scale industries, industrial goods were produced in artisanal and small-scale shops. Here one and the same person generally performed the whole production process and there was no division of labour into intellectual and manual work or into simpler and more complex operations. Mechanization and large-scale production, on the contrary, is characterized by a detailed division of labour. Management, organization and control of the production are now the main task of technical, scientific and other highly qualified personnel.

The tasks of these specialists are being further differentiated by technical development. This differentiation is taking place both in the special field of science or technology (e.g. mechanical, chemical and other engineers) and on the education level. Most countries have technical specialists with full university (academic) training and technicians who have completed a secondary type of education; in some countries there is also a third type of technical education, intermediate between the secondary and the university levels and with courses of two or three years based on a previous secondary-level curriculum.

The tasks of the manual workers are also differentiated by technical development. From the point of view of skill requirements there are three main levels. The more sophisticated operations are performed by skilled workers, whose education requires a longer period (generally several years) of organized apprenticeship and education. A second group of workers perform simpler tasks for which training periods of some weeks or at the most of some months are sufficient. This group, which includes machine operators and the personnel on some assembly lines, is comprised of semi-skilled workers. The non-skilled workers perform tasks such as material handling and other auxiliary-type jobs which require no previous organized training.

Manual work is also differentiated as to its technical content. A rather large number of artisanal skills are losing ground or even disappearing. Certain crafts have acquired a new content while retaining their old name. New technologies, electronics in particular, have given birth to practically completely new skills.

As a result of the division of labour, briefly described above, and of the special technologies characterizing individual industrial sectors, already discussed in more detail, certain skill patterns have become typical for various industries. These skill patterns can be described from two different aspects, emphasizing either the level of education of the labour force or its skill structure.

The particular industrial sectors are characterized by one or more of the following three conditions: *(a)* the use of the same (or of similar) materials; *(b)* the production of the same (or a similar) type of product; and consequently *(c)* the same or similar technology of production. It can be argued on purely logical grounds that these similarities ought to require similar skill patterns for plants in the same industrial sector, even in different countries. If such similarities in the skill inputs of the individual industries do in fact exist, the clear recognition of the relevant interrelationships will not only be helpful in planning and promoting industrial development, but will provide better possibilities of gearing industrial development to the existing (or foreseeable) labour force and also of developing a labour force appropriate to existing or probable future industries.

Some remarks on this subject however seem to be necessary.

(i) The skill pattern of the labour force, which is one of the most important (or even the most important) input of industrial production, is more flexible than other types of inputs, because the possibilities of substitution are much greater. The materials to be used in the production of any given product should normally be exactly the same, although in some cases a few different material mixes are possible. But in the skill content of the labour force there are always greater possibilities of substitution between adjacent categories, for example between engineers and technicians, between skilled and semi-skilled, or between semi-skilled and unskilled workers. This is also largely true of the special crafts, similar operations being performed, for example, by mechanicians and fitters and so on.

(ii) The effective skill content of any one profession or craft is not always identical in different countries—sometimes not even in one and the same country. Professional denominations are largely traditional and by no means rational or based on scientific analysis. For example, the formal schooling of engineers and technicians can reach very different levels in different countries. Even in one and the same country skilled workers in different industries who have undergone different types of training can have different effective qualifications. (In Hungary for example, practically all of the skilled workers in the engineering industries have completed at least three years of organized apprenticeship after leaving primary school. In the clothing industry, as well as in the building materials industry, on the other hand, about 50 per cent of the skilled workers are considered to be such on the basis of practical experience, and have no formal, school-type certificate.)

(iii) The data in national statistics on the qualifications of the labour force are very often scarce, especially those concerning subdivision by the various industrial sectors. Such data are often even contradictory. In the data for the United Kingdom, for example, the figures for 1961 and 1965 on the proportion of skilled workers in the clothing industry varied from 12 to 77 per cent. Similar variations are found for leather production (from 21 to 79 per cent) and for wood products and furniture (from 52 to 78 per cent). Part of this discrepancy is explained by a difference of coverage, but even the discrepancies between statistics having apparently the same coverage seem to be quite large.[1]

(iv) The international comparability of labour statistics concerning qualifications remains very restricted in spite of the efforts made by some international organizations.

Bearing these things in mind, and within the limits of the available information, we shall now attempt to investigate three aspects of the differen-

[1] Computed on the basis of United Kingdom data given in:

			Clothing	*Leather*	*Wood processing*
(a)	1961	Census, Industry Table, Part I, Table 5	30	79	78
(b)	1965	*Annual Abstracts of Statistics*, No. 102, Table 131	74	53	60
(c)	1965	Industries in Great Britain, *Ministry of Labour Gazette*, Jan. 1966, Table 23	77	57	63
(d)	1965	Industries in Great Britain, *Ministry of Labour Gazette*, Jan. 1966, Tables 1–20	12	21	52

The difference between *(c)* and *(d)* is caused by a different interpretation of the "skilled worker" level; *(d)* refers to "skilled operatives" covering also semi-skilled workers, while *(c)* refers to workers having undergone apprenticeship or equivalent training.

ces in the skill requirements of individual industries:

(a) the average skill content (or quality) of the labour force;

(b) the requirements of a highly qualified technical labour force (engineers, scientists and technicians);

(c) the requirements of manual workers, mainly skilled and semi-skilled.

(a) Classification of industries by the average skill content of the labour force

As we have already seen, before the industrial era the principal method of transmitting the knowledge and skills necessary for production was the direct passing-on of working experience. Formal education in schools did not play a major role as far as training for production was concerned. The knowledge necessary to perform certain operations—which at times were complex and required sophisticated knowledge—was transmitted orally and by practical experience from generation to generation. This contrasts with the industrially developed societies of today where by far the greater part of technical knowledge and experience is laid down in written form, and formal education in schools plays a central role in the training and development of skills. This of course does not mean that the direct handing over of work experience, in general by on-the-job training, does not have its importance in industrial societies, but it is more of the nature of a continuation and completion of formal schooling, on which it is very largely based.

The quality of the labour force therefore is determined largely by the levels of schooling. There is, however, no exact and internationally accepted method of measuring and comparing the quality and complexity of labour, although several methods have been proposed, based essentially on three types of consideration.

(i) Some economists have suggested that the quality and complexity of labour be measured by the wages earned by a given category of manpower. This method presupposes a perfect market mechanism under which all goods including labour—are bought and sold at the most "rational" price. As more schooling is necessary in order to perform more complex tasks, the investment in schooling is repaid—even with a certain rate of interest—by the higher wages earned by labour of higher quality. Although this type of reasoning may have some justification, to measure the differences in the quality of labour in this way seems inappropriate. It is well known that occupational wage differences are also influenced by various factors other than effective skill content: occasional scarcities, traditional status, the physical effort required, working conditions etc. It can even be seen that, in industrial countries, the wage differentials between the simple and the more complex tasks have a tendency to decrease, while the differences in the required qualifications are increasing.

(ii) Another method of measuring the quality of labour is based on the length of the worker's educational curriculum (i.e. the number of years spent in school or in formal training). This method eliminates distortions due to accidental wage differentials. But the costs of education, from the point of view both of society and of the individual, vary greatly at different stages of schooling; e.g. lower costs at the beginning and higher later on. This is not only because the costs of education are higher at the secondary than at the primary level, and even higher again at the university or post-graduate level, but also because the "opportunity cost" of keeping a person out of the working population, the loss of national income for society and the loss of earnings for the individual, is higher the older and the better educated that person is.

(iii) The method which is proposed here to measure the quality and complexity of labour takes into account not only the time spent in school (or in other formal training) but also the total costs of education at the different levels. These costs comprise *(a)* investment, personnel and material cost of educational institutions; *(b)* living costs of the students (mainly borne by the families); *(c)* other costs connected with the students, borne by society (grants, scholarships etc.); and *(d)* the opportunity cost of education to society, namely the loss in national income due to the delay in entering the labour force.

The relative levels of the quality and complexity of labour based on this reasoning and on actual Hungarian data are shown in table 4.

On the basis of this or some other appropriate system of weights the average level of qualification of the labour force can be computed for the individual industrial sectors, provided that the scholarity level (or more exactly the number of years spent in school) be known. This method will give better results than taking into account only the number of years spent in school, because the importance of the more highly qualified manpower will be more appropriately reflected.

Table 5 and figure II show the average complexity of labour in various Hungarian and United States industries, as well as the deviation from the industrial average in both cases. (Sufficiently detailed data for table 5 were available only for two countries, the United States and Hungary: the comparison and analysis were based on effective length of education and training, but on Hungarian costs.) It has to be noted that international comparisons are never accurate from every point of view. In the present case the weights are based on the relative costs of education and on the costs of living in Hungary. United States costs would naturally be different. However, as the aim of the comparison is only to demonstrate general tendencies, this system of coefficients can be accepted. Some important conclusions can be drawn from these data.

The comparison deals with countries on very different levels of economic and industrial development. Accordingly, the resulting coefficients are higher in the United States both for the individual sectors and for industry as a whole. However, despite this difference and the difference in the size and other circumstances of the two industries the deviations of the individual sectors from the industrial average are similar in the two countries. As the last two columns of the table show, the variation from the average amounts to 31 points in one case (precision engineering) and to between 8 and 12 points in four other cases (chemical industry, mining, electrical machinery, wood processing); no appreciable difference appears in the other sectors. With two exceptions the complexity of labour can be classified as high, medium or low in the same industrial sectors, compared with the average for industry as a whole.

Table 6 gives a comparison of selected industries in the United States and Hungary on the basis of the average complexity of labour.

TABLE 4. LEVELS OF EDUCATION AND OF COMPLEXITY OF LABOUR IN SELECTED OCCUPATIONS IN HUNGARY

Occupation	*Schooling*		*Level of complexity of labour*
	Number of years	*Ending level*	
Unskilled worker	8	elementary	1.00
Skilled worker	11	apprenticeship	1.33
Technician	12	secondary	1.92
Engineer	17	university	3.81

Source: J. Kovács, "Szakképzés es beruházás" (Education and Investment), *Közgazdasági Szemle*, 1966, 7/8, 899–914.

TABLE 5. THE LEVEL OF COMPLEXITY OF LABOUR IN SELECTED INDUSTRIAL SECTORS, UNITED STATES (1960) AND HUNGARY (1960)

Industry	*Average level of complexity of labour*		*Industry total = 100*	
	United States	*Hungary*	*United States*	*Hungary*
1. Mining	1.79	1.06	110	96
2. Metallurgy	1.49	1.05	92	97
3. Engineering	1.70	1.20	104	115
3.1 Machinery except electrical	1.70	1.17	104	105
3.2 Electrical machinery and appliances	1.71	1.23	105	114
3.3 Precision engineering	1.71	1.46	105	136
3.4 Iron and metal mass products	1.63	1.09	100	101
4. Building materials	1.47	0.91	90	84
5. Chemical and rubber	1.89	1.16	116	105
6. Wood processing	1.31	0.99	81	92
7. Paper	1.50	1.02	92	96
8. Printing	1.74	1.20	107	111
9. Textile	1.47	1.09	90	96
10. Leather and fur	1.50	1.08	96	95
11. Clothing	1.50	1.01	92	94
12. Food	1.47	1.00	90	93
Average	1.63	1.08	100	100

Source: Computed on the basis of R. S. Eckaus, "Economic Criteria for Education and Training", *Review of Economics and Statistics*, May 1964, and Hungarian 1960 Population Census.

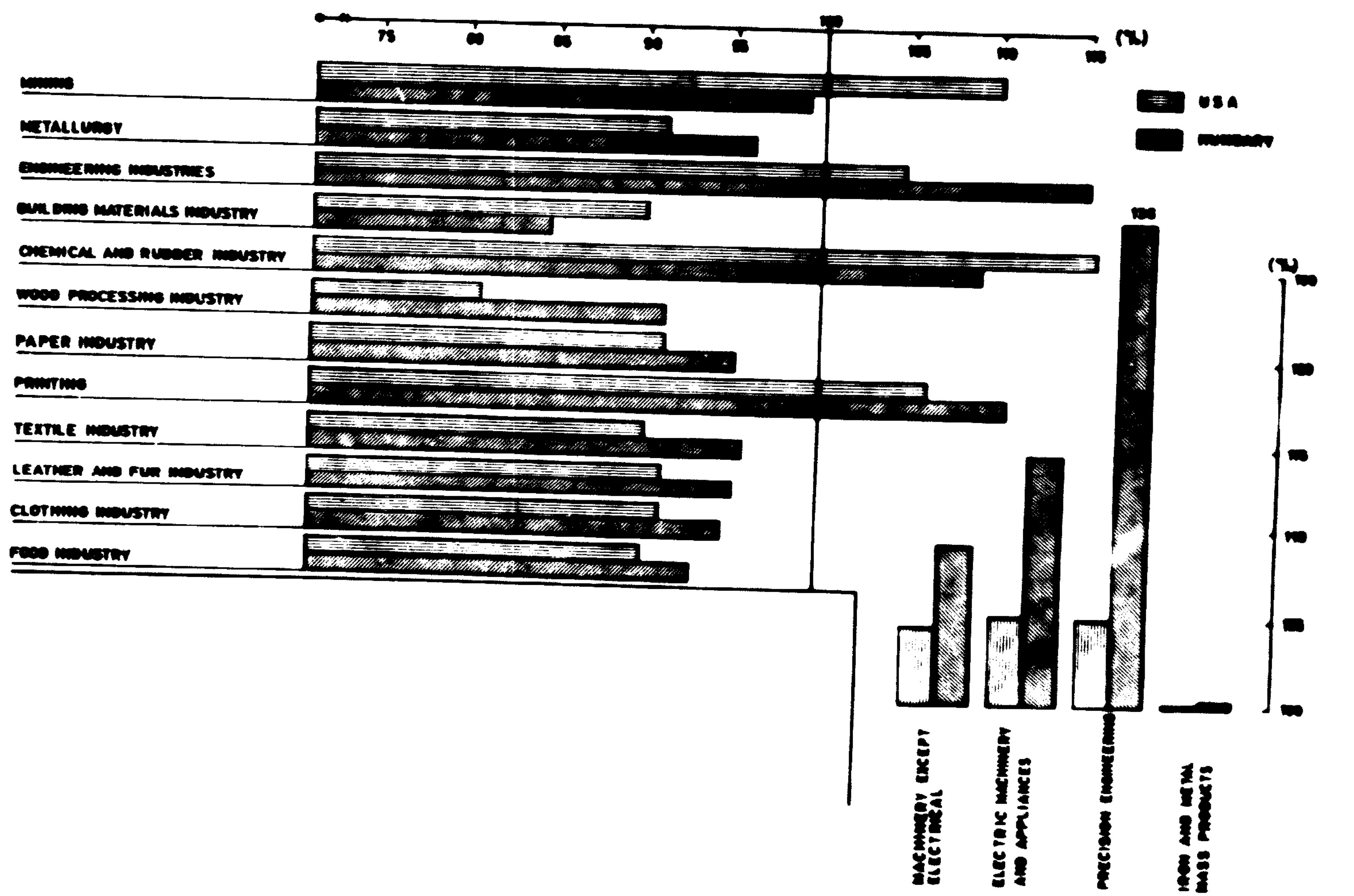


Figure 11. The level of complexity of labour in selected sectors (in the United States in 1950 and in Hungary in 1900). Industry total = 100

TABLE 6. COMPARISON OF INDUSTRIES IN THE UNITED STATES AND HUNGARY: AVERAGE COMPLEXITY OF LABOUR

United States	*Both countries*	*Hungary*
	I. High	
Mining	Chemical and rubber industry	
	Engineering industries	
	Machinery except electrical	
	Electrical machinery and appliances	
	Precision engineering	
	Printing	
	II. Medium	
	Iron and metal mass products	Mining Metallurgy
	III. Low	
Metallurgy	Building materials industry	
	Wood processing industry	
	Paper industry	
	Textile industry	
	Leather and fur industry	
	Food industry	

As shown in table 6, the coefficient is medium (i.e. within ± 3 per cent of the industrial average in both countries) for iron and metal mass production. Hungary has an average complexity level in mining and metallurgy, while the data for the United States show a high level in mining and a low one in metallurgy. The difference between the complexity levels in mining can probably be explained by the fact that the share of less-qualified labour is smaller in the United States due to the favourable geological conditions and the high level of mechanization. In Hungary, on the contrary, geological conditions in mining (particularly in coal mining) are much less favourable, and production, partly on this account, is considerably less mechanized; the share of less-qualified labour is therefore higher. It is more difficult to find an explanation for the difference between the complexity levels in metallurgy. Long-term statistics show that the absolute number of skilled workers has decreased in the United States since 1920. This phenomenon is perhaps connected with technical development of a type that particularly reduces the number of skilled workers.

At any rate, the conclusion can be drawn that the relative qualification level of the labour force employed in individual industries is determined basically by industrial technology, more or less independently of the size of the country or the actual level of industrial development.

(b) Classification of industrial sectors by share of highly-qualified technical manpower (engineers, scientists, technicians)

An increase in the number of white-collar workers, in particular of highly-qualified technical specialists, is a well-known phenomenon accompanying economic and technical development. What is less well-known is how the share of this highly-qualified manpower in the total labour force is distributed among the main sectors of the economy and among the individual sectors of industry. It is this last aspect which interests us

TABLE 7. ENGINEERS, SCIENTISTS AND TECHNICIANS IN SELECTED INDUSTRIAL SECTORS: UNITED STATES AND HUNGARY (1961)

Industry	*Technical specialists per 1000 of employed*						*Relative levels — Total industry = 100*					
	Engineers and scientists		*Technicians*		*Technical specialists Total*		*Engineers and scientists*		*Technicians*		*Technical specialists Total*	
	USA[a]	H[b]	USA[a]	H[b]	USA[a]	H[b]	USA[a]	H[b]	USA[a]	H[b]	USA[a]	H[b]
1. Mining	44	12	16	23	60	35	102	92	59	85	84	88
2. Metallurgy	28	18	15	36	43	56	65	139	56	141	61	140
3. Engineering	77	19	53	45	130	64	179	146	197	167	186	160
3.1 Machinery except electrical	48	17	42	42	90	59	109	131	156	155	129	148
3.2 Telecommunication engineering	106	24	75	55	180	79	244	193	278	204	257	198
3.3 Precision engineering	83	27	56	55	141	82	193	208	215	204	201	205
4. Building materials	20	9	10	15	30	24	42	69	37	56	43	60
5. Chemical and rubber	98	31	44	30	142	61	228	238	163	111	203	152
6. Wood processing	5	2	3	11	8	13	12	15	11	41	11	33
7. Paper	20	9	9	11	29	20	42	69	33	41	41	50
8. Textile	7	5	4	19	11	24	16	38	15	70	16	60
9. Food	12	7	7	12	19	19	28	54	26	45	27	48
All industries:	43	13	27	27	70	40	100	100	100	100	100	100

[a] USA = United States.
[b] H = Hungary.

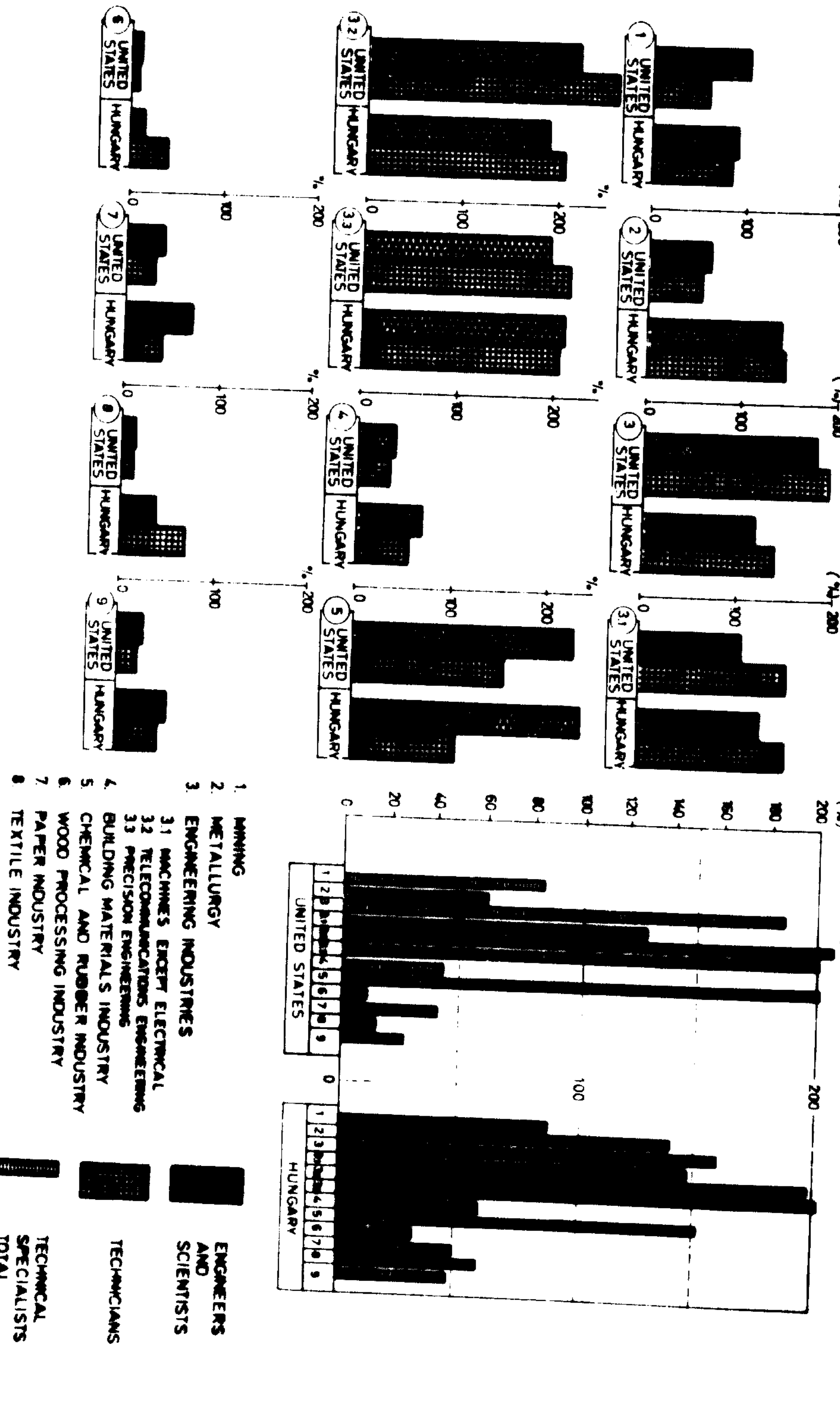


Figure III. Engineers, scientists and technicians in selected industrial sectors (relative levels). Industry totals = 100 here. Detailed data are available for the United States and for Hungary, and table 7 and figure III show (as expected) that the number of technical specialists per 1,000 employees is substantially higher in the United States (70) than in the Hungarian industry (40).[8]

The deviations of individual sectors from the industrial average can be very large. The range is between 11 and 257 per cent in the United States and between 33 and 205 per cent in Hungary. Compared with this wide range the difference between the technical skill intensities of any one industry in the two countries is not very considerable. If we divide the individual industries into three categories for high, medium and low-skill intensity (shares of highly-qualified technical manpower) as is done in table 8, we find a difference only for metallurgy, which shows high intensity in Hungary and low intensity in the United States. Industrial technology is thus again found to be dominant in determining the relative requirements of highly-qualified technical manpower.

[8] The real difference is probably less than appears. Hungarian data refer to the number of persons having obtained the appropriate diplomas whereas the United States data concern persons working as engineers, technicians or scientists. According to the *U.S. Census of Population, 1960* only a little more than 50 per cent of persons working as engineers and only about 75 per cent of persons working as scientists had completed a university education of four years or more, and only 80 per cent of persons working as technicians had at least twelve years of schooling. Adequate correction would either bring down the United States figure substantially or raise the Hungarian figure somewhat.

TABLE 8. COMPARISON OF SELECTED INDUSTRIES IN THE UNITED STATES AND HUNGARY BY SHARE OF HIGHLY-QUALIFIED TECHNICAL MANPOWER IN TOTAL EMPLOYMENT

United States	*Both countries*	*Hungary*
	I. High	
	Telecommunication engineering	Metallurgy
	Precision engineering	
	Machinery except electrical	
	Chemical industry	
	II. Medium	
	Mining	
	III. Low	
Metallurgy	Building materials	
	Textiles	
	Paper industry	
	Wood processing	
	Food industry	

This analysis can be carried one step further. As technical specialists belong to different categories, one can ascertain which kinds of specialists are working in the individual industries. Some aggregation at the outset is necessary due to the large number of specialities. As about 70 to 80 per cent of all engineers are mechanical, electrical or chemical—at least in the industrially developed countries—we can narrow down our closer investigation to these occupations. In some industrial sectors the occupations typical of the sector play an important role, for example, those of mining or metallurgical engineers.

TABLE 9. DISTRIBUTION OF ENGINEERS AND SCIENTISTS IN SELECTED SECTORS OF THE HUNGARIAN INDUSTRY

(percentages)

1	2	3	4	5	6	7
Industry	*Mechanical* (Engineers)	*Electrical* (Engineers)	*Chemical* (Engineers)	*2 + 3 + 4*	*Special profession of the sector*	*Others*
Mining	20.3	4.5	9.0	33.8	54.7[a]	11.5
Metallurgy	33.6	4.5	14.4	52.5	37.6[b]	9.9
Machinery	67.5	10.8	7.0	85.3	—	14.7
Telecommunication engineering	29.4	46.6	10.7	86.7	—	13.3
Precision engineering	49.9	29.5	4.3	83.7	—	16.3
Electricity	40.7	46.7	3.4	90.8	—	9.2
Building materials	35.6	2.6	35.1	73.3	20.5[c]	6.2
Chemical and rubber	20.0	5.0	59.5	84.5	—	15.5
Wood processing	73.5	2.7	16.5	92.7	—	7.3
Paper	52.5	6.1	31.4	90.0	—	10.0
Textile	54.8	3.9	29.8	88.5	—	11.5
Leather and fur	17.5	0.8	74.8	93.1	—	6.9
Clothing	85.7	1.1	3.3	90.1	—	9.9
Food	37.2	4.2	46.8	88.2	—	11.8
All industries:	43.3	13.8	19.7	76.8	—	23.2

[a] Mining engineers; [b] Metallurgical engineers; [c] Building engineers.

TABLE 10. THE SHARE OF SKILLED WORKERS IN THE TOTAL NUMBER OF BLUE-COLLAR WORKERS

Industry	Number of skilled workers per 100 of blue-collar workers				Industry total = 100			
	France (1962)	Hungary (1961)	United Kingdom (1965)	United States (1960)	France (1962)	Hungary (1961)	United Kingdom (1960)	United States (1960)
Metallurgy	31	38	23	35	79	95	77	126
Engineering	47	35	44	36	121	116	139	130
Building materials	24	20	16	21	61	50	53	76
Chemical and rubber	23	34	17	25	59	85	70	91
Wood processing	32	30	52	20	81	75	175	74
Paper	27	24	12	24	69	60	40	89
Printing	59	44	56	43	150	110	186	159
Textile	23	31	9	14	59	77	32	52
Leather and fur	31	28	21	19	79	70	70	66
Clothing	72	49	12	6	184	125	40	22
Food	28	27	11	18	73	66	36	66
All industries:	39	40	30	27	100	100	100	100

Sources: France: *Recensement Général de la Population de 1962*, Population active, INSEE 1964; Hungary: *Skills and Income of Workers*, Statistical Periodical Publications, 1963, 2; United Kingdom: *Ministry of Labour Gazette*, Jan. 1966; United States: *Census of Population 1960*, Occupation by Industry, PC/2/-7C.

Table 9, which is based on Hungarian data, shows the distribution of engineers by occupation and industry.

As column 5 clearly shows—with the exception of three sectors—at least 75 per cent, and in some cases even 90 per cent, of the engineers belong to three leading categories: mechanical, electrical or chemical. The special occupations of the sector play an important role only in mining and in metallurgy. The dominant occupation is determined by the character of the industrial technology, which may be mainly mechanical or mainly chemical. Chemical engineers thus form the leading occupational group in the chemical, leather and fur, and the food-processing industries, while the importance of chemical and of mechanical engineers is about equal in the building-materials industry. The importance of mechanical engineers is appreciable in every industry; theirs is the leading occupation in seven out of the fourteen industrial sectors. Electrical engineers play a dominant role only in telecommunication engineering and electricity.

The intensity of utilization of highly-qualified technical manpower is highest in the engineering and the chemical industries. This circumstance is connected with the characteristics of the industrial technologies used in these sectors, which have (as table 3 showed) particularly high product development, and for which highly-qualified technical specialists are required. Furthermore, the preparation of the production process is important in the engineering industries and requires a great amount of technical work.

TABLE 11. SHARE OF SKILLED WORKERS IN TOTAL NUMBER OF BLUE-COLLAR WORKERS IN SELECTED INDUSTRIES

Same in the four countries	Different in the four countries			
	France	Hungary	United Kingdom	United States
I. Higher than the industrial average				
Engineering Printing	Clothing	Clothing	Wood processing	Metallurgy
II. Lower than the industrial average				
Building materials Chemical Paper Textile Leather and fur Food	Metallurgy Wood processing	Metallurgy Wood processing	Metallurgy Clothing	Wood processing Clothing

(c) *Classification of industrial sectors by requirements of skilled workers*

Because of the lack of detailed and internationally comparable labour statistics, a realistic comparison is particularly difficult between blue-collar workers of different skills. It is hardly possible to distinguish the real differences in the manpower structure from the differences in the statistical system or in the denomination of the different categories.

Tables 10 and 11 show the share of skilled workers in the industrial labour force of four countries: France, Hungary, the United Kingdom and the United States.

The pattern is less uniform here than in the previous comparisons. The division by table 11 into only two categories of industrial sectors facilitates comparison: the share of skilled workers in the total number of blue-collar workers is higher in the first category and lower in the second, than the industrial average. As the table shows, eight of the eleven industrial sectors fall in the same category for all four countries, the three other sectors—metallurgy, wood-processing and clothing—having different categories in the different countries.

The clothing industry belongs to the group of low-skill intensity in the United Kingdom and in the United States, but to the group of high-skill intensity in France and Hungary. The following tentative explanation can be given for this: small-scale clothing industries have been absorbed and replaced by large-scale plants. In this process, workers who acquired skills in small-scale industry (e.g. tailors, dressmakers and seamstresses) were transferred into large-scale enterprises where, for at least some of them, their work was more of a semi-skilled than of a skilled nature. For reasons connected with this artisan tradition, workers coming from small-scale industries and even newly-trained workers can be considered as skilled, although their jobs are more likely to be on the semi-skilled level. It can be clearly established that the high proportion of skilled workers in the Hungarian clothing industry can be explained by this rather than by technology. A similar situation may exist in the French clothing industry, where in addition *haute couture* plays an important part. In the United Kingdom and even more in the United States, on the other hand, a large-scale clothing industry has been developed for a long time and tradition is less important. We were not able to find convincing reasons however for the differences in metallurgy, where the share of skilled labour is high in the United States and low in the other countries, and in wood processing, where this share is high only in the United Kingdom.

The engineering industries employ a high proportion of skilled labour in the countries we are considering. As was shown in table 10 the proportion of skilled labour in the engineering sector in all the countries is higher than the industrial

Table 12. Change in the occupational structure of the skilled industrial labour force in the United States from 1900 to 1960

(percentages)

Occupation	*1960*	*1950*	*1940*	*1930*	*1920*	*1910*	*1900*
Craftsmen, foremen and kindred workers — totals[a]	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
I. Occupations characteristic of large-scale production:							
Mechanics, repairmen and kindred workers	44.4	45.6	40.7	38.7	34.0	28.0	20.0
Skilled workers in metallurgy	1.8	2.2	3.4	3.8	5.0	6.4	6.2
Electricians	8.1	5.4	5.1	6.0	6.1	4.0	2.7
Foremen in metal manufacturing	4.0	3.6	2.6	2.6	2.0	2.3	2.0
Total I	58.3	56.8	51.8	40.3	47.9	36.6	31.8
II. Occupations based on small-scale production:							
Bakers, millers etc.	1.7	2.3	3.6	3.7	3.3	4.3	5.0
Tailors and shoemakers	1.1	2.4	4.4	5.0	7.2	10.2	12.5
Upholsterers and cabinet-makers	1.9	2.4	2.4	2.5	1.9	2.2	2.2
Opticians, lens grinders and polishers, jewellers, watchmakers, gold- and silversmiths	0.8	1.1	1.1	1.2	1.3	1.5	1.6
Printers and bookbinders	4.9	5.2	6.2	6.5	5.5	7.0	6.7
Plumbers and pipe fitters	4.5	5.0	4.9	5.7	5.5	5.6	4.8
Total II	15.2	18.4	22.6	25.4	24.7	30.6	35.8
Total of I and II	71.4	75.2	74.4	76.0	72.6	66.4	67.0

Source: Occupation Trends in the USA, 1900, Department of Commerce and US Census of Population, 1960, Occupation by Industry PC (2) 7C.
[a] Excluding skilled construction workers.

TABLE 13. CHANGES IN THE OCCUPATIONAL STRUCTURE OF THE SKILLED INDUSTRIAL LABOUR FORCE IN HUNGARY FROM 1930 TO 1965

(percentages)

Occupation *Skilled industrial workers total*	*1930* *100.0*	*1949* *100.0*	*1960* *100.0*	*1965* *100.0*
I. Occupations characteristic of large-scale production				
Fitters, tool makers etc.	10.3	17.3	13.2	13.4
Mechanics	5.4	3.5	3.0	1.8
Electricians	6.5	5.4	3.0	2.3
Skilled workers in metallurgy	1.4	1.3	1.2	0.6*
Turners and other skilled machine-tool operators	6.5	5.2	3.5	6.4
Total I	30.1	38.7	30.0	40.5
II. Occupations based on small-scale production				
Skilled workers in the food industry	3.6	4.5	6.0*	12.3
Tailors, shoemakers and kindred skilled workers	13.0	16.2	27.0	26.7
Skilled workers in the wood processing industry	6.5	6.8	10.4	15.5
Printers and bookbinders	0.8	0.7	1.1	2.2
Plumbers and pipe fitters	2.2	1.8	0.7*	0.6
Total II	26.9	30.0	46.9	58.1
Total of I and II	56.0	68.7	76.8	86.6

Source: Population census for 1930, 1949 and 1960 and current statistics for 1965.
* Partly based on estimate.

average. The engineering sectors therefore strongly influence the industrial average and in comparison the skill intensity in other sectors is low, except for printing.

It is therefore rather difficult to discover the direct relationships between skill composition and technologies. It seems however that skill intensity is high in sectors with heterogeneous products, high product diversification and a high rate of product change; it is low, on the contrary, in sectors having homogeneous products and production processes, less product diversification and a low rate of product change.

Structural change in the skill composition within the group of skilled workers shows a clear trend: such trades as are closely connected with mechanization and automation in general, with new techniques and with large-scale production, tend to increase while the share of trades connected with small-scale and domestic industry tends to decrease. Data showing this tendency are set out for the United States from 1900 to 1950 in table 12 and for Hungary from 1930 to 1965 in table 13.

The United States data, which cover more than half a century, show that the share of skilled workers connected with the operation and particularly with the maintenance of machinery and equipment, and of electricians, foremen and machine-operators in the engineering industries more than doubled within the total skilled industrial labour force. The share of workers with skills based on traditional small-scale production decreased. The decline was greatest in the tailoring and shoemaking trades, where not only the percentage of the whole but also the absolute number of skilled workers has steadily decreased since the beginning of the century. The Hungarian data in table 13 show the same tendency. In France also the skills connected with the engineering and chemical industries and with metallurgy increased from 42 to 48 per cent of the total in the period 1954–1962, while the share of the other skills, connected mainly with the light industries, decreased from 58 to 52 per cent.

(d) Composition of the skilled labour force by industrial sector

The skill composition of the industrial labour force can be differentiated not only by the categories of skilled, semi-skilled and non-skilled workers but also by trade. Trades can have very different denominations and skill content in different countries because of traditions, the system of education and the level of development of the industry.

In Hungary, for example, there is at present a system of regular apprenticeship lasting three years for 315 different trades. Out of the total of 315, more than two thirds of the skilled labour force belong to 35 trades and 42 per cent is concentrated in only six. As manpower statistics broken down by industries and by skills were available only for Hungary, this analysis of the skill composition is based on the statistical data of only one country.

Table 14 shows the share of skilled workers in these six trades (columns 1–6), and for the special occupation of some of the sectors (column 8).

The six trades in question appear in every industrial sector, and account for more than 50 per cent in six of the thirteen sectors and for 11 to 31 per cent in five others. The basic trades of the engineering industry (columns 1–4: fitters, mechanics, skilled machine tool operators and electricians) account for four out of the six leading skills. This fact is obviously connected with machinery repair and maintenance. The same holds true of bricklayers and of joiners and cabinet makers (columns 5 and 6), who are also needed for repair jobs in every sector. These data show that 46 per cent of the skilled labour force belongs to some special trade of the individual sectors of industry, such as mining, printing etc. The characteristic trades of the engineering industry are thus seen to play an important role in every industrial sector.

TABLE 14. THE OCCUPATIONAL STRUCTURE OF SKILLED MANPOWER IN HUNGARIAN INDUSTRY (1965)

Industry	Fitters, [illegible]	Mechanics	Turners [illegible]	Electricians	Bricklayers	Cabinet makers, joiners	Total 1–6	Special occupation of the sector	Sum total 7+8
	1.	2.	3.	4.	5.	6.	7.	8.	9.
Mining	13.3	0.5	1.2	6.6	3.5	3.5	27.7	63.6	91.3
Metallurgy	30.1	3.3	7.0	6.7	4.0	5.3	58.3	30.5	88.8
Machinery	40.0	6.3	17.4	4.6	2.1	5.8	76.1		76.1
Precision engineering	16.1	37.5	18.1	6.0	3.5	3.5	84.1		84.1
Electricity	15.7	7.1	1.5	56.7	6.3	3.1	90.5		90.6
Building materials	28.3	0.1	0.9	5.5	13.7	7.3	57.3	16.4	73.6
Chemical	15.6	0.5	2.9	4.5	3.1	3.3	31.3	60.0	91.3
Wood processing	0.3	0.1	3.5	1.6	3.5	57.5	72.7		72.7
Paper	5.3	0.1	2.5	5.3	2.6	0.1	16.0	84.0	100.0
Printing	2.1	0.1	1.0	2.1	1.0	1.0	7.3	77.1	84.4
Textile	7.5	0.2	1.2	0.5	0.9	0.7	11.4	86.6	98.0
Leather and fur	1.5	0.2	0.4	0.6	0.4	0.1	3.6	86.1	90.7
Food	5.7	0.6	1.2	2.4	1.5	2.1	13.0	77.3	90.3
All industries	19.3	3.4	6.5	5.5	3.4	5.0	44.1	46.2	90.3

Source: Computed by the Planning Office from Work conditions and wages of industrial workers. Statistical Periodical Publications 1966, 3, and census of 1965.

4. SUMMARY AND CONCLUSIONS

(a) *Structural changes in the labour force*

Economic and social development go together with a structural change in the labour force, in which there is consequently a characteristic structure corresponding to any given level of economic development. The main feature of this structural change in the course of development is a shift in the sectoral distribution of the labour force and, in particular, a decrease in agricultural manpower. First comes a substantial increase of employment in industry; this slows down or even becomes stabilized and later gives way to a more accelerated expansion of the share of employment in the service sectors. In addition, the share of white-collar workers increases at the expense of that of blue-collar workers, there is an accentuated growth in the former, mainly of technical specialists and in the latter, mainly of well qualified skilled workers. The educational levels generally rise and school education plays an increasing role in training and skill formation for practical jobs.

(b) *Characteristics of manpower in industry*

Manpower employed in industry (or more precisely in individual industrial sectors) is the central interest in this study. The most important characteristics of such manpower are its educational level, the share of technical specialists (engineers, technitists and technicians) and of skilled workers in the total and the occupational composition of the qualified labour force. Manpower in individual industrial sectors has a characteristic structure as to educational levels and occupational composition. This structure, although mainly determined by the industrial technology used in the sector, is closely affected by: the homogeneous or heterogeneous character of the products and production processes, the diversity of the product mix and the rate of product change; the batch sizes of production, the amount of work necessary for product development, and the mechanical or chemical character of the technology in the main production process.

The average complexity (educational level) of labour can be appropriately measured by a system of coefficients, which takes into account not only the length of time necessary to attain the different levels, but also the direct and indirect costs of education and training. This method makes evident the importance of the more highly qualified labour force. The complexity of labour as measured by this or any other method is higher in countries having better developed industries. The complexity of labour in the individual industrial sectors differs from the industrial average and this difference is characteristic of each sector, having the same tendency in industries at very dissimilar levels of development. This fact can be traced to the influence of technology on the composition of labour in the industrial sectors.

(c) *Characteristics of the flow of the labour force*

The flow of the labour force among sectors and occupations shows some fairly regular characteristics. Non-skilled agricultural manpower is transferred mainly to non-skilled occupations in industry and other economic sectors. Part of it is then absorbed rather slowly into occupations requiring semi-skilled and skilled workers. Sectoral and regional mobility can be relatively high, particularly for the non-skilled labour force. Occupational mobility towards jobs requiring higher qualifications is however rather slow, due to the problems of training and educating both adults and the younger generation. Manpower planning and the forecasting of expected requirements are important, because they can facilitate this slow difficult process through planning and preparing formal education and other methods of training and through harmonising the educational and training output with the structure of actual requirements. Difficulties often arise in connexion with the non-concordance of these structures and also with educational outputs which are higher than what is needed, especially in developing countries where relatively large resources have to be devoted to education.

(d) *Existing manpower resources*

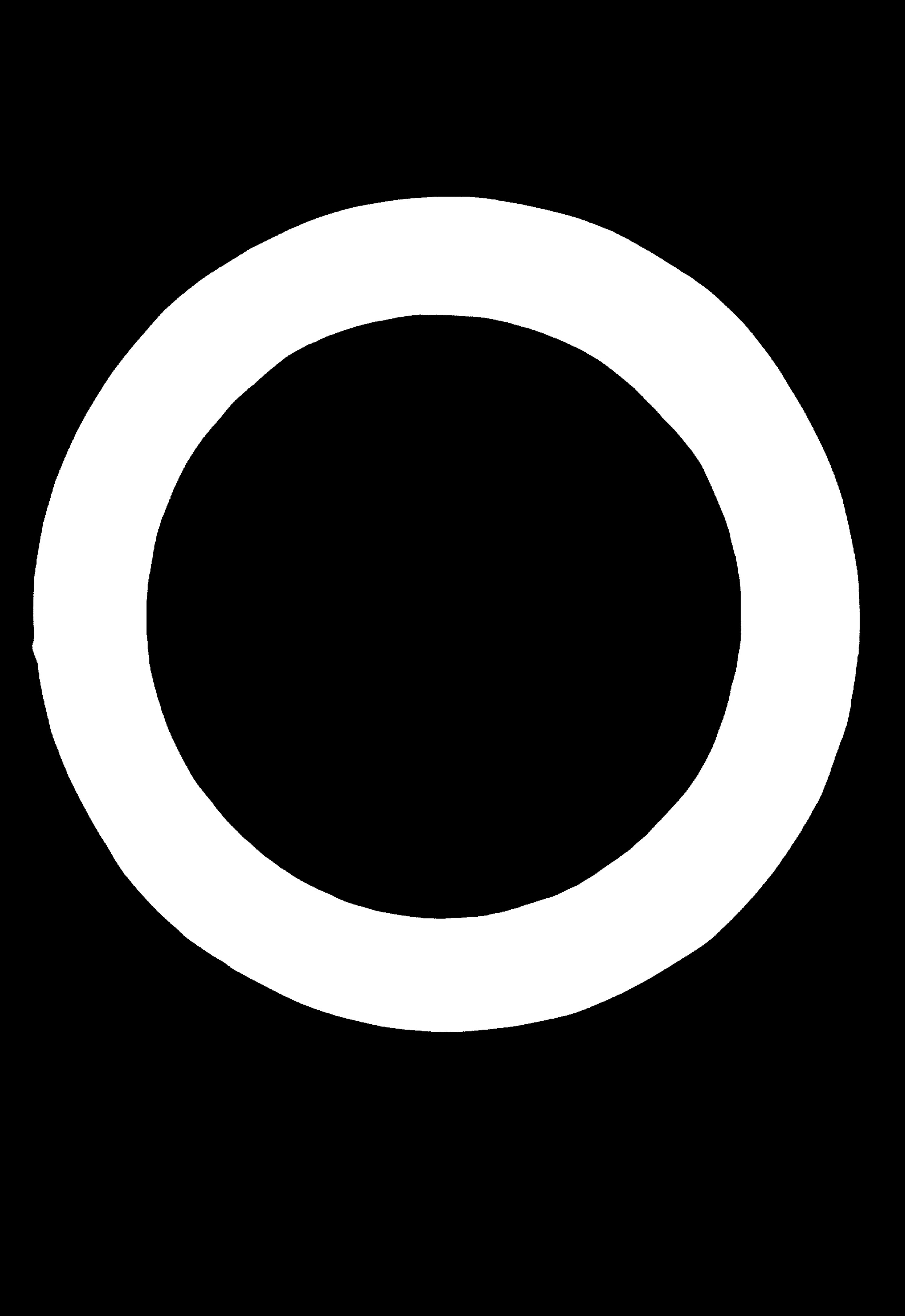
As the skill and educational structure of the labour force can be modified only slowly it is very important to take into proper account the existing resources of manpower. Small-scale industries can represent an important basis of manpower development, in particular when the skills they require can be well utilised in large scale plants, as in the case of the clothing, printing, leather and fur industries etc. The engineering industries, which play a particularly important role in development and which employ about one third of the total industrial labour force in developed countries, deserve special attention in this respect. Manpower in the mechanical maintenance and repair workshops, which are established early or already exist in developing countries, can be used as a nucleus from which to form the labour force in the engineering industries proper. On the other hand, as the skills typical of the engineering industries are also necessary in every other industrial sector, they can be used as a basis in forming the repair and maintenance labour force of other sectors.

(e) *Comparisons of international manpower data*

A comparison and analysis of international manpower data is likely to yield valuable information for manpower planning and development and is therefore essential to the solution of problems in this field, particularly those of developing countries. Lessons drawn from international data, however, can reflect only the main interconnexions and tendencies. Too great hopes seem to have been raised about the possibility of using such data to build general and universal mathematical models for manpower planning or to establish manpower utilisation coefficients which would permit the transposal (taking into account the relative productivity levels) of the findings in one country into the plans of another. This is scarcely possible for two reasons: actual manpower utilisation is influenced not only by technology but also by historical and social circumstances and this, reinforced by the substitutability of different labour inputs, can produce manpower structures in one country which are far from appropriate for another; secondly, international comparability of labour statistics is very restricted.

This of course does not mean that international manpower statistics are useless; on the contrary, steps should be taken to improve the data and increase their comparability; particularly the data pertaining to occupational statistics. Efforts are being made in this direction by the International Labour Organization, which with the help of experts and certain other international organizations is modernizing the International Standard Classification of Occupations. There is however some conflict between the requirements of historical statistics (comparability with previous censuses) and the requirements of planning. In the present statistical system the occupations, spheres of activity, skills and educational achievements are intermixed. For manpower planning the number of persons actually working in a given occupation and the number educated for that occupation are the most important aspects, since social loss may result from possible differences. The increasing role of school-type formal education has to be taken into account especially in the training of the more highly-qualified labour force.

Statistics should therefore be gathered in such a way as to reveal the levels and main types of skills and education, as well as the actual requirements of jobs. From the practical point of view of collecting statistical data, experience seems to prove that only census data, taken at regular intervals and on the same or at least a similar basis can be sufficiently complete to permit real international comparison. The International Standard Classification of Occupations is used mainly in censuses, which should be considered as the main source of internationally comparable data. Special surveys can, of course, play an auxiliary role. An attempt should therefore be made to reconcile the traditional requirements of censuses with the new requirements of manpower planning. The United Nations could play an important role in ensuring that these new requirements, which are especially important for developing countries, be taken into account at the occasion of the world census of 1970.



JOB EVALUATION AS A SOURCE OF INFORMATION ABOUT SKILL REQUIREMENTS

D03191

Lawrence B. Cohen, Department of Industrial Engineering, Columbia University, United States of America

It is desirable for many purposes, planning for industrial development among them, to have information about the skill requirements of occupations, establishments and industries. The technique of job evaluation, a method of determining wage scales, employs information about the skill requirements of the jobs it evaluates, which it collects directly from the establishment for which the wage scale is to be developed. The purpose of this paper is to examine the kinds of information about skills collected in a job evaluation so that their usefulness for other purposes may be assessed.

It will be shown that the skill information available from a job evaluation can be used to express the skill requirements of the establishment for which the evaluation has been made. In this demonstration, three important assumptions are made which furnish constraints upon the findings.

First, the skill data obtained from job evaluation are applicable to the establishment (more precisely, to the culture) from which they are drawn. The possibility of transferring the skill materials to a different place poses issues with which this paper will not deal. Our subject here is confined to the problem of the adaptability of the data to an end use other than the one intended, but without the added variable of applicability to a different place.

Second, the discussion will assume that the skill materials arise from a professionally competent job evaluation.

Third, it will also assume that the procedures of job evaluation, as laid down by authoritative sources, are properly carried out. This implies that the required data conforming to the needs of the evaluation are available as specified and that there are no omissions, short cuts, or implied materials in so far as the skill factor is concerned.

The last two assumptions signify that the discussion below will not question the validity and reliability of the skill information as collected, but will confine its attention to the information as it should be according to the best practice of the technique.

The paper will begin with a review of the structure of job evaluation so as to identify the parts with the skill information desired. It will then examine in detail the skill factor in job evaluation. The final section will assess the usability of the skill information as a source of material for identifying the skill requirements of an establishment, and will suggest methods of utilising the data.

I. THE RELEVANT PARTS OF JOB EVALUATION

Job evaluation is a systematic method of establishing the wage scale of an establishment or of a larger aggregate. It is used fairly widely in the United States and in other industrialised countries, both jointly in collective bargaining and unilaterally by an employer or sometimes by a union. A substantial number of books exist that deal with job evaluation, many of which explain the technique.[1]

There are four principal job evaluation methods, within each of which individual variant systems exist. The four kinds of job evaluation are (a) ranking, (b) grading or classification, (c) point system, and (d) factor comparison. Detailed descriptions of these methods are given in most textbooks on the subject. Their individual characteristics and differences will become evident from the ensuing discussion.

(a) Job information

Each of the four methods starts from a job analysis and description. As the term implies, this consists of an investigation (analysis) of each job

[1] Among others are: David W. Belcher, *Wage and Salary Administration*, 2nd ed., Englewood Cliffs, N.J., Prentice Hall, 1962; William Gomberg, *A Labour Union Manual on Job Evaluation*, Chicago, Labour Education Division, Roosevelt College, 1947; Adolph Langsner and Herbert G. Zollitsch, *Wage and Salary Administration*, Cincinnati, Ohio, South Western Publishing Company, 1961; Elizabeth Lanham, *Administration of Wages and Salaries*, New York, Harper and Row, 1963; Lawrence C. Lovejoy, *Wage and Salary Administration*, New York, Ronald Press, 1959; and Jay L. Otis and Richard H. Leukart, *Job Evaluation*, Englewood Cliffs, N.J., Prentice Hall, 1954.

with respect to its compensable content, after which a description or specification of the job is drafted. The nature of the job analysis depends upon the use to which the data are to be put. The use may be restricted to the job evaluation itself, in which case the analysis must serve the special requirements of the particular method. Perhaps the company plans to use the data for other purposes, such as hiring, placement, training, or the reorganization of work. The analysis will then be designed to such an end use, and both the data collected and their presentation will be suitable to the multiple purposes of the investigation. Since these purposes vary, it is convenient to restrict our present inquiry to job evaluation.

The *ranking method* needs only very brief written job descriptions, since it is generally performed by people who already possess a substantial familiarity with the jobs being evaluated. Many instances of ranking can doubtless be found in which this step of the procedure has not been carried out. Even where a job analysis is made, the information required for the ranking method will tend to be quite brief: a summary of duties or a brief statement of required skills and experience, and perhaps of other salient compensable features of the job. There is no need in the ranking method for a detailed analysis of skill requirements, and accordingly little should be expected.

The *grading or classification method* requires more information about skill requirements. Grading involves a comparison of each job with a selected set of bench mark jobs in respect of a variety of compensable characteristics, among which skill (broadly defined) is prominent. The information collected in a job analysis will thus serve the needs of a comparison of skill requirements and a classification of them within some order of skills. The grading method cannot be used without information about skill content, and the job descriptions, especially when examined in conjunction with the bench mark jobs, will illuminate quite clearly the skill requirements of the jobs.

The *point system* of job evaluation requires that the skill and other requirements of each job be assigned a certain number of points according to an arbitrary scale prepared before the job analysis is undertaken and applied consistently to all jobs. The scale sets the frame of reference for the job analysis. It specifies which factors of skill are significant and it weights them (within both the total skill factor and the total evaluation) by the number of points it assigns for each gradation (also arbitrarily fixed).

To meet the needs of this procedure a considerable amount of detail about skill requirements has to be collected, probably more than for any of the other methods.

The *factor comparison method* utilizes job descriptions which contain information about skill requirements. In this method, jobs are ranked and ordered with respect to skill as well as to other factors. The information does not have to be as detailed as for the point system.

(b) Assessment of skill requirements

Job evaluation requires that the skill information be assessed. The differences between the four methods lie in their ways of assessing job information. From this source also arise the characteristics of the required information, in particular, of skill information.

The ranking method makes a global assessment, comparing the jobs in an establishment and ranking them in relation to each other from the viewpoint of their compensability. If job descriptions are committed to writing, the skill information will not be detailed, nor necessarily consistent from job to job. The final result is an ordering of jobs by wage rate.

Similarly the grading method produces an over-all judgement of jobs based upon their total content rather than upon assessments of their component compensable factors.

The point system produces assessments of skill requirements both by component and for the sum skill as a whole. Thus there may be separate evaluations of general education requirements, job knowledge, experience, and any other factors making up the composite of skill requirements, as well as for the total job, each expressed as a total number of points. The points have no meaning outside the particular plant or evaluation system. For example, a given number of points will not signify a given level of education except within the specific job evaluation plan, but within the plan it will indicate the relative standing of the jobs with respect to each component skill factor.

The factor comparison method ranks jobs, just like the ranking method, but it ranks them by compensable factor, just like the point system. It differs from the latter in that it does not assign points, and it usually treats skill as a whole, not by parts. Since the bench mark jobs are usually described in detail the ranking makes it possible to specify the skill requirements of the jobs.

(c) Assessment of total job

Each of the four methods produces a final assessment of the total job. Ranking, grading, and factor-comparison yield a wage scale directly from their evaluation procedures. The point system yields both an ordering by points on a scale and thereafter a wage scale. A significant analytical finding suggests that the total assessments may reflect the relative skill requirements of the jobs.

(d) *Conclusions*

Information bearing on skill requirements arises from the following parts of job evaluation: the job analysis, description and specification; the evaluation or assessment of the skill factor; and the assessment of the total job by points or total wage scale.

and a fairly similar kind of detail—more than ranking, less than a point system. Since each involves a comparison of skill requirements with those of bench-mark jobs their job analyses search for the kinds of information used about skill which facilitates comparison, such as the machines, equipment, and tools, or job skills required. The point system generally needs the most detailed kind of skill information, but the depth of detail varies with the particular kind of point system.

Second, the quality and depth of information in any given application of the job evaluation technique depends upon the people who make the evaluation. None of the methods is rigorous, and the data requirements have to satisfy only the

TABLE 1. THE PARTS OF JOB EVALUATION IN THE FOUR METHODS

Part of job evaluation	*Method of job evaluation*			
	Ranking	*Grading*	*Point system*	*Factor comparison*
Analysis and description of skill requirements	Desirable but not always done	Yes	Yes	Yes
Numerical assessment or ranking of skill requirements	No	No	Yes	On bench mark basis
Numerical assessment or ranking of total job requirements	Ranking	Ranking	Numerical	Ranking
Wage scale	Yes	Yes	Yes	Yes

Table 1 summarizes the availability of each of these parts within each of the four job evaluation methods.

It now remains to examine these aspects of job-evaluation techniques in greater detail, in order to establish what kinds of information are produced and how they can be utilised.

2. THE SKILL FACTOR IN JOB EVALUATION

Three observations about the skill information contained in job evaluation must be made before the subject can be analysed.

First, the kind of information which may be found in job evaluation depends upon the method employed in the particular case. Each method requires its own kind of information; it has its own categories, end uses, and need for detail. To some extent these may overlap. But there are differences, especially in the degree of detail which is needed. Ranking requires the least (except where the rankers have a marked bias toward skill as the determinant of rank and wage rate). Grading and factor comparison require about the same amount

people whose judgements evaluate the jobs or the end results. Some evaluators will desire more and deeper information, while others will feel able to make the necessary judgement with less. Some applications must be submitted to the scrutiny of company officials, unions and workers, and therefore may need the support of abundant factual material; others may not be subject to close review and hence may require no such ammunition for defence. This variability in the quality and depth of information applies to each of the four methods. It can thus happen that the descriptions for a given ranking installation—nominally the least demanding in respect to skill information—may be better than those of a given point system installation: thus would reverse the assessment made under the first point above.

Third, there are profound cultural biases in the skill information furnished by job evaluation. These biases begin with the notion that skill is a category deserving of differential compensation. They are perceptible in the definition of the skill factor and its several components. After the categories are specified, biases will be expressed in the observation of jobs, in deciding which aspects reflect skills and which skills deserve noting, and in the drafting of the description and specification.

The biases derive from many sources, some of which may be identified. The culture of the society and its particular form in the locale of the job evaluation will cause some skill features to stand out while others remain unperceived. For example in an area with broadly diffused mechanical skills (an ability to use various kinds of tools etc.) the need to know some of these skills may not be mentioned. In a completely unilingual area the ability to speak and understand the language will probably not be noted, while in a multilingual area a knowledge of more than one language may be a salient skill requirement of a job. Thus many aspects of general education, employment experience, work discipline, and manual and other skills may not appear on the job description because they are taken for granted. Similarly the place of employment will often have its own sub-culture pertaining to jobs and job skills which will cause some features to be emphasized while others may be neglected. To illustrate, a plant may, out of wage tradition, sharply differentiate between a more modern and a less modern piece of equipment, endowing the newer one with greater worth, in part on account of skill, although in point of fact the older one may make the greater skill demands. The sub-culture may also work in the opposite direction.

Before turning to investigate the skill information provided by a job evaluation it is well to recognize these characteristics of actual skill data. Having noted them here our discussion will in future assume that the skill data reflect the phenomena which they purport to describe, notwithstanding their limitations.

(a) The meaning of skill

The term skill in job evaluation derives its meaning from the purpose of the procedure: to discriminate among employees in respect to compensation. Skill is a basis for such discrimination; greater skill requirements, other things being equal, command higher wage rates. Skill merits higher wages because it may be scarce in relation to employer demand, it may represent a measure of investment by the employee, or its acquisition may involve a cost to the employer. Thus the skill gradient as measured by job evaluation has significant economic undertones. It may differ from measures of skill based upon other considerations such as natural gifts, length and intensity of preparatory training, personality characteristics, etc.

Not only each of the four general methods but also each of the individual systems within each method may have its own words with which to denote the general concept of skill. The variety of language available can be seen in the various books of job evaluation and in their citations of individual sytems. A study of a large number of these sources leads to the generalizations about the definition of skill which will be put forward here.

The skill concept in job evaluation divides into three main parts. They consist of the skills arising from (*a*) general education, (*b*) occupational training, and (*c*) personal traits. As will be shown, these in turn are made up of many sub-factors.

The skills arising from general education, as they apply to job requirements, pertain to language and mathematics. The language skills are ability to understand the spoken language, to speak, to read and to write. Each of these in turn can be graded by reference to the kinds or levels of materials encountered on the job. Mathematical knowledge is similarly capable of specification: counting and ordinal ranking, simple addition, subtraction, simple multiplication and division, fractions, proportions etc. In higher skill jobs, especially in administrative ranks, other fields of knowledge obtainable through general education may be required. For example, a university degree is required for certain professions such as medicine, the law, and others. This first part of the skill concept embraces all the subject matter which is usually acquired through formal schooling, but not through professional or occupational education.

The second part of the concept includes all skills obtained by occupational training and experience. Here the sources of the skill rather than the subject matter may be specified. First, there is formal schooling, which includes trade and professional schools as well as formal training programmes within a particular company. Next, there is prior job experience: the skills required by a given job may be specified by the previous jobs considered prerequisite to the one in question. Finally, there are particular skills which can be stated outright, such as typing, stenography, or the ability to use certain tools and machinery.

The third part of the skill concept pertains to personal characteristics which may be partly native and partly cultivated. Ordinarily intelligence is not part of this concept; it may be taken into account elsewhere in the skill category, or in other aspects of the job, such as responsibility factors and the like. Other native traits may be specified, such as sensory, manual, muscular, or memory skills, but these are perhaps more relevant to hiring practices than to establishing wage scales. Within this category are certain specific dexterities, such as computational speed and accuracy, and the like. Social skills and personality characteristics may also be considered aspects of the skill content of jobs.

This review will suffice to demonstrate that job evaluation has a comprehensive notion of skill and that a wide range of information relative to skill may be required in order to carry out an evaluation.

(b) *The available skill information*

This skill concept furnishes a general frame of reference for collecting information about jobs. Not every evaluation investigates skill requirements as broadly or as deeply as this concept suggests. But any competent evaluation must have a good deal of it, certainly enough to outline the profile of skill requirements for the job, if not to fill in all the details.

Job information is collected in various ways: by observation, by interviewing informants including the job incumbents or supervisors and others who may have relevant information, and by examining records. Once collected, the information is subjected to analysis in order to adapt it to the purposes of job evaluation, that is, to make salient those aspects of skill which are relevant to the ensuing parts of the procedure. Each evaluation system specifies the kinds and the form of information which it requires. In part, the original data can be used as collected; for the rest, the evaluator must analyse it and make valid inferences about skill requirements. In most evaluations the final information is assembled and put into systematic form and can be located in the job descriptions (or job specifications or evaluation sheets) of the particular case. These documents, one for each job, furnish the final statement of job content, including the skill requirements. They vary from system to system, and it may be necessary to utilise various source documents within a single evaluation in order to obtain the essential materials. In any case, at some point in a job evaluation, the factual data are assembled and can serve as primary, and highly reliable, sources as to the skill requirements of the jobs.

While systems and individual installations differ, it is possible to describe, perhaps in a general way, just what kind of skill information becomes available through job evaluation. This will be done separately for each of the three major sub-factors identified above.

(i) *General education*

The requirements as to general education may be specified in one or both of two possible ways: by actual skill or by grade level achievement in school. Ordinarily the evaluator will assume some minimal level of language skill, such as ability to understand and speak, and will not note it unless there are special requirements, such as for a receptionist, telephone operator, or any other position having significant duties of communication or relations with the public or with other employees. In multilingual areas this assumption may not be valid. Reading and writing abilities, especially if they pertain to any part of the job tasks, will be noted, and probably some indication of their level. Arithmetic requirements will also be specified, usually by type of operation or by reference to a subject, e.g. shop mathematics, algebra etc.

Grade-level achievement, where relevant, is usually stated in terms of standard schooling practices, in the United States by levels such as completion of elementary school (through eighth grade), high school, or one or more years of college. Sometimes such specification reflects the essential requirements of a job, but very often it reflects the predilections of a given enterprise and the calibre of its staff, account being taken of the availability of applicants and the firm's ability to meet the going rate. For example, the specification of a secretary may state a year's college education as a requirement, but a high school graduate may be fully capable of performing the full range of occupational tasks. The year's college may be required because it is supposed to contribute to the maturity, polish, and perhaps the informational range of the incumbent.

It should be noted that both forms of specification produce exact and concrete statements as to general educational requirements. If they reflect the facts of the jobs, the evaluation documents yield explicit and unambiguous data on this facet of skill requirement.

(ii) *Occupational knowledge*

Information collected about occupational training will be similarly specified concretely as to time, experience, or achievement.

Experience is usually expressed as previous jobs which have had to be held by the incumbent, or by length of time employed in an enterprise. In many establishments there are fairly definite routes of progress from unskilled to highly skilled occupations. Employees enter at a job appropriate to their experience, and then progress onward as

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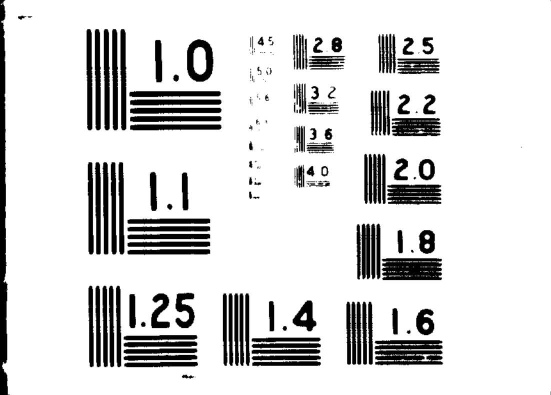


their knowledge expands and as opportunities arise. A very common example of this may be found in the maintenance trades, where men may enter as apprentices and proceed through the intervening grades until they achieve the status of first-class carpenters, machinists, tin-smiths etc.

Information about requisite prior experience can be distorted by existing company practices originating in training policies or in union-management or other personnel arrangements. Where these exist they tend to overstate rather than understate the prior-experience requirement. A particular company may have a sequence of jobs through which its salesmen have to pass before becoming sales trainees. They may start with serving as mail clerks and deliverers, and proceed through other jobs, all specifically laid out. A training justification may exist for the sequence: the individual has the opportunity to become acquainted with the company and its component parts, the products, the fairly complex paper routines, the personnel etc., but it also may be true that much of what is essential could have been learned more quickly by formal procedures, and perhaps much of what is learned is not necessary for becoming a salesman. The procedure also enables the supervisory and executive staff to observe the individual and to make the necessary personal assessments. But the training programme may be made possible by the fairly low rates of pay to the trainees, and by the substantial number of eager job applicants. Were this job sequence to appear upon the job specification the experience requirement would reflect practice, not actual training needs. Similarly, union-management agreements governing job sequences may be developed as part of a seniority system, as wage progression, or as an apprenticeship programme. Strictly from the point of view of training, the established sequence may be unnecessary, but it may be the one to appear on the job description. These examples illustrate the possible distortions which may appear in the data and which can be cleared up by appropriate inquiry.

Required occupational experience may be expressed as training time, a factor which appears on almost every evaluation. How long does it take to train a man without previous experience: on this job, or in the job sequence, or to become proficient on the job? Ordinarily respondents are given choices which will differentiate among large classes of jobs: a day or less, a week, a month, three months etc. These allow time for individual differences. Sometimes the information can be obtained from performance records, but usually supervisors or experienced workers are the sources of the estimates of training time.

This training time information is perhaps among the most important measures of the skill requirements. It is admittedly an estimate, and subject to the industrial climate and population of an area, especially the cultural constraint noted above. But with all these limitations it furnishes a very valuable measure of the skill content of jobs, measured by the time (and hence the cost) it takes to train an incumbent.

Finally, occupational training may be expressed as a level of achievement. This may be done in terms of formal schooling, or by mastery of certain techniques. Formal schooling refers to trade, business, or secretarial schools, or others providing formal courses of study, usually of a specialized occupational nature. Levels of achievement may be designated by ability to operate certain kinds of machines (typewriter, key-punch, lathe, punch-press, truck etc.) or perform certain tasks (weld, mix chemicals from formulae, write shorthand, translate, draft etc.). Both kinds of achievement imply training, sometimes of a formal kind.

(iii) Personal traits

The elements of skill grouped under personal traits are usually judgements inferred from occupational tasks or policies of the particular enterprise. They are probably of little interest to the subject proper of skill requirements. Those which are trainable have already been considered in the two preceding factors. Their native abilities and personality traits, while reflected to some extent in personal skills, are perhaps outside the problem at hand. In any case the job evaluation may produce information specifying requirements of this kind wherever important to the job.

3. Utilizing skill information

The information provided by a job evaluation can be used to specify the skill requirements of a given job. It is also possible to summarize the information for a part of the whole of an establishment, and possibly for multiple establishments or an industry.

A general method of summarizing the skill data will be described here. It is intended only to illustrate how skill requirements for an aggregate can be drawn from job data, assembled, and expressed in summary form. To apply the method in practice it would be necessary to take into account the kind of information available from the source, and the purpose to which the summary is to be put.

The method is sufficiently flexible to allow its use with quite a wide variety of source data and end uses.

The method consists of assembling the source data into summary tables, each applying to a distinct skill factor. The illustrative tables are: general education by grade level, and by skill; and occupational knowledge by training time, formal schooling, and specific skills. Others can readily be formulated. In general a table is drawn up by listing the jobs by name in the first column, assigning the remaining columns to a graded sequence of skills, and then entering in the appropriate box the job's skill requirement. In some cases a mark (X or V) is sufficient, in others the number of employees. The resulting array may then be summarized by suitable measures including the mean requirement, the range, and (where desired) a distribution. The tables are five in number and cover the following information: (1) general education—grade level; (2) general education—skill; (3) occupational knowledge—training time; (4) occupational knowledge—skills, and (5) occupational knowledge—formal training.

Table 2 organizes information pertaining to the general education requirements of jobs. It draws from the evaluation the job titles and the grade level required by the job (the grade level may be available directly, or it may have to be interpreted from points assigned at the job). The number of employees is sometimes provided by the evaluation; if not, it must be obtained from other company sources.

Below the table is a suggested form of summary. This arranges the information into a distribution by grade level, and for each of which it gives the total number of employees and the percentage. From the distribution a weighted average and a range can be determined. The result: a profile of educational requirements for the jobs of a particular establishment (or other aggregate).

Table 3 suggests a method of arraying the specific skill requirements arising from general education. The information is obtainable directly or by inference from the evaluation data. The skill categories would have to be formulated on the basis of the source data and the purpose of the array. The detail shown on the table may be excessive, or insufficient, or otherwise distorted, and can readily be modified to suit the actual need. The columns of the table can be filled in by a mark or by entering the number of employees.

TABLE 2. GENERAL EDUCATION: GRADE LEVEL

Job	*Number of employees*	*Grade level*

Distribution

Grade level	*Number of employees*	*Percentage*
		Weighted Average:
		Range:
Total:		100.0

The summary at the bottom shows the percentage of employees required to have each of the skills. Even if only marks are entered in the columns of the table it is still possible to summarize the information. By adding up the number of marks (jobs) in each skill the totals and percentages can be calculated for the total number of jobs.

Table 4 is an array of the training time required for each job. The elements for this table are the job titles, the required training time for the job, and the required training time for each of the prerequisite jobs.

TABLE 3. GENERAL EDUCATION: SKILLS

Job	*Skills (Enter number of employees)*						
	Understand	*Speak*	*Read*	*Write*	*Simple arithmetic*	*Advanced arithmetic*	*Algebra*
Total:							
Percentage of total:							

TABLE 4. OCCUPATIONAL KNOWLEDGE: TRAINING TIME

Job	*Training time*	*Training time: preceding jobs*				*Total time*	*Number of employees*
		1	2	3	4		

Distribution

Training time	*Number of employees*	*Percentage*
Average:		
Range:		
		100.0

The number of employees is obtainable either from the evaluation or from other sources. In the usual evaluation (if training time is provided) the table will require a fair amount of paper work, tracing each of the jobs through its prerequisites and then noting the information.[2] When the data are fully entered on the table the training time of each job can be added to yield a job total.

Information can be summarized as noted on the table: a percentage distribution by length of training time, the weights, the average training time, and the range of times. As a single measure of the skill requirements of an establishment this one is probably the most relevant and succinct.

Table 5 suggests a method of summarizing specific occupational skill data. A job evaluation can be expected to furnish information about the specific skills required for a job—skills designated by tools or machines which are employed, or by precise skills which must be executed. The purpose of such a summary is to furnish guidance as to how the information ought to be classified. Table 5 illustrates a very general set of categories not intended for any specific end use. As in the previous tables, marks or the number of employees are entered in the appropriate cells and may be summarized as needed according to the patterns described above.

TABLE 5. OCCUPATIONAL KNOWLEDGE: SKILLS

Job	Number of employees	Skills							
		Machines				Tool use			Inspection
		1	2	3	4	1	2	3	

Table 6 arrays the formal schooling required for occupational training. As in Table 5 the categories depend upon the particular purpose of the summary. In general such a table will be applicable only to establishments having specialized jobs in given trades, techniques, professions etc.

TABLE 6. OCCUPATIONAL KNOWLEDGE: FORMAL TRAINING

Job	Number of employees	Individual courses of study	Occupational schools

As has been noted, these tables are only illustrative of the use of data, array, and methods of summarization. On their pattern others can be readily constructed, given the nature of the source data and the end use, and making use of the job facts collected during the investigation. It is also possible to use the evaluated information, such as the assigned points in the point system, or the assigned wage per hour in the factor-comparison

[2] In some cases it may be possible to organize the material in the form of an input-output matrix, listing all the jobs in the firms column (as row captions) and also in the top row (as column captions). For each job in the first column, indicate in the subsequent columns which jobs are prerequisite, and if possible, their sequence. This procedure is by no means always feasible, because of the size of the job list, the differences among jobs, the possible alternative sequences, and other complexities of the individual establishment. Where it can be prepared the matrix has many other valuable uses.

system. These will then have to be interpreted in respect to the skill requirements which they are supposed to reflect.

The method thus far described provides for multiple tables of skill requirements. This corresponds realistically to the nature of the required skills. It may be desirable for certain purposes to summarize the requirements by some over-all measure: certain suggestions may be made for this purpose.

It is unlikely that the skill requirements of an establishment or an industry can be expressed in any meaningful way by a single characterization. To say that an industry requires skilled or semi-skilled employees, or that its general skill requirements have an index of so-and-so on some arbitrary scale does not reflect adequately the complex reality of skill requirements. Rather, it seems more appropriate to describe skill requirements by a distribution which reflects both the skill attainments and the inputs needed to achieve them. The information from the job evaluation points to a distribution as the most apt way of characterizing skill requirements.

For any given purpose a summary of one of the skill factors may be the most appropriate. Suppose, for example, a general educational system is to be designed or evaluated for its service to local industry: the summarization of a general education table conforms to such an end use. The other tables may be considered similarly appropriate for various given purposes.

For some particular purpose two or more of the tables may be relevant. It would then be useful to ascertain whether one of the tables is sufficiently representative to serve as surrogate for the others: if not, methods of combination must be sought. The tables giving time distributions can possibly be combined directly. As to the others it may be possible to establish cost information which would allow them to be brought together on that basis.

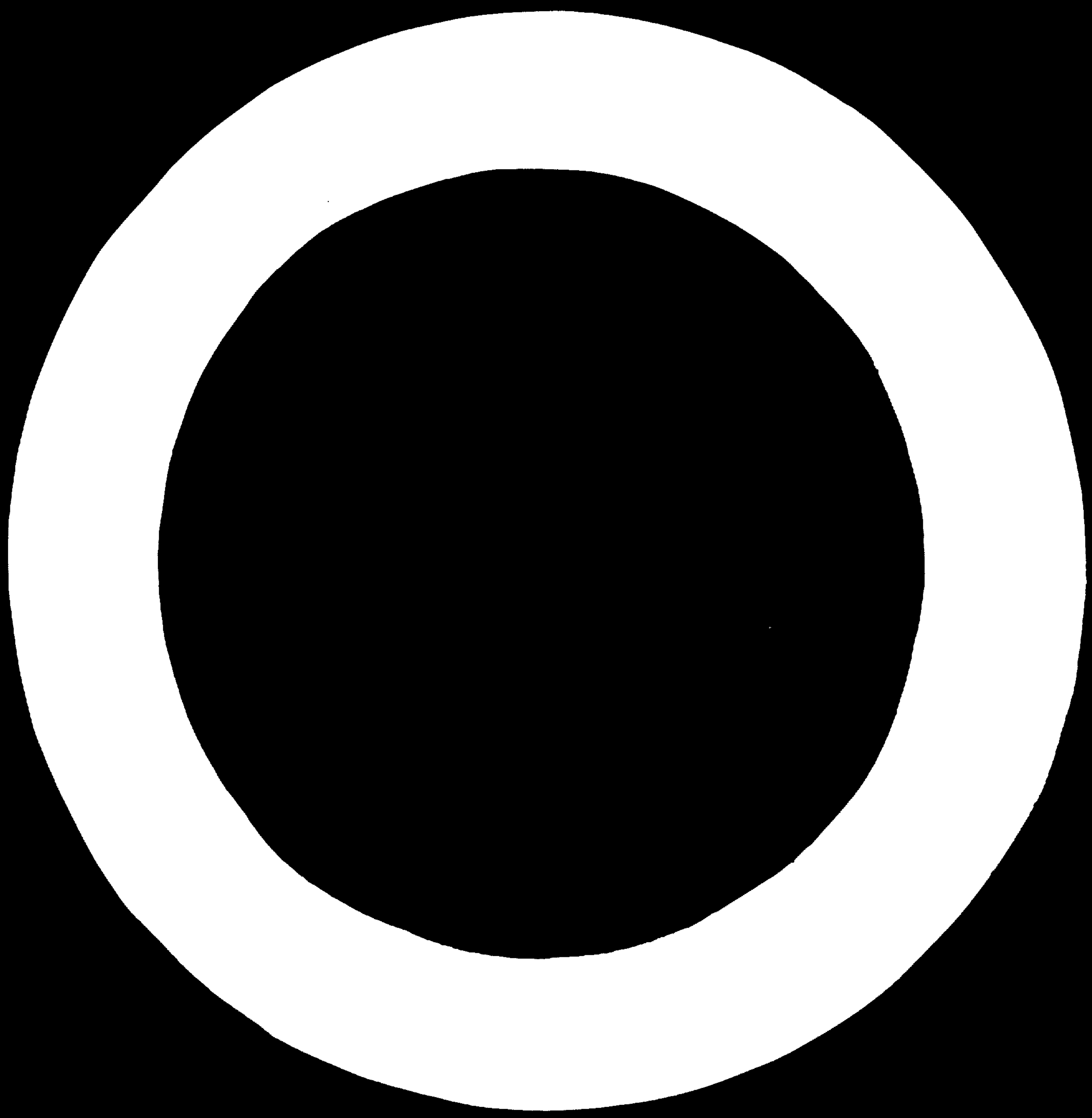
4. Conclusion

It has been shown that a competent job evaluation can furnish relevant information about the skill requirements of the establishment in which it is made. Methods have been put forward by which the available information can be summarized so as to depict the skill requirements of the enterprise as a whole. These results are applicable to the particular establishment from which the skill data derive.

The extent to which the data of any particular establishment may be generalized, in so far as skill requirements are concerned, to other establishments in the same culture or in other cultures will require further study.

Part Two

CHOICE OF TECHNOLOGY AND OTHER THEORETICAL ISSUES



CHOICE OF TECHNOLOGY: A CRITICAL SURVEY OF A CLASS OF DEBATES

A. K. Sen, Delhi School of Economics, New Delhi, India

D03192

1. Efficiency and Optimality

Before one can enter the debate on the complex question of the choice of technology in the context of development planning, certain preliminary issues have to be cleared up. These include the concept of technical efficiency, which is one of the dominant concepts in the field of policy-oriented economics.

Suppose we are considering some technical choice i which permits the production of an output combination x using an input combination y. If it is possible to produce the same bundle of commodities x with less of at least one, and no more of any, of the inputs, then the technical choice i is not efficient. This is simply because efficiency implies producing a given quantity of output with as few inputs as possible. Similarly, if with that collection of inputs y, an output combination can be produced which exceeds x in at least one, and is no less in terms of any, of the outputs, then again the technical choice i must be regarded as inefficient. This is because efficiency also implies that for any given collection of inputs we should try to get the maximum of outputs.

In fact, we can combine the two criteria together by treating inputs as negative outputs.[1] Thus defined, what efficiency requires is that no more of any one output can be obtained given the amount of the others.

This takes us a certain distance, but not very far. If a certain technical choice leads to a greater output of a given commodity and a lower output of some other commodity than a different technical choice would do, the criterion of technical efficiency does not help us at all. Both these technical choices may satisfy the test of efficiency and yet we may be left with a problem still to be solved.

The concept of technical efficiency is often applied at a given point of time, but there is no difficulty in extending it over time. All we need to do is to treat a certain commodity today as different from the same commodity tomorrow. In other respects the definitions, concepts and criteria need not be altered. The same problem of incompleteness persists, naturally, even in this extended view of technical efficiency, embracing more than one point in time. In fact, in comparing two alternative technological possibilities, we might face a possibility of having more of a certain commodity at point of time t and less of some commodity at a point of time $(t+1)$. Once again the criterion of technical efficiency cannot solve this problem.

The main usefulness of the criterion of efficiency is that it permits a preliminary sorting out. A number of technological possibilities may be eliminated on grounds of inefficiency, and then we shall be left with a set of efficient technological possibilities, the choice between which must be made on the basis of some other criterion. Efficiency is like a test applied in the "qualifying round", and it needs to be supplemented by some other criterion to determine which is the winner amongst those alternatives that have qualified.

This is where the notion of optimality comes in. This is one of the basic concepts used in economics: an optimum choice represents the "best" among the feasible alternatives. Naturally, if we are to choose the optimum combination we must have some criteria for discrimination between the various alternatives.

A preliminary point of logic may be cleared up at this stage. We can distinguish between two conditions for rational choice: the existence of either a "complete ordering" or a "choice set". The former requires that any two alternatives should be consistently comparable with each other in terms of some ordering relation, such as "being at least as good as . . .". This property is sometimes called "connectedness". Another required condition is "transitivity", which demands that if x is regarded as being at least as good as y, and y is regarded as being at least as good as z, then x should be regarded as at least as good as z.[2] When

[1] See Debreu (Bibliography, p. 56, No. 11). A good introduction to the problems of efficiency can be found also in Koopmans (No. 33).

[2] On the logic of ordering, see Arrow (No. 1) and Debreu (No. 11). It may be noted that the way we have defined any two alternatives being comparable not only guarantees "connectedness" but also yields "reflexivity", which requires that every alternative be regarded as "at least as good as" itself. When the alternatives considered are the same, what was defined as "connectedness" is in fact a condition of "reflexivity". By and large in optimal policy decisions, reflexivity is not a major source of worry; in fact, a minimal degree of sanity seems to be sufficient. The real problem arises with connectedness and transitivity. On this, see in particular Arrow (No. 1).

these conditions are satisfied, a complete ordering exists over the relevant conditions.

The existence of a choice set is somewhat different. This requires the existence of some alternative which is regarded as at least as good as every alternative in the available set. This simply means that a "best" alternative exists. The existence of a choice set may be regarded as sufficient for the purposes of choosing an optimal policy.

It is important to note that the existence of a complete ordering is neither a sufficient, nor a necessary condition for the existence of a choice set. It is not sufficient because, although we may be able to order alternatives in a certain fashion, if there is an infinite number of them, it is possible that no best alternative may exist. For example, alternative 2 may be preferred to 1, alternative 3 to 2, alternative 4 to 3, and so on, *ad infinitum*. It is not a necessary condition because, although we may be able to compare some alternative with all the others and find it to be at least as good as them all, there may, nevertheless, be intransitivities, or a lack of connectedness. For example x may be regarded as better than y and also better than z; but we may not be able to compare y and z by the criterion we are using. Even so, we may feel safe in choosing x, since it is the best alternative, although we cannot compare its two inferiors y and z.

In spite of this difference between the conditions for the existence of a choice set and those for the existence of a complete ordering it is clear that there is an intimate relationship between these two aspects of rational choice. In fact, most of the discussions on optimality have been concerned with obtaining a criterion for a complete ordering, and it has been supposed that this in itself will guarantee the identification of a best alternative. This presupposition makes eminently good sense when the number of alternatives is finite, when a consequence of the existence of a complete ordering is the existence of a choice set. When, however, the number of alternatives is infinite, this consequence may or may not follow. Furthermore, even when a complete ordering does not exist we may still be able to find what is the best thing to do. Although we shall not be concerned very much in this paper with this contrast it is important for us to bear in mind the difference between these two requirements of rational selection. Indeed, in some problems the distinction can be extremely important.

Whether we prefer a choice set or a complete ordering, we need some method of ordering, a criterion to tell whether a certain alternative x is better or worse than, or indifferent to, another alternative y. The concept of technical efficiency can be used partly for this purpose, and we may find that x is more efficient than y and simply eliminate y. However, as we noted before, this does not help when x and y are both efficient. Much of the debate on the choice of techniques is concerned with supplementing the criterion of technical efficiency by some other criterion that will permit us to choose between the efficient alternatives. In the discussion that follows we shall be concerned with a choice among a set of efficient alternatives, and shall assume that the inefficient ones have already been pruned away.

We shall thus have no further use for the concept of efficiency as such, which (it will be assumed) has done its job, and the discussion will concentrate on some supplementary criteria to take us beyond efficiency. The lively debate on technological choice which has taken place over the last two decades has been concerned with methods of supplementing the relatively uncontroversial criterion of technical efficiency. To this range of problems we now turn.

2. Suboptimality of Savings Rate and Choice of Technology as a Problem of "Second Best"

Investment decisions can be classified into various types, according to whether they depend on the optimum size of investment, the optimum capital-intensity, or the optimum sectoral allocation. While it is important that we recognize these investment decisions to be different, we cannot regard them as independent. Indeed, much of the controversy on the choice of technology concerns the dependence of the amount of savings on the factor proportions selected.

A simple illustration may bring out the difference between some of the schools of thought. It may be argued that wage earners tend to have a higher propensity to consume than profit earners. This is likely to be spectacularly true in a socialist economy, where the profits are earned by the state, but it may hold good even in the case of a privately-owned enterprise. Given this assumption, it appears that the proportion of additional income that is saved will depend on the distribution of that additional income between the wage earners and the profit earners. And this distribution, in its turn, depends on the choice of technology, since a more labour-intensive technique will (other things being equal) tend to lead to a higher share of wages.

A special case of this has been much discussed: the assumption that the wage earners have a propensity to consume of 1 and profit earners have a propensity to consume of 0. This is, however, a rather limited case, and the problem with which we are concerned relates to much more general conditions, viz, the propensity to save of profit earners is systematically higher than that of wage earners. Given this assumption a direct link would be established between the degree of labour intensity chosen and the proportion of the additional income that will be saved.

Situations often occur in which one technique will lead to a higher amount of total output and another technique will generate a higher amount of total savings. If we wish to attach additional weight to the savings generated, over and above the weight that is attached to all output (be it saved or consumed), then clearly this will affect our decisions regarding which techniques to choose.

For the purpose of this discussion total output and total savings may be regarded as two separate commodities, even when they are assumed to be physically homogeneous, as in some simple models. The question of economic efficiency discussed in the last section may be applied to such a case. Any technique which generates less of either total savings or total output and no more of the other may be simply rejected as inefficient. But after this preliminary pruning operation had been carried out, we would be left with a set of techniques that could not be compared purely on efficiency grounds. We should then have cases in which a higher amount of total savings results in a lower amount of total output. What our choice is in such a situation will depend crucially on the additional weights to be attached to savings as against output.

At this stage we might ask: Why must we attach any additional weight to savings as such? After all, savings involve a certain sacrifice of present in favour of future consumption, and what reason is there for us to believe that it is always better to sacrifice present consumption for a corresponding future amount? Indeed there is no such compelling reason in general. What the debate on choice of technology did was to assume (often implicitly) a suboptimal rate of savings, some outside constraint preventing the savings rate from rising to the optimal level. As a consequence there was always reason to look kindly on any policy which led to a higher proportion of savings.

Why this suboptimality should arise is itself a complex question. In the case of private-enterprise economy it can certainly be argued that the rate of savings may be considerably below optimal.[3]

In particular, it has been argued that people might be willing to sign a contract forcing everyone to save a certain amount for the future, even when they may not do it individually under the market mechanism: a situation of this kind has been christened the "isolation paradox".[4]

There seems to be considerable agreement at a practical level regarding the need for raising the rate of saving in many under-developed countries. Indeed one has only to look through the planning documents of a variety of countries to see that one of the persistent themes is the need for a higher rate of saving and a higher rate of growth.[5] These documents are clearly based on certain assumptions, usually implicit, about the objectives to be achieved by the economy, in terms of which the existing rates of saving appear to be below optimal. Sometimes the arguments are fairly sophisticated,[6] sometimes not.

Whatever the reasons for the suboptimality of the savings rate, it seems to be clear that this is a persistent diagnosis for most under-developed economies. In the presence of such suboptimality it is not difficult to see why additional weight has to be attached to the part of the additional income that is saved and invested as against the part that is consumed. It is in this context that much of the controversy on the problem of choice of technology in recent years become fully clear.

Essentially the problem is that of choice of technology in a world of suboptimal savings. It can also be viewed as a problem in the theory of "second best".[7] Since misallocation at the margin of choice between savings and consumption is due to some specific constraint, this will be reflected in the choice of the degree of labour intensity implicit in the technological selection. The problem would have been totally different if the case had been one of allocating an optimal of savings among techniques with varying degrees of labour intensity.

A distinction should be made in this context between

(a) a general equilibrium formulation where the amounts of savings, the degrees of

[3] See PIGOU (No. 58), RAMSEY (No. 62), BAUMOL (No. 4), DOBB (No. 15), SEN (Nos. 72 and 76), MARGLIN (Nos. 42 and 43), FELDSTEIN (No. 20) and others.

[4] SEN (No. 72). See also BAUMOL (No. 4), MARGLIN (No. 42), HARBERGER (No 25), LIND (No. 40), PHELPS (No. 57), and SEN (No. 76).

[5] See R. F. KAHN (No. 31) for a review of some of the planning documents in this context.

[6] Optimum savings models have generally tended to yield extremely high rates of savings, very much in excess of the usual rates observed anywhere in the world. See, among others, TINBERGEN (Nos. 79 and 80), GOODWIN (No. 23), CHAKRAVARTY (No. 6), and SEN (No. 75).

[7] See LANCASTER and LIPSEY (No. 34).

labour intensity, and the pattern of investment are to be simultaneously selected; and

(b) a partial equilibrium formulation where the technical choice is confined to finding an optimal labour intensity for a marginal project.

In the former case the inoptimality of the savings rate should not be assumed although it may result from the allocational exercise. In the latter case an over-all suboptimality of savings may be taken as given, since the project in question is too small to affect the over-all inoptimality of savings.

Some kind of an objective function may be given which depends on technical choice and the proportion of savings. In the absence of any constraint on savings, our choices should lead to an optimal situation with the usual marginal equalities, if the exercise is of the former kind: in the absence of a specific constraint on the rate of savings, the rate of transformation between consumption at time t and the consumption at time $(t+1)$ will equal the rate at which we are ready to substitute the one for the other.[8] There will then be no need for a marginal preference in favour of future consumption, implying additional weight on the savings generated. Even in the general-equilibrium framework, if some outside constraint is imposed which prevents the rate of saving from rising above a certain level, a suboptimality of savings can result. It will then be appropriate to attach additional weight to savings as against the part of the income immediately consumed.

Such constraints can arise for a variety of reasons, including political difficulties in taxation. The planners may want a higher rate of saving in terms of the objectives assumed by them, but fail to achieve this for fear of political reactions.[9] Given this political constraint the suboptimality of the savings rate that may be generated will tend to influence the optimal technical choice in the direction of relatively more capital-intensive techniques, as implying a relatively higher rate of savings.

This is precisely where a different school of thought may make itself heard, arguing that such political constraints do not in fact occur, that the total amount of income to be saved can be determined by the planner in any way he likes, and that he can then see that this decision is executed through the machinery at his disposal, such as wages and incomes policy, taxation policy and monetary policies. If this is true then the link snaps between the choice of techniques and the proportion of income saved. Then technical choice may be made with the main purpose of maximizing the amount of output,[10] and the proportion of the output to be invested can be decided at a separate stage.

In the context of such an assumption it will be right to argue that the amount of income generated in a surplus-labour economy ought to be maximized even at the expense of savings. This argument could spring from the assumption either that there is no suboptimality of savings or that the proportion of income that can be saved, even if constrained, is not dependent on the distribution of income. Various elaborations of these arguments can be found in economic literature.

Having commented on what appear to be some of the major issues that divide the different schools of thought in the debate on technical choice, we may now proceed to discuss the controversy itself in some greater detail. We develop a general framework in the next section and then express the various criteria in terms of comparison and contrast. This general framework uses a very simple model with one homogeneous commodity, which nevertheless illustrates almost the entire controversy that has taken place in recent years on choice of techniques for an under-developed economy. At a later stage, in the context of a model on concave programming, we shall discard this assumption, and discuss the problem in a multi-commodity context.

3. A GENERAL FRAMEWORK

Let there be a production function relating output (Q) to labour (L) and capital (K).

$$Q = Q(L, K) \tag{1}$$

We assume this to be homogeneous of the first degree, i.e. with constant returns to a scale. Let the wage rate be given by w, the propensity to consume of wage earners by c_1 and the propensity to consume of profit earners by c_2. The amount of the income that is saved is represented as S, which is expressed by the following relationship:

$$S = Lw(1-c_1) + (Q - Lw)(1-c_2). \tag{2}$$

[8] This is on the assumption of smooth differentiability. When there is only a limited number of basic alternatives, with resultant "kinks" in the transformation surfaces, the corresponding rule will take the form of a set of inequalities. See DORFMAN, SAMUELSON and SOLOW (No. 12, chap. 12).

[9] Whether this range of problems can arise in a fully socialist economy is a matter for discussion. For some indications that they do, see PAJESTKA (No. 55) and MARGLIN (No. 45).

[10] The implicit framework here is that of a one-commodity model, but the corresponding conditions for a multi-commodity model are easy to obtain.

We assume that the supply of labour is unlimited.[11] The object of the exercise is to maximize a certain weighted sum of output and savings.[12] It is to be remembered that savings S is a part of output Q, so that the weight attached to S is in the nature of a premium, i.e. it is an additional weight, over and above the weight that S receives as a part of Q. Let this premium on savings be given by λ, which we have taken to be positive, since we have assumed the savings rate to be suboptimal.[13] The object therefore, is to maximize the following welfare function

$$V = Q + \lambda S. \qquad (3)$$

Given the amount of capital the problem of the choice of techniques is simply to find the right amount L, which will determine the appropriate degree of capital intensity (K/L). Due to the assumption of constant returns to scale, it does not matter how we choose K, for the discussion is all in terms of ratios per unit of capital. It is clear that the first order condition of maximization of the objective function is given by the following when K is given:

$$\frac{\partial V}{\partial L} = 0. \qquad (4)$$

Given the equations (1), (2) and (3) it can be seen that the conditions of maximization given by equation (4) requires the following:

$$\frac{\partial Q}{\partial L}\,[1 + \lambda(1 - c_2)] = \lambda w\,(c_1 - c_2). \qquad (5)$$

As a condition on the marginal productivity of labour we can re-write relationship (5) as follows, defining that magnitude to which the marginal product of labour is to be equated as "the real cost of labour" (w^*):

$$w^* = \frac{\partial Q}{\partial L} = \left[\frac{(c_1 - c_2)\,\lambda}{1 + (1 - c_2)\,\lambda}\right] w. \qquad (6)$$

Much of the controversy on the choice of technology for an under-developed economy with surplus labour can be seen to be variations on the theme represented by equation (6). With this general framework we can sort out the different contributions in this controversial field.

One clarifying remark should be made before we proceed further. The evaluation of alternative techniques depends crucially on the value of λ, i.e. on the additional weight to be attached to investment as against consumption. The value of λ in its turn depends on the relative weights to be attached to consumption today as against that in the future. What we are really attempting, therefore, is to provide a one-period model which tries to catch the essence of comparison of the relevant sets of time series of consumption representing alternative technological possibilities.

That the problem of choice of techniques cannot be solved except in terms of making explicit value judgements about alternative sets of time series has been discussed by Sen[14] who also argued that the different criteria proposed really boil down to doing this very thing in a highly implicit manner.[15]

4. CONTRIBUTIONS BY LEWIS, POLAK, BUCHANAN AND KAHN

In his classic study of the theory of economic growth Lewis analysed the problem of choice of techniques for economies with surplus labour. He argued:

> "Special care is to be taken in those countries which have a large surplus of unskilled labour, for in such circumstances money wages will not reflect the real social cost of using labour. In these circumstances capital is not productive if it is used to do what labour could do equally well; given the level of wages such investments may be highly profitable to capitalists, but they are unprofitable to the community as a whole since they add to unemployment but not to output... It is then arguable that the real cost of using labour in cottage industry is zero, whereas factory production uses scarce capital and supervisory skills."[16]

It is clear that some assumption exists under which the "real cost of using labour" will in fact be zero, as argued by Lewis. Equation (6) raises

[11] For a contrast of views on the empirical acceptability of this assumption, see NURKSE (No. 52), LEWIS (Nos. 37, 38 and 39), ECKAUS (No. 16), MELLOR and STEVENS (No. 49), ROSENSTEIN-RODAN (No. 66), LEIBENSTEIN (No. 35), VINER (No. 81), HABERLER (No. 24), OSHIMA (No. 53), FEI and RANIS (No. 19), SCHULTZ (Nos. 68 and 69), JORGENSON (Nos. 28 and 29), MARGLIN (No. 46), SEN (Nos. 73 and 76), and MEHRA (No. 48).

[12] In a general equilibrium framework the weights should vary with the choice of techniques, and the objective function should be "non-linear". However, in the case of a small project, the total savings and the consumption for the economy as a whole may not be much affected by the marginal choice. There the weights can be taken as given, much as the perfectly competitive firm takes prices as given.

[13] The choice discussed here is for a marginal project. A wider exercise should take λ as a variable. The optimality conditions, however, will remain the same for appropriate values of λ.

[14] SEN (No. 70).

[15] Explicit attempts at making these comparisons can be found in SEN (Nos. 70 and 71), ECKSTEIN (No. 17), BAGCHI (No. 2), and others. This problem has been penetratingly studied by MARGLIN (No. 45), in an approach to be commented on later in this paper.

[16] LEWIS (No. 38, pp. 140 and 386).

the question: what is it that Lewis is assuming which leads to this result? It should be one of two things: he is assuming either that $c_1 = c_2$ (both the classes have the same propensity to consume), or that $\lambda = 0$ (there need be no premium on savings). The first does not seem to be the assumption that Lewis is making; the second, however fits in very well with his presentation. While Lewis is concerned with inadequate rates of growth in under-developed countries, his analysis is not based on an explicit identification of "optimal" rates of saving. This is partly because he focuses attention on factors other than capital accumulation influencing the rate of growth. But it is also due to the fact that he does not discuss growth in terms of optimization, and so no concept of suboptimal growth (or sub-optimal savings) can emerge. Assuming, therefore, that no special weight is to be attached on savings as against consumption, i.e. $\lambda = 0$, it would appear that Lewis' deduction that the real cost of labour is nil would follow from (6):

$$w^* = 0. \tag{6.1}$$

Polak[17] had suggested, in a pioneering discussion of the balance-of-payments problems of countries reconstructing after the war, that there was a special virtue in maximizing output per unit of capital. Buchanan made a similar suggestion:

> "If investment funds are limited, the wise policy, in the absence of special considerations, would be to undertake first those investments having a high value of annual product relative to the investment necessary to bring them into existence."[18]

This has sometimes been referred to as the "rate of turn-over criterion". It was strongly criticized by A. E. Kahn[19] because it assumed that capital was the only scarce factor. He argued that the social opportunity cost of employing labour to produce the output has to be deducted from the figure of the value added. Thus what one should try to achieve is the maximization of output, taking into account all the relevant opportunity costs. This criterion has sometimes been known as the "social marginal productivity criterion".

Even in this context, however, it may be argued that the real cost of labour could be taken to be zero when dealing with a surplus labour economy. In fact Kahn himself found the maxim of Polak and Buchanan to be "particularly desirable" in such an economy.[20]

[17] POLAK (No. 59).

[18] BUCHANAN (No. 5, p. 24).

[19] KAHN (No. 30).

[20] KAHN (No. 30, p. 51).

This too can be seen to be a case of deriving a zero shadow price of labour by taking λ equal to zero. There is indeed no discussion here about any sub-optimality of savings requiring an additional weight to be put on savings as against consumption. In the absence of such suboptimality it does indeed make sense to assume the real cost of labour to be nil. It would thus appear that the contributions of Lewis, Polak, Buchanan and Kahn concentrate on a situation where λ is taken to be nil and savings are not assumed to be suboptimal.

5. CONTRIBUTIONS BY DOBB, GALENSON AND LEIBENSTEIN

One of the most penetrating analyses of the problem of the choice of techniques for a planned economy in the context of surplus labour was provided by Maurice Dobb, whose *An Essay on Economic Growth and Planning*[21] must be regarded as a classic in the field of devolopment planning. It is a little unfair to identify him only with a criterion he formally proposed, since much of the ground-clearing in this intricate branch of economics was also done by him.[22]

Dobb has emphasized the crucial link between choice of techniques on the one hand and the rates of saving and of growth on the other. His own emphasis is very much on the maximization of the rate of growth. It is clear that if this is our only objective the weight that is attached to savings as against consumption today is infinitely large, since it is the savings rate and not immediate consumption which affects the rate of growth.[23]

It can be verified that the more the relative weight to be attached to savings as against consumption the higher is the value of λ. As we move towards the extreme cases of trying to maximize only the rate of growth, λ becomes "very large". And equation (6) reduces to the following formula:

$$w^* = \left[\frac{c_1 - c_2}{1 - c_2}\right] w. \tag{6.2}$$

In Dobb's calculation the real cost of labour was identified with the wage rate itself and this will indeed be the case, on his assumptions. Since

[21] DOBB (No. 15).

[22] DOBB (Nos. 13, 14, and 15).

[23] In all these discussions the impact of consumption on productivity through such things as nutrition is being assumed away. DOBB himself touches slightly on this question in the context of discussing the higher productivity of labour in the advanced economies given the complementary equipment [DOBB. No. 14, pp. 37—38; see also in this context GALENSON and PYATT (No. 22)].

it is assumed that workers consume everything,[24] i.e. $c_1 = 1$, from equation (6) we get:

$$w^* = w. \tag{6.3}$$

The criterion put forward by Galenson and Leibenstein[25] has been the hub of much controversy. Although much misunderstood, it had a phenomenal impact. It has a number of different aspects, including an important emphasis on the effect of increased income on the rate of growth of population, which was a somewhat special element in their criterion. For our present purpose, however, the Galenson-Leibenstein criterion is very similar to that of Dobb. The emphasis on maximizing the rate of growth makes it appropriate to consider equation (6.2). Further, with the assumption of $c_1 = 1$, (6.3) gives the relevant labour cost.

A formula used by Galenson and Leibenstein is:

$$r = \frac{p - e\,w}{c} \tag{7}$$

where

p = output per machine,
e = number of workers per machine,
w = wage rate, and
c = cost of machine.[26]

It is clear that maximization of r amounts to maximizing the rate of profit per unit of capital.[27] If the choice of techniques is aimed at maximizing r, then labour is to be valued at the market wage rate. This corresponds to (6.3).

Galenson and Leibenstein, like Dobb, concentrate on the case where $c_1 = 1$, and $c_2 = 0$. The latter assumption is redundant for the specific allocational rule recommended, i.e. even for (6.3). That $c_2 = 0$ is not a necessary assumption has not been widely recognized. Ranis argues that the "Galenson-Leibenstein case is based on two rather extreme assumptions", one being the zero marginal propensity to consume out of profits is equal to 1.[28] Hirschman and Sirkin, in their critique of the Galenson-Leibenstein criteria, recommend discarding the assumption that all profits are reinvested, since it is "particularly unrealistic".[29] This assumption is in fact redundant for the Galenson-Leibenstein rule, since (6.3) follows from (6.2) whenever $c_1 = 1$, no matter whether c_2 is zero or positive, as long as it is less than unity. In fact the precise value of c_2 makes no difference to the allocation rule for growth maximization, given $c_1 = 1$.

6. CONTRIBUTIONS BY CHENERY

H. B. Chenery has made a number of penetrating contributions to the discussion of choice of techniques. He has consistently emphasized, beginning with his earliest contribution to the subject,[30] the need for a programming frame-work, and has explicitly considered trade balance considerations and income distribution as parts of the welfare function. Since both these elements have been relatively neglected,[31] Chenery's contributions have been particularly apt.

However, in the context of the specific debate on the degree of labour intensity to be chosen in a labour-surplus economy, Chenery identified the cost of labour as the "increase in consumption",[32] which would make it identical with the criterion proposed by Dobb, Galenson and Leibenstein, i.e. corresponding to (6.3). It is not clear, however, whether this was what he really intended, viz. to put all emphasis on growth and none on immediate consumption. As he explained:

> "The effect on national income, ΔY, can be approximated by applying a set of corrections to the businessmen's calculation of the annual rate of profit."[32]

There is a strong ambiguity here, since this way of measuring the national income amounts to attaching a weight of zero to immediate consumption and putting all the weight on investment, which is not the standard practice in national income calculations. This would make sense in the context of the extreme assumptions of growth maximization, where the price of immediate consumption in terms of saving is taken to be nil; but this does not seem to have been the intention of Chenery. Perhaps what he intended was to get a weighted sum of consumption and investment, and it may be surmized that he was moving towards the same type of problem as we have been concerned with in the determination of λ.

In his later explorations of the problem Chenery[33] has clarified the picture very substantially

[24] DOBB also assumed that $c_2 = 0$, i.e. all profits are saved. This assumption is optional for (6.3).

[25] GALENSON and LEIBENSTEIN (No. 21).

[26] Note, however, that capital here is identified with fixed capital only. This, under certain circumstances, may be very misleading because of the quantitative importance of working capital. On this see SEN (No. 71, pp. 110–113).

[27] Galenson and Leibenstein are much concerned with the case represented by (7) but they treated it really as an "illustration". While this case corresponds to the allocational rule given by (6.3), i.e. $w^* = w$, they really aimed at a more general case, as explained by LEIBENSTEIN (No. 36) and GALENSON and PYATT (No. 22).

[28] FEI and RANIS (No. 19, p. 300).

[29] HIRSCHMAN and SIRKIN (No. 27, pp. 469–470).

[30] CHENERY (No. 7).

[31] See, however, POLAK (No. 59).

[32] CHENERY (No. 7, pp. 82–83).

[33] CHENERY (Nos. 8, 9, and 10).

by a series of discussions based on an explicit presentation of an objective function involving a variety of considerations, with a programming exercise leading to the choice of an optimum technological pattern, along with an optimum investment allocation in general. The emphasis is very much on the interdependence of the different sectors and on the possibility of using accounting prices. The ambiguity referred to above about the cost of labour does not occur in these later discussions.

7. CONTRIBUTIONS BY BATOR, FEI AND RANIS

Francis Bator argued in a provocative paper that there was no conflict between maximizing present output and maximizing the growth rate. Since the controversy at that stage was very much concentrated around this particular problem, this was a startling statement. However this result followed simply from his assumption that "the rate of saving is independent of the (as if) market imputed distribution of income".[34]

In terms of our model this would correspond to the assumption that $c_1 = c_2$.[35] If the rate of savings is to be independent of the rate of distribution of income there cannot be any difference in the effective propensity to consume of the two classes. This immediately yields the result $w^* = 0$, as in (6.1). Given this assumption about savings the extra weight to be attached to them makes no difference whatever to our choice of techniques. A choice of techniques that maximized the immediate income would then also maximize the amount of savings, and therefore, irrespective of the weights to be attached to the two, the optimum policy should be to maximize immediate output. With a surplus labour economy this involves choosing a technique of production as labour intensive as possible, without sacrificing efficiency.

In this context we might contrast the result of the "real cost of labour" being nil as discussed by Polak, Buchanan, Lewis and Kahn,[36] and by Bator.[37] While the former group is not concerned with the suboptimality of savings as such, and therefore implicitly assumes $\lambda = 0$, Bator is concerned with it. He does not, however, have to link the problem of the generation of savings with the choice of techniques because of his assumption of $c_1 = c_2$. Either assumption is sufficent to yield the result: $w^* = 0$.

The models of Fei and Ranis are by and large not optimality models. They are essentially concerned with what happens rather than what should happen. However, in their *Development of Labour Surplus Economy*[38] we find an assumed relation between income distribution and savings. While critical of the Galenson and Leibenstein formulation, Ranis is also much concerned with growth. He is, however, relatively optimistic about the possibility of taxation bringing about a change in the savings rate from that determined by the market. This is not surprising because of Ranis' concern with possibilities of taxation in the financing of economic development, and his study of the rather successful Japanese case.[39]

However, we cannot attribute any specific criterion to Ranis and Fei since they do not state explicitly any optimality conditions from which an optimal choice of technique can be derived. Nevertheless, their works provide some insight into the problem in question.

8. CONTRIBUTIONS BY ECKSTEIN

In 1957 Eckstein[40] put forward a synthesis of the different criteria proposed. His discussion can be translated into the framework ot equation (6). In effect his procedure amounts to obtaining a value of λ by the explicit use of a discounting operation of future consumption possibilities. The discount rates are related to the utility functions of the individuals and their chances of survival over time.

Eckstein defends the use of an individual's "pure time discount" in social choices by appealing to "consumers' sovereignty"—a somewhat dubious concept, since the consumers involved are not only those now living but also those yet to be born; and since even for the present generation of consumers their sovereignty may not receive adequate expression in their individual time preferences because of the various types of interdependencies discussed by Baumol, Sen, and Marglin.[41]

But apart from this question Eckstein did achieve a synthesis which sorted out many of the outstanding issues. If the cases discussed by Polak, Buchanan, A. E. Kahn, Lewis and Bator[42] cor-

[34] BATOR (No. 3, pp. 98–99).

[35] This does not necessarily happen automatically, and Bator assumes an efficient fiscal machinery which yields such a result through deliberate policy.

[36] POLAK (No. 59), BUCHANAN (No. 5), LEWIS (No. 38) and KAHN (No. 30).

[37] BATOR (No. 3).

[38] FEI and RANIS (No. 19).

[39] RANIS (No. 63).

[40] ECKSTEIN (No. 17).

[41] BAUMOL (No. 4), SEN (Nos. 72, 76) and MARGLIN (No. 42).

[42] POLAK (No. 59), BUCHANAN (No. 5), KAHN (No. 30), LEWIS (No. 38) and BATOR (No. 3).

respond to the allocational rule (6.1) and those discussed by Dobb[43] and by Galenson and Leibenstein[44] correspond to (6.2) or (6.3), Eckstein[45] aimed at the general formula (6).

9. CONTRIBUTIONS BY MARGLIN: SAVINGS AND TECHNICAL CHOICE AS VARIATIONAL PROBLEMS

Marglin's main contribution has been to provide an integrated framework of analysis for problems of optimum accumulation and those of technological choice. The usual variational studies of optimum accumulation have tended to ignore problems of technical choice, or have (alternatively) denied any special link between savings and technical choice via the distribution of income.[46] In 1966 Marglin[47] provided a framework for a successful integration of these two facets of investment allocation. We cannot do justice here to Marglin's many-sided contributions, but we present below some comments on his main approach.

We use the following symbols: C = total consumption, K = total capital stock, Q = total output, l = employment per unit of capital, q = output per unit of capital, and U = utility at a given point of time. U is assumed to be a function of C of that period, i.e. $U = U(C)$.[48] The function to be maximized is the aggregate of U over time.[49] $\dot{K}$ stands for investment, i.e. $\dot{K} = dK/dt$. The exercise consists in maximizing U, given the following relations between output, savings and consumption for the economy as a whole:

$$Q = K\,q(l) \tag{8}$$

$$S = \dot{K} = K\,[q(l) - w\,l]\,(1 - c_2) + K\,l\,w\,(1 - c_1) \tag{9}$$

$$C = K\,q(l)\,c_2 + K\,l\,w\,(c_1 - c_2) \tag{10}$$

Alternative tools of variational analysis can be used in the exercise. Marglin poses the problem in terms of Pontryagin's "maximum principle"[50] even though he proves the optimality of his conditions independently. We first follow his poser and then relate it to the preceding discussion.

Taking K as the "phase variable" and l (representing the technological choice) as the "control variable", the following "Hamiltonian" expression can be formulated:

$$\begin{aligned} H = {} & U(C) + \Psi\dot{K} \\ = {} & U\,[K\,q(l)\,c_2 + K\,l\,w\,(c_1 - c_2)] + \\ & + \Psi\,K\,[q(l) - w\,l](1 - c_2) + \Psi\,K\,l\,w \times \\ & \times (c_1 - c_2). \end{aligned} \tag{11}$$

Ψ is the utility price of capital investment and H the total value of output in terms of utility in a given period. When Ω represents the control region the optimal time sequence of technological choice will have to satisfy the following necessary condition given by Pontryagin's maximum principle for non-terminal points of time:[51]

$$H(\Psi, K, l) = \operatorname*{Sup}_{l\,\varepsilon\,\Omega} H(\Psi, K) \tag{12}$$

The other necessary condition given by Pontryagin concerns the value of Ψ, which yields:

$$\dot{\Psi} = \frac{\partial H}{\partial K}\,. \tag{13}$$

We may restrict l within the closed interval (l, l), where l is the value for which the marginal product of labour equals the wage rate, i.e. $q'(l) = w$, and l is the value for which the wage bill just exhausts the total product, i.e. $q(l) = l\,w$. These two limits correspond respectively to the Dobb-Galenson-Leibenstein solution and the Lewis-Polak-Buchanan-Kahn solution.[52] If l lies in the interior of the region Ω, we should then require:[53]

$$\frac{\partial H}{\partial l} = 0. \tag{14}$$

From (11) and (14) we obtain:

$$\frac{U'(C)}{\Psi} = \frac{w\,(c_1 - c_2) - q'(l)\,(1 - c)}{q'(l)\,c_2 + w\,(c_1 - c_2)}\,. \tag{15}$$

Since Ψ is the price of investment in terms of utility and $U'(C)$ is the value of consumption in the same terms, the left-hand side of equation (15)

[43] DOBB (Nos. 13, 14, 15).

[44] GALENSON and LEIBENSTEIN (No. 21).

[45] ECKSTEIN (No. 17).

[46] See RAMSEY (No. 62), GOODWIN (No. 23), SAMUELSON (No. 67), CHAKRAVARTY (No. 6) and SEN (No. 75).

[47] MARGLIN (No. 45).

[48] This assumption of the independence of one period's utility from the value of consumption in other periods is not very satisfactory (see HICKS, No. 26, pp. 256–258). This is, however, not crucial in the problem discussed here.

[49] Since MARGLIN deals with an infinite horizon he follows RAMSEY, (No. 62) in assuming a utility function bounded from above. The maximization of total utility is posed as equivalent to the minimization of the integral of the difference between "bliss" and total utility in each period. MARGLIN takes $U(0)$ as minus infinity and $\lim U'(C) = 0$, with diminishing utility throughout as C goes to infinity.

[50] PONTRYAGIN *et al.* (No. 60).

[51] Theorem 1 in PONTRYAGIN (No. 60, pp. 19–21, 189–191).

[52] The latter is not strictly correct, since they wish to maximise q, i.e. choose $q'(l) = 0$. Marglin assumes that $q'(l)$ is positive throughout so this solution is not possible in his case. He therefore puts the limit where the wage bill exhausts the output. On the contrast between these two cases see SEN (No. 71, pp. 29–31).

[53] MARGLIN shows that a set of assumptions of non-satiation and of continuity suffice to guarantee this (No. 45, pp. 40–41).

corresponds to the society's marginal rate of indifferent substitution between consumption and investment. Since λ is the extra weight to be attached to investment as against consumption we can write:

$$1 + \lambda = \frac{\psi}{U'(C)}. \tag{16}$$

From equations (15) and (16) we can obtain the following value of the real cost of labour, w^*:

$$w^* = q'(l) = \left[\frac{(c_1 - c_2)\lambda}{1 + (1 - c_2)\lambda}\right] w.$$

This is precisely the same equation as that given by equation (6).[54] The relationship between the two ways of posing the problem is indeed a close one, and our earlier formulation can be seen to fit well into the picture of finding an optimum path of technical choice over time. There λ is simply assumed to be given; here it is assigned its proper value derived from the variational exercise. The two exercises, therefore, fit well into each other.

It is to be noted, however, that Marglin's definition of the "shadow price" of labour differs from our definition of w^*. He defines it as that expression with which we should equate the marginal product of labour, in terms of the true value of the output, including a greater weight on that part of it which will be reinvested (taking the whole of the marginal output as going to the enterprise). Our real cost of labour was equated to the market value of the marginal product. Because of this definitional difference, Marglin's shadow price of labour can exceed the market wage w in some cases, whereas our w^* is contained in the interval $(0, w)$. Analytically, however, the two rules are exactly equivalent. Defining w^{**} as Marglin's shadow price of labour we obtain his allocation rule as:

$$w^{**} = \frac{\partial Q}{\partial L}[1 + (1 - c_2)\lambda] - (c_1 - c_2)\lambda w. \tag{17}$$

It is clear that (6) and (17) are exactly equivalent rules. Which particular definition we use is entirely a matter of convenience.

The main contribution of Marglin lies in the explicit link-up of λ in the one-period model with optimization over time involving variational methods. It differs from the usual optimum accumulation models in having an explicit constraint on savings, based on the distributional assumptions; and from the usual discussions on choice of techniques in doing an optimum accumulation exercise over time with variational methods, using an explicit utility function.

[54] Note that $q'(l) = \frac{\partial Q}{\partial L}$, because of the assumption of constant returns to scale.

10. Programming and the shadow price of labour

The whole question of choice of techniques is seen to turn on the relative weights to be attached to investment and consumption, i.e. on λ, and this depends on the extent of suboptimality (if any) of the savings rate, which in its turn depends on our utility function. We have examined how "the difference between the schools of thought regarding the valuation of labour really boils down to a difference in objectives".[55] The real cost of labour w^* given by equation (6) has varied from the one extreme of 0, as given by (6.1), to the other extreme of w, as given by (6.3), depending on the weights to be attached to consumption and savings in the objective function (3).

An alternative way of defining the cost of labour is to identify it as the shadow price of labour in the sense of programming. This is obtainable by formulating the problem of resource allocation in the economy, including that of choice of techniques, as an exercise in programming. The objective function V is some concave function of the process selection vector $\mathbf{p}$ representing the intensity of each activity. The "slack" (or excess supply) of each resource j is taken to be a concave function of $\mathbf{p}$, viz. $f_j(\mathbf{p})$, given the total supply of resource j. With m types of resources the set of $f_j(\mathbf{p})$ can be represented by $F(\mathbf{p})$.

With each choice of process intensities $\mathbf{p}$, some purchasing power is created, depending on the level of employment, wages etc. and given the demand functions we can trace the minimum amounts of consumer goods that must be produced to meet these demands. Let $E(\mathbf{p})$ represent the "excess production vector", standing for the difference between the actual production and these minimum output requirements.

The choice variables consist of the elements of the vector $\mathbf{p}$, which includes technological choice. The problem is:

Maximize	$V = V(\mathbf{p})$	(18)
subject to	$\mathbf{p} \geq 0,$	(19)
	$F(\mathbf{p}) \geq 0,$	(20)
and	$E(\mathbf{p}) \geq 0.$	(21)

If $V(\mathbf{p})$, $E(\mathbf{p})$ and $F(\mathbf{p})$ are linear, this will be a problem of linear programming. Further, with the framework of linear activity analysis, we can get an output vector $\mathbf{q}$ linearly related to the activity vector $\mathbf{p}$, and can then make V some function of $\mathbf{q}$. We take, for this analysis, a very general interpretation, and assume no more than that $V(\mathbf{p})$, $E(\mathbf{p})$ and $F(\mathbf{p})$ are all concave, but not

[55] SEN (No. 71, Chap. V, p. 62).

necessarily strictly concave. This makes the problem one of concave programming, covering also the special case of linear programming.

Let $\mathbf{p}^*$ be an optimal solution to the problem, and let r^* and s^* be the optimal dual variables related respectively to the resource constraints and the demand constraints. They have the usual saddle-point properties.[56] In the case of linear programming, r^* is interpretable simply as the set of shadow prices of the respective resources. Even in the more general case of concave programming, the dual variables specify the limits of marginal returns to the respective resources.

It can be demonstrated that the inner product of $E(\mathbf{p})$ cum $F(\mathbf{p})$, and s^* cum r^*, must be zero in the optimal solution.[57]

$$[s^*, E(\mathbf{p}^*)] + [r^*, F(\mathbf{p}^*)] = 0. \qquad (22)$$

Every r_j, s_i, f_j and E_i must be non-negative, so that a strictly positive f_j must imply a zero r_j^*. However, a strictly positive f_j implies that there is some excess ("slack") of resource j. Thus, either a resource has no slack, or its dual variable (corresponding to the shadow price) is nil.

There is nothing startling in this result, which is a standard one in concave programming. But it might seem as though it contradicts our analysis of the real cost of labour. It appears that, irrespective of the objectives, either there is full employment of labour, or its shadow price must be nil. Since we are concerned with a surplus labour economy it looks as if labour must be taken to be costless, no matter what objective function we choose. This seems to contradict what we have said earlier.

There is, however, no real contradiction. If there is surplus labour even under optimal allocation, the marginal return to an additional unit of labour must be zero. In this sense the shadow price of labour has to be nil. This does not mean that the marginal product of labour is nil in the sense *(a)* that no more output can be physically produced by using more labour, or *(b)* that it is zero in terms of its market value. We may be able to produce more of V, given the resource requirement constraints, but not the demand constraints. In this problem, where the constraints (21) are ignored, the marginal return to a unit of resource j may not be zero, even when r_j^* as previously defined is nil. Second, $V(\mathbf{p})$ involves some valuation of the output, but it may not coincide with the market valuation of it. If we take $\mathbf{q}$ to be the output vector associated with the technological choice vector $\mathbf{p}$, and y to be the vector of market prices, it is entirely possible that the inner product of $\mathbf{q}$ and y may respond positively to an additional unit of resource j, even though $V(\mathbf{p})$ does not respond to it.

[56] See KARLIN (No. 32, theorem 7.1.1).

[57] See the proof of the Kuhn-Tucker theorem in KARLIN (No. 32, pp. 200—203).

11. CONCLUDING REMARKS

We have concentrated in this critical survey on the broad currents of controversy. There are numerous other themes within these general trends of thought which we have not been able to present fully.

Our basic framework was developed in terms of some very general assumptions. By making more specific assumptions we have tried to present the different criteria as special cases within that general framework. Thus our emphasis has been on the common analytical structure in these various theories. Differences in recommended policies have been systematically traced to the differences in empirical or value assumptions, so that a common core of analysis has emerged.

This study of analytical unity in the diversity of policy recommendations is aimed mainly at clarifying the issues in dispute. Issues not very prominent in the controversy, including problems of "efficiency" (see section 1), have not received as much attention as they could perhaps have had. Our main focus has been on things controversial. Since this is a bias, even if justifiable, I would like to draw the attention of the reader to this fact before I end.

BIBLIOGRAPHY

1. K. J. ARROW, *Social Choice and Individual Values*, New York, 1951.
2. A. K. BAGCHI, "The Choice of the Optimum Techniques", *Economic Journal*, Sept. 1962.
3. F. BATOR, "On Capital Productivity, Input Allocation and Growth", *Quarterly Journal of Economics*, Feb. 1957.
4. W. J. BAUMOL, *Welfare Economics and the Theory of the State*, London, 1952.
5. N. S. BUCHANAN, *International Investment and Domestic Welfare*, New York, 1945.
6. S. CHAKRAVARTY, "Optimum Savings with Finite Planning Horizon", *International Economic Review*, Sept. 1962.
7. H. B. CHENERY, "The Application of Investment Criteria", *Quarterly Journal of Economics*, Feb. 1953.
8. H. B. CHENERY, "The Role of Industrialization in Development Programs", *American Economic Review*, May 1955.

9. H. B. CHENERY, "The Interdependence of Investment Decisions", in Abramovitz *et al.*, *The Allocation of Economic Resources*, Stanford, 1959.

10. H. B. CHENERY, "Comparative Advantage and Development Policy", *American Economic Review*, 1961.

11. G. DEBREU, *The Theory of Value*, London, 1959.

12. R. DORFMAN, P. A. SAMUELSON, and R. M. SOLOW, *Linear Programming and Economic Analysis*, New York, 1958.

13. M. H. DOBB, "A Note on the so-called Degree of Capital-Intensity of Investment in Underdeveloped Countries", *Economie Appliquée*, Vol. 7, 1954, No. 3; reprinted in: *On Economic Theory and Socialism*, London, 1955.

14. M. H. DOBB, "Second Thoughts on Capital-Intensity", *Review of Economic Studies*, Vol. 24, 1956.

15. M. H. DOBB, *An Essay on Economic Growth and Planning*, London, 1960.

16. R. S. ECKAUS, "Factor Proportions in Underdeveloped Countries", *American Economic Review*, Vol. 45, Sept. 1955.

17. O. ECKSTEIN, "Investment Criteria and Intertemporal Welfare Economics", *Quarterly Journal of Economics*, 1957.

18. O. ECKSTEIN, "A Survey of Public Expenditure Criteria", in R. Musgrave *et al.*, *Public Finance: Needs, Sources, Utilization*, Princeton, 1961.

19. C. H. FEI and G. RANIS, *Development of Labor Surplus Economy: Theory and Policy*, Homewood, 1964.

20. M. S. FELDSTEIN, "The Social Time Preference Discount Rate in Cost-Benefit Analysis", *Economic Journal*, June 1964.

21. W. GALENSON and H. LEIBENSTEIN, "Investment Criteria, Productivity and Economic Development", *Quarterly Journal of Economics*, Aug. 1955.

22. W. GALENSON and G. PYATT, *The Quality of Labour and Economic Development in Certain Countries*, Geneva, I.L.O., 1964.

23. R. M. GOODWIN, "The Optimum Path for an Underdeveloped Economy", *Economic Journal*, Dec. 1961.

24. G. HABERLER, "Critical Observations on Some Current Notions on the Theory of Economic Development", *L'Industria*, Vol. 2, 1957.

25. A. C. HARBERGER, "Techniques of Project Appraisal", National Bureau of Economic Research, Conference on Economic Planning, 1964.

26. J. R. HICKS, *Capital and Growth*, Oxford, 1965.

27. A. O. HIRSCHMAN and G. SIRKIN, "Investment Criteria and Capital Intensity Once Again", *Quarterly Journal of Economics*, Aug. 1958.

28. D. W. JORGENSON, "Testing Alternative Theories of the Development of a Dual Economy", in I. Adelman and E. Tharbecke (eds.), *The Theory and Design of Economic Development*, Baltimore, 1966.

29. D. W. JORGENSON, "Subsistence Agriculture and Economic Growth", *Oxford Economic Papers*, 1967.

30. A. E. KAHN, "Investment Criteria in Development Programs", *Quarterly Journal of Economics*, Feb. 1951.

31. R. F. KAHN, "The Pace of Development", in Hebrew University, *The Challenge of Development*, Jerusalem, 1958.

32. S. KARLIN, *Mathematical Methods and Theory in Games, Programming, and Economics*, Vol. 1, Reading, Mass., 1959.

33. T. C. KOOPMANS, *Three Essays on the State of Economic Science*, New York, 1957.

34. K. LANCASTER and R. G. LIPSEY, "The General Theory of Second Best", *Review of Economic Studies*, Vol. 24, 1956.

35. H. LEIBENSTEIN, "The Theory of Underemployment in Backward Economies", *Journal of Political Economy*, Vol. 65, Apr. 1957.

36. H. LEIBENSTEIN, "Investment Criteria and Empirical Evidence—A Reply to Mr. Ranis", *Quarterly Journal of Economics*, Feb. 1963.

37. W. A. LEWIS, "Economic Development with Unlimited Supplies of Labour", *Manchester School*, May 1954.

38. W. A. LEWIS, *The Theory of Economic Growth*, London, 1955.

39. W. A. LEWIS, "Unlimited Labour: Further Notes", *Manchester School*, Jan. 1958.

40. R. C. LIND, "The Social Rate of Discount and the Optimal Rate of Investment: Further Comment", *Quarterly Journal of Economics*, May 1964.

41. I. M. D. LITTLE, "The Real Cost of Labour, and the Choice between Consumption and Investment", *Quarterly Journal of Economics*, Feb. 1961.

42. S. A. MARGLIN, "The Social Rate of Discount and the Optimal Rate of Investment", *Quarterly Journal of Economics*, Feb. 1963.

43. S. A. MARGLIN, "The Opportunity Costs of Public Investment", *Quarterly Journal of Economics*, May 1963.

44. S. A. MARGLIN, *Public Investment Criteria*, London, 1967.

45. S. A. MARGLIN, *Industrial Development in the Labour-Surplus Economy*, mimeographed, Jan. 1966.

46. S. A. MARGLIN, "Mr. Jorgenson Against the Classics", in I. Adelman and E. Tharbecke (eds.), *The Theory and Design of Economic Development*, Baltimore, 1966.

47. G. MATHUR, *Planning for Steady Growth*, Oxford, 1966.

48. S. MEHRA, "Surplus Labour in Indian Agriculture", *Indian Economic Review*, Apr. 1966.

49. J. W. MELLOR and R. D. STEVENS, "The Average and Marginal Product of Farm Labor in Underdeveloped Economics", *Journal of Farm Economics*, Vol. 38, Aug. 1956.

50. J. MIRRLEES, "Choice of Techniques", *Indian Economic Review*, Aug. 1962.

51. J. MIRRLEES, *Optimum Planning for a Dynamic Economy*, Ph. D. Thesis, Cambridge University, 1963.

52. R. NURKSE, *Problems of Capital Formation in Underdeveloped Countries*, Oxford, 1953.

53. H. T. OSHIMA, "Underemployment in Backward Economies: An Empirical Comment", *Journal of Political Economy*, Vol. 66, June 1958.

54. M. PAGLIN, "'Surplus' Agricultural Labor and Development: Facts and Theories", *American Economic Review*, Vol. 55, Sept. 1965.

55. J. PAJESTKA, "Some Problems of Economic Development Planning", in Oscar Lange (ed.), *Problems of Political Economy of Socialism*, New Delhi, 1962.

56. A. PEPELASIS and P. A. YOTOPOULOS, *Surplus Labour in Greek Agriculture 1953—1960*, Athens, 1962.

57. E. S. PHELPS, *Fiscal Neutrality toward Economic Growth*, New York, 1965.

58. A. C. PIGOU, *Economics of Welfare*, 4th ed., London, 1932.

59. J. J. POLAK, "Balance of Payments Problems of Countries Reconstructing with the Help of of Foreign Loans", *Quarterly Journal of Economics*, Feb. 1943.

60. L. S. PONTRYAGIN *et al.*, *The Mathematical Theory of Optimal Processes*, New York, 1962.

61. K. N. RAJ, *Some Economic Aspects of the Bhakra Nangal Project*, Bombay, 1960.

62. F. P. RAMSEY, "A Mathematical Theory of Saving", *Economic Journal*, Dec. 1928.

63. G. RANIS, "The Financing of Japanese Economic Development", *Economic History Review*, Vol. 11, Apr. 1959.

64. Joan ROBINSON, *The Accumulation of Capital*, London, 1954.

65. Joan ROBINSON, *Exercises in Economic Analysis*, London, 1960.

66. P. N. ROSENSTEIN-RODAN, "Disguised Unemployment and Underemployment in Agriculture", *Monthly Bulletin of Agricultural Economics and Statistics*, Vol. 6, July—Aug. 1957.

67. P. A. SAMUELSON, "Efficient Paths of Capital Accumulation in Terms of the Calculus of Variations", K. J. Arrow *et al.* (ed.), *Mathematical Methods in the Social Sciences*, 1959 (Stanford, 1960).

68. T. W. SCHULTZ, *Transforming Traditional Agriculture*, New Haven, 1964.

69. T. W. SCHULTZ, "Significance of India's 1918—1919 Losses of Agricultural Labour—A Reply", *Economic Journal*, Vol. 77, Mar. 1967.

70. A. K. SEN, "Some Notes on the Choice of Capital-Intensity in Development Planning", *Quarterly Journal of Economics*, Nov. 1957.

71. A. K. SEN, *Choice of Techniques*, Oxford, 1960; 2nd ed., 1962; 3rd ed., 1968.

72. A. K. SEN, "On Optimizing the Rate of Saving", *Economic Journal*, Vol. 71, Sept. 1961.

73. A. K. SEN, "Peasants and Dualism with or without Surplus Labour", *Journal of Political Economy*, Oct. 1966.

74. A. K. SEN, "Labour Allocation in a Co-operative Enterprise", *Review of Economic Studies*, Nov. 1966.

75. A. K. SEN, "Terminal Capital and Optimal Savings", in C. H. FEINSTEIN *et al.* (ed.), Capitalism, Socialism and Economic Growth, *Essays in Honour of Maurice Dobb*, Cambridge, 1967.

76. A. K. SEN, "Isolation, Assurance and the Social Rate of Discount", *Quarterly Journal of Economics*, Feb. 1967.

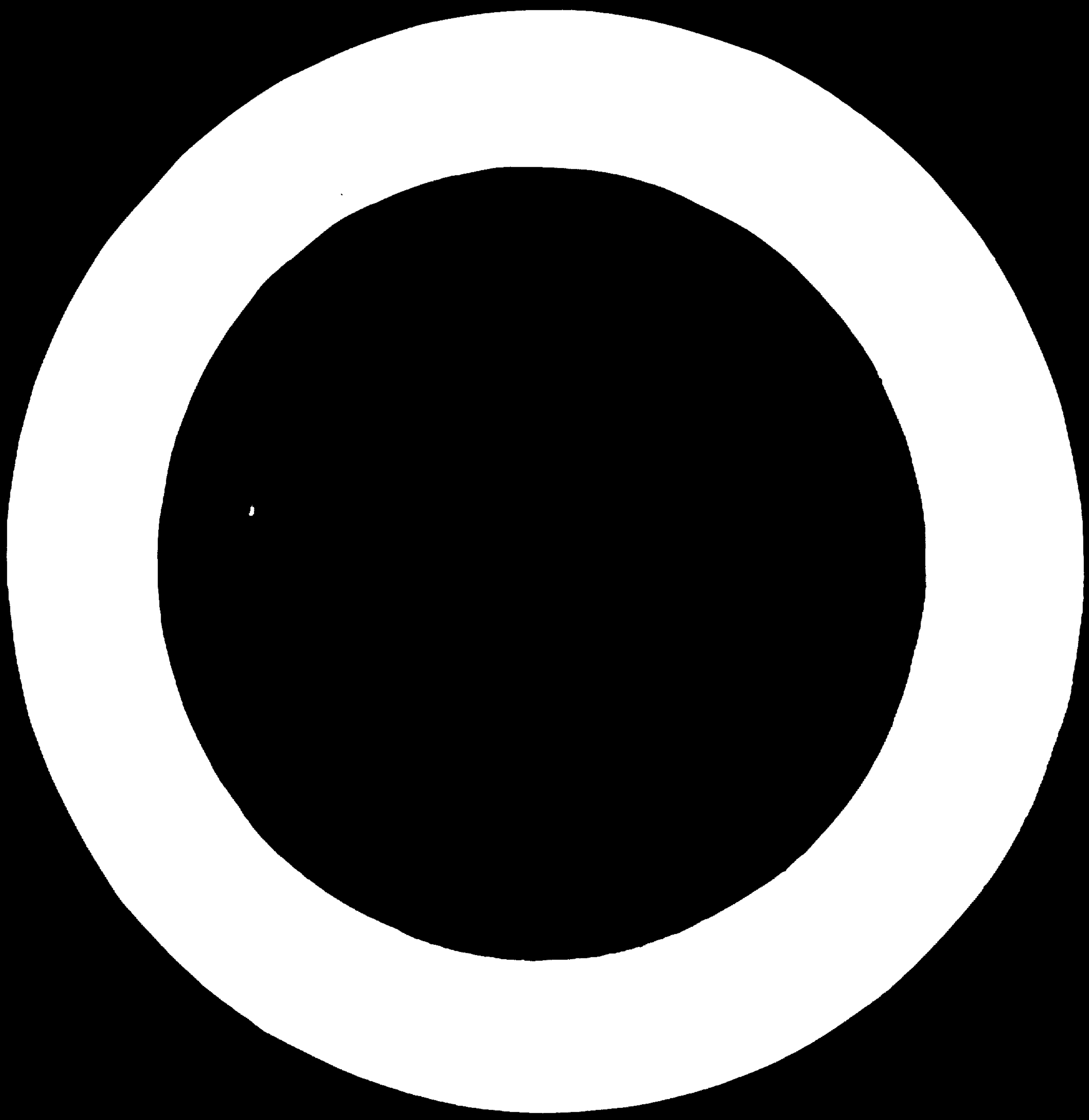
77. A. K. SEN, "Surplus Labour in India: A Critique of Schultz's Statistical Test", *Economic Journal*, Vol. 77, Mar. 1967.

78. T. N. SRINIVASAN, "Investment Criteria and Choice of Techniques of Production", *Yale Economic Essays*, 1962.

79. J. TINBERGEN, "The Optimum Rate of Saving", *Economic Journal*, Dec. 1957.

80. J. TINBERGEN, "Optimum Savings and Utility Maximization over Time", *Econometrica*, Apr. 1962.

81. J. VINER, "Some Reflections on the Concept of 'Disguised Unemployment'", *Contribucoes a Analise do Desenvolvimento Economico*, 1957.



INVESTMENT CRITERIA IN DEVELOPING COUNTRIES

Kazimierz Laski, Central School of Planning and Statistics, Poland

THIS ESSAY DEALS with an important theoretical problem encountered in the study of economic growth in developing countries: the problem of criteria in regard to investment in those countries and, in particular, in regard to choosing the optimal degree of mechanization of production in a given situation.[1] Since the institutional conditions are by no means a matter of indifference even in dealing with such a limited and (in a way) purely quantitative problem, we have to begin by assuming a certain system of relations of production, i.e. a certain system of social production. Indeed, "purely quantitative" analysis, isolated from social realities, is either non-existent or is reduced to algebraical exercises deprived of any practical meaning. For these reasons we shall distinguish between an economy with comprehensive planning, having no major disparities in the social distribution of national income (in other words, where a fair degree of egalitarianism exists) and a mixed economy, where a large private sector and a dynamic public sector coexist and where there are large differences in social distribution of national income.

The need to draw this distinction results from the fact that the problem of financing economic growth is entirely different in each type of economy; consequently the basic contradiction to be resolved is completely different in each case as are the criteria in regard to investment. In particular, the problem of the optimal level of mechanization—which is the subject of this paper—becomes vital only in an economy with comprehensive planning. That is why our analysis is directly applicable to this type of economy, in particular to socialist economies. At the same time, however, we shall formulate some conclusions applicable to a mixed economy.

Our analysis begins with a description of the model of growth of national income under constant capital-output ratio. Against this background the controversy between consumption in the short run and in the long run is sharply revealed, and emphasis is laid on the fact that it cannot be alleviated by the structure of investment by branches (section 1). The analysis abandons the assumption that capital output ratio remains constant, in view of technical progress and of the available gamut of techniques (section 2). The possibility of choosing the level of capital-output ratio in the presence of surplus labour leads to the dilemma of maximization of national income versus maximization of economic surplus; in this context there is a lengthy critique of the solution postulating maximization of economic surplus (section 3). The author goes on to describe a solution postulating a reduction of capital-output ratio for the purpose of utilizing the existing labour resources (section 4). Conflict between the present and future levels of consumption can determine the degree of mechanization and the rate of income growth only within the limits set by various physical constraints, especially the foreign trade barrier (section 5). A decision determining the level of capital-output ratio is made after taking into account all the enumerated factors; the marginal recoupment period is thus fixed, to serve as an instrument in choosing between comparable investment projects (section 6). Some conclusions regarding a mixed economy are added in the final section.

1. MODEL OF GROWTH WITH CONSTANT CAPITAL-OUTPUT RATIO

(a) *Redundant labour and the problem of skilled labour*

We concentrate our study on developing countries where surplus labour exists. This means that the apparatus of production, even if fully used, cannot employ all those who can work and are looking for work.

[1] The literature used for this essay includes writings by Polish economists, especially Michal KALECKI's *Zarys teorii wzrostu gospodarki socjalistycznej* (An Outline of the Theory of Growth in a Socialist Economy), 2nd ed., Warsaw, 1967, Ch. 10, and two articles by Professor Kalecki: "Zagadnienia finansowania rozwoju gospodarczego w mało rozwiniętych krajach kapitalistycznych" (Problems of Financing Economic Growth in Developing Capitalist Countries), in a collection of essays by M. KALECKI and I. SACHS *Z zagadnień finansowania rozwoju krajów o "gospodarce mieszanej"* (Problems of Financing Growth in "Mixed Economies"). PWN, Warsaw, 1967, and "Różnice w węzłowych problemach gospodarczych między wysoko rozwiniętą i zacofaną gospodarką kapitalistyczną (Differences in Key Economic Problems between Advanced and Underdeveloped Capitalist Economics in *Ekonomista* (Warsaw), 5, 1966. The author is very grateful to Dr. Ignacy Sachs, Director, Institute of Research on Developing Countries, Central School of Planning and Statistics in Warsaw, for his helpful suggestions and penetrating criticisms. Any views expressed in this paper are, of course, solely the responsibility of the author.

A surplus of labour in these countries may be (and often is) coupled with acute shortage of skilled labour, particularly in some specialized fields. Suppose that, to fill this gap, special allocations for investment and current expenses are ear-marked in economic development plans or, alternatively, assistance of foreign experts and instructors is envisaged. But first of all we assume that, whatever the degree of mechanization we finally choose, the demand for skilled labour will hardly be affected. Indeed a high degree of mechanization may render it possible to employ unskilled labour; but, on the other hand, it will also call for a number of very highly skilled workers. All things taken together, a high degree of mechanization may require the same amount of skilled labour as a low degree of mechanization. This is the assumption we shall stick to in our further considerations, leaving aside the special problem of skilled labour.

(b) *Model of growth*

In economies with comprehensive planning, based by definition on full employment, the existence of surplus labour is obviously a remnant of earlier forms of social production or of a colonial past. It can hardly be removed overnight if its proportion is large in comparison with that of employed labour. In any case, it is essential under the circumstances to proceed to a rapid development of the apparatus of production, i.e. to increase considerably the number of working places. Thus the problem of investment comes to the front.

We shall use the Kalecki model[2] to investigate the relationships that occur in this case. Let Y denote gross national income (including depreciation) equal to the value of final goods (and material services in trade, communications etc., but excluding non-material services in administration, education, culture, and housing) in the year t. Y is divided into two parts: one, I, destined for productive investment and the other, C, for consumption in the broad sense, including individual consumption, collective consumption (i.e. consumption of non-investment materials) by the non-productive sector, and non-productive investment not covered by I.[3]

Let ΔY stand for increment of national income in the year $t+1$, i.e. the difference between the national incomes in the years $t+1$ and t. This increment is mainly the effect of investment in the year t, assuming that the gestation period is one year and that all the investment projects started in the year t are set in operation at the beginning of the year $t+1$. The increment of national income in the year $t+1$ obtained as a result of new productive capacities resulting from I, is equal to $(1/m)\,I$ where m denotes the marginal capital-output ratio, i.e. investment per unit increment of national income.

The increment of national income in the year $t+1$ is also related to obsolescence and wear and tear of productive capacities. Let the ratio of decrease (as a percentage) of the national income on this account be a; the resulting loss of income in the year $t+1$ will be equal to aY. This, of course, detracts from the increment of national income obtained on account of investment.

Finally, we know from experience that a certain increment of national income occurs without investment, being due merely to better use of productive capacities (improved organization of production, reduced spoilage, better training, more shifts per working day etc.). If this improved use of productive capacities continues, and if the corresponding improvement ratio (as a percentage) is u, then the increment of national income on this account in the year $t+1$ will be uY.

Thus net increment of gross national income in the year $t+1$ will total

$$\Delta Y = \frac{1}{m} I - aY + uY.$$

Dividing both sides by Y, we obtain

$$\frac{\Delta Y}{Y} = \frac{1}{m} \cdot \frac{I}{Y} - a + u$$

and

$$r = \frac{1}{m} i - a + u$$

where r represents (as a percentage) the relation $\Delta Y/Y$, i.e. the rate of growth of national income in the year $t+1$ as compared with the year t, and i represents (as a percentage) the relation I/Y, i.e. the share of gross productive investment in gross national income, or the investment rate in the year t.

The formula takes into account factors determining the rate of growth of national income in a socialist economy, but is not directly applicable to a capitalist economy. Indeed, in a capitalist economy, u will fluctuate a great deal in correspondence with the phase of the business cycle and, more specifically, with market demand; in some cases it may even become a negative value. Conversely, in a socialist economy under normal conditions u is a constant and positive value.

[2] See M. Kalecki, *Zarys teorii wzrostu gospodarki socjalistycznej* (An Outline of the Theory of Growth in a Socialist Economy), op. cit., Ch. 2.

[3] To simplify the analysis we abstract from changes in working capital and stocks, and assume that foreign trade is balanced.

Let us further assume that the ratio a, determined by the life-span of investment projects, is constant. Finally, let us make the assumption, without explaining it for the time being, that capital-output ratio m is uniquely determined and does not depend on the planner. With constant u, a and m, the rate of income growth, r, will be related only to the investment rate i.

These, of course, are not all the factors that come into play. Productive capacities, old and newly-completed alike, require labour, which is the force directly producing national income. Consequently, from this point of view, national income is related to the number of employees and their productivity (in the broad sense, including the effects of economic use of the objects of work and the effects of foreign trade) measured in gross value-added per employee. Let β denote the annual rate of employment increase (as a percentage) and α the annual rate of increase in productivity (also as a percentage), then the annual rate of growth of national income—with permissible approximation—will be equal to the sum of the two rates, i.e.

$$r = \alpha + \beta.$$

(c) *Acceleration of growth and the conflict between current and future consumption*

Let us assume for the moment that the level of productivity remains constant. Then $\alpha = 0$ and

$$r = \beta.$$

Thus the rate of growth of national income is equal to the rate of employment increase.

Suppose that β also denotes the rate of labour increase and that, at the moment when our analysis begins, some surplus labour exists. The relation between employed and unemployed labour will thus remain constant and surplus labour will also grow at the rate β.

In such an event it is both possible and necessary to raise the rate of growth of national income so as to find work for surplus labour and attain full employment within a longer or shorter interval of time.

Figure I presents the rate of income growth r as a linear function of the investment rate i. The gradient of the straight line AB is $1/m$. It crosses the axis of ordinates at point A at a distance equal to $(u-a)$ from the origin; it is assumed that $(u-a) < 0$. The co-ordinates of point B depict the initial rate of growth $r_0 = \beta = BD$ and the initial rate of investment $i_0 = 0D$. If the rate of growth is to climb to $r = \beta' = CE$, then the rate of investment must be raised to reach $i = 0E$.

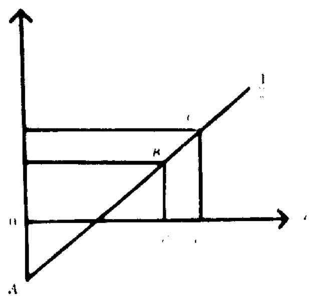


Figure I

But in the case we are now investigating, the investment rate cannot be raised without a reduction of real wages assuming, as we do, that real wages are the only form of individual consumption. Indeed, with national income and employment growing at the rate β, investment must grow at a rate higher than β if its share in national income (i) is to increase. Correspondingly, the other part of national income, i.e. consumption, must grow at a rate lower than β, since its share in national income $(1-i)$ must diminish; and if employment increases at the rate β and consumption at a rate lower than β, then consumption per employee, i.e. real wages, will have to fall. The greater the increase in the investment rate, caused by the postulated acceleration of growth of national income and employment, the greater the fall in real wages.

Once the new, higher rate of growth $r = \beta'$ is attained, real wages will stop falling and consumption will begin to increase at the rate β' higher than β. This will continue as long as labour reserves are available. Anticipating the moment when full employment is achieved, the planner reduces the investment rate to the initial $i_0 = 0D$; consequently, while national income and employment are increasing at the rate β', investment is growing at a rate lower, and consumption at a rate higher, than β'. As a result, consumption per employee, i.e. real wages, will rise to reach the initial level. The final rate of growth of national income and employment is β, equal to the initial rate.

Let the variant of growth without acceleration be named the hypothetical variant and the variant envisaging acceleration, the actual variant. By comparing the two variants it is easy to see that acceleration of growth entails sacrifices in current consumption. Indeed, at the beginning of the process, total consumption, and especially consumption per employee, is lower in the actual than in the hypothetical variant. In the long run, however, the situation is reversed. At a certain moment total consumption, which in the actual variant increases at the rate β' higher than β, will exceed the level of consumption that would be reached at the same moment in the hypothetical variant. Once the reserves of surplus labour are exhausted, the initial level of real wages will be regained;[4] consumption (both total and *per capita*) will then be higher in the actual than in the hypothetical variant by as many times as the actual employment exceeds the hypothetical employment. In other words, the actual consumption will exceed the hypothetical by as much as total labour resources exceeded employment at the initial moment.

Thus the liquidation of underemployment is always advantageous in the long run. This explains why it is regarded as an inalienable feature of socialist economy, its direct objective being to satisfy the needs of the population to the fullest extent. But there is another side to the picture: the way leading to the liquidation of unemployment will adversely affect consumption in the short run.

This conflict between the levels of current and of future consumption represents the basic contradiction in a socialist economy. It can be settled by finding a compromise between short-term and long-term consumption, but this would entail decisions of a political nature beyond the realm of strictly economic considerations.

Because of the assumptions we have made we are faced with the conflict between short-term and long-term consumption in all its gravity. In particular, I have in mind the assumption that productivity remains constant, owing to which an increase in the share of investment in national income involves drastic sacrifices in the short run and, indeed, throughout the period of accelerated growth, in the form of a decrease in real wages. But even if this assumption is relaxed the conflict, though much milder, will continue to exist. In our further consideration we shall come back several times to this contradiction.

(d) *Investment structure independent of the relationship between factors of production*

We shall now examine the assumption regarding the marginal capital-output ratio m. Its value is related on the one hand to the values of capital-output ratios in various branches of production and on the other to the structure of investment by branches. Assuming for the moment that capital-output ratios in various branches are uniquely determined, let us see whether the value of m can be altered through a change in the structure of investment. Our aim is, of course, to diminish the capital-output ratio, so as to achieve acceleration of growth while sacrificing much less (or perhaps nothing at all) of current consumption. This explains why some economists engaged in the problem have time and again insisted on giving priority to the development of those branches in which the capital-output ratio is relatively low. In other words, they have postulated that the structure of production must be shaped in accordance with the existing relation between investment (capital) and labour.

It is not hard to prove that their reasoning is completely fallacious. If there is no substitution of goods and if no investment is made on account of foreign trade alone, the structure of national income is connected not with the relation between investment and labour but only with the structure of needs that national income is expected to satisfy. For example, if food production is more capital-absorbing than, say, clothes production, we still cannot insist that the production of clothes be developed at the expense of food production. Not even the greatest quantity of clothes can substitute for food. The problem becomes all the more obvious when we compare the extractive and the manufacturing phases of production. The production of raw materials, of course, requires a much higher capital-output ratio than the manufacture of industrial goods. But the two phases are technologically so interrelated that any development of the manufacturing industries is absolutely inconceivable without a corresponding raw-material basis. Note that the postulate giving priority to less capital-absorbing agriculture rather than to more capital-absorbing industry is based on a misunderstanding. Available statistics show that when the easiest-to-reach reserves are spent, a further increase in agricultural production becomes not less but very much more capital-absorbing.

The structure of the national income and the resulting structure of investment must thus be determined independently of relative scarcity of the factors of production. This is done simply by assuming a certain structure of consumption regarded as desirable for a certain period; it may be derived from surveys of family budgets in high-income brackets, from patterns of consumption in more advanced countries, or from the planner's attitudes and preferences. The structure of future consumption thus obtained will determine the output of consumer goods; this being the point of departure, requirements referring to earlier phases of production, including investment, can be fixed

[4] Note that this conclusion is related to the assumption that the initial rate of employment increase is equal to the rate of labour increase. If this is not the case, i.e. if the initial rate of employment increase is lower than the rate of labour increase, then real wages will not regain their initial value upon the disappearance of surplus labour. Indeed, the share of investment i will then increase permanently and consequently the share of consumption $1 - i$ will diminish, since production per employee is assumed to remain constant. But even in such an event, total and *per capita* consumption in the actual variant will sooner or later exceed the corresponding level in the hypothetical variant.

by means of a system of technical coefficients. As a result we attain the planned targets of output of consumer goods (including necessary supplies of raw materials) on the one hand and of output of capital goods (also including necessary supplies of raw materials) on the other. Finally, the relationship between the two spheres of production is established by forecasting the future distribution of national income. Thus there emerges a picture of the production structure to which the distribution of investment is subordinated in a double sense: for investment is distributed not only among the spheres of production of consumer goods and of capital goods, but also among industries engaged in manufacturing final goods and those in the earlier phases of production.[5]

Although this paper is not concerned with investment structure by branches, perhaps a short comment will not be out of place here. I wish to emphasize that in the case of a developing country this structure must envisage an important and growing place for industry. We have seen that accelerated economic growth requires a higher investment rate, i.e. a greater share of investment in national income. But investment goods—steel, machinery and equipment, building materials etc.—can be supplied only by industry. Consequently the structure of investment in the countries concerned must provide for a development of industry, the machine-building industry particularly, more rapid than that of other branches of production. Furthermore, the structure of consumption, especially when national income is low, tends to change in favour of increasing the volume of industrial goods in total consumption; this is another reason why industry must be given an increasingly important place in the structure of investment. Finally—though this is somewhat out of context in the present study—priority for industrial investment in the over-all volume of investment and for industry in over-all material production is necessary to bring about the desired changes in the structure of foreign trade, i.e. to increase substantially the volume of industrial exports at the expense of agricultural exports.

All this calls for certain changes in the structure of production and investment with a view to the industrialization of the country; in fact, any plan of development in developing countries is really a plan of industrialization. Let it be noted once again that all these changes are not in any way related to the existing capital-output ratio and can (though not necessarily do) run counter to it.

[5] See M. Kalecki, "An Outline of a Method of Constructing a Perspective Plan", in *Essays on Planning and Economic Development*, Vol. 1, PWN, Warsaw, 1963.

(e) *Substitution and foreign trade in relation to investment structure*

The reasoning outlined above will be somewhat modifed because of substitution of goods and because of foreign trade. If one has to choose between two substitutional goods it is advisable to develop the production of that which, taking into account its effect, has the lower capital-output ratio. Similar comparisons can be made between investment projects related only to foreign trade, i.e. favouring exports or replacing imports, taking into account the expected gains in foreign currency through exports or the savings in foreign currency through imports, and choosing the ones with the relatively lowest capital-output ratio. (It is important, however, to be guided not only by the current situation but also by long-term trends in the relationship between domestic costs and world prices.) Although these factors modify our earlier conclusions regarding the shape of investment structure as dependent on the structure of consumption, their role should not be over-estimated.

Substitution of goods is an exception rather than the rule, and investment purely to stimulate exports or to discourage imports represents but a small portion of the total volume. True enough, this portion will be far larger in a small or medium-sized country than in a large one, which of course does not have to rely so much on world markets. But note that we are concerned here with investment related solely (or mainly) to foreign trade; its part in total investment will thus be smaller than the respective part of foreign trade in current production. Substitution of goods and foreign trade phenomena having been taken into account, the structure of the bulk of investment must be determined independently. Consequently, basing ourselves on the capital-output ratios in different branches of production, we arrive at a uniquely determined capital-output ratio per unit increment of national income with a given structure. This capital-output ratio may serve as a tool of economic policy only in regard to investment related to industries producing substitute goods or to foreign trade alone. This is where we can apply the theses to be formulated later in this paper regarding choice of techniques. Indeed, if there are two substitutes and each requires a uniquely determined technique, then the two techniques can be regarded as alternatives in relation to the expected effect. Similarly, exports can be regarded as a mechanism to produce either imports or foreign currency for purchasing the needed items abroad. Hence, uniquely determined techniques of producing different goods for export are alternatives in relation to a unit of foreign currency.

We shall assume further on that the structure of investment is given and constant, and that any possible change in it has no impact upon the value of m which consequently does not depend on structural changes. The assumption holds good also in regard to changes in the distribution of investment between integrated production of capital goods (sector 1) and integrated production of consumer goods (sector 2); such changes, of course, do occur, since the investment rate can be altered. In other words, we simplify by assuming that the capital-output ratio in integrated production of capital goods is the same as in integrated production of consumer goods. Since in either case it is integrated production – i.e. not only the final phase but also all the earlier phases of production, from top to bottom, including production of the semi-finished goods, energy, raw materials etc. needed for the final product – the assumption may not necessarily be wrong.

2. Competing production techniques and technical progress

(a) *Production curves*

To assume the existence of a single technique for producing any goods (material services) is inconsistent with daily experience and economic practice. Efficient techniques, i.e. techniques that prove competitive in the two-dimensional world of investment (capital) and labour, exist in many (though not all) branches. While requiring more investment per unit of output, these techniques also require less labour per unit of output; that is, they ensure higher productivity. In other words, such techniques are more capital-absorbing but also more productive. They will survive after the elimination of inefficient techniques: those that are more capital-absorbing without being more productive.

Thus a non-mechanized (or a less-mechanized) technique can stand comparison with a more-mechanized technique only if it "costs" less investment. This condition is not always fulfilled, as was demonstrated in the oft-quoted example of the spinning wheel that proved more capital-absorbing than the mechanized spinning mill.[6] But a loom on a lower level of mechanization (or automation) is less capital-absorbing than a loom on a higher level. A similar phenomenon normally occurs with clothes, food, and timber production, and in many cases also with heavy industries, including engineering and mining. Even when the basic technological processes are uniquely determined and any less-mechanized variant is hardly conceivable, labour-absorbing methods can still be successfully used in intra-factory transport and in every other auxiliary process. Finally, agriculture, construction of any type (including housing, road building, irrigation and land improvement), and transportation are typical fields where competition of efficient techniques on different levels of mechanization is the rule.

It is dangerous to disregard the fact that competing (efficient) techniques exist in many branches of production. It is also dangerous to exaggerate this fact by assuming that innumerable or very numerous efficient techniques exist in every branch of production, so that they can be depicted as continuous functions. Statements to this effect are sometimes accompanied by an unsubstantiated promulgation of the so-called law of diminishing returns. In actual fact, the interrelation between efficient techniques can be explained by putting them in a certain order.[7]

Some branches of production have uniquely-determined technologies preventing any choice of capital-output ratio (usually that is not the case with auxiliary processes). In many other fields there are several efficient techniques and so it is possible and necessary to choose the capital-output ratio. But a unit of income increment comprises many branches of production, and if each branch averages only two efficient techniques we can, by combining them, obtain a relatively large number of aggregated production techniques, i.e. methods of producing a unit of national income with a given structure.[8]

Taken together, they constitute a gamut of techniques which, placed in the proper order, may be plotted diagrammatically to form the production curve. Each point on the curve represents a unit of national income increment with a given structure. The co-ordinates of each point represent capital-output ratio (abscissae) and productivity (ordinates). Production curve KL in figure II depicts productivity π as a function of capital-output ratio m, growing at a diminishing rate. The fact that the curve rises at a diminishing rate can be explained, as I have pointed out before, by the

[6] See Ch. Bettelheim, *Studies in the Theory of Planning*, Bombay, 1959.

[7] See O. Lange, "Quantitative Relations in Production", in *Problems of Economic Dynamics and Planning*, Warsaw, 1964.

[8] Suppose we have k branches, with two efficient techniques in each; then the number of aggregated techniques will be 2^k, or very many, since k comprises many branches.

order in which the various techniques have been placed, without resorting to the mythical law of diminishing returns.

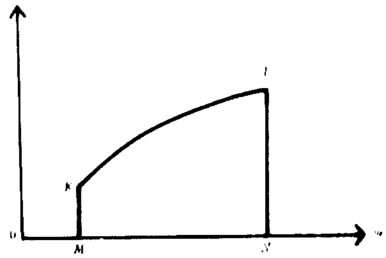


Figure II

In figure II different techniques are depicted by means of productivity and capital-output ratio. But the diagram also demonstrates changes in another important indicator, capital-labour ratio (k), which represents investment per unit of employment increase. The capital-labour ratio accompanying a given technique can be found by multiplying the co-ordinates of the given point on the production curve. Thus in point K it is $0M \times KM$, i.e. the area of the rectangle whose sides are equal to $0M$ and KM. Moving along the production curve to the right, toward techniques with higher capital-output ratio and higher productivity, the capital-labour ratio also increases.

Indeed, $\pi = \frac{\overline{Y}}{\overline{E}}$ and $m = \frac{I}{\overline{Y}}$;

hence $\pi \cdot m = \frac{\overline{Y} \cdot I}{\overline{E} \cdot \overline{Y}} = \frac{I}{\overline{E}} = k$

where $\overline{Y}$ = national income resulting from investment I and

$\overline{E}$ = employment in investment projects I.

Point K represents the aggregated technique with the lowest capital-output ratio; its capital-output ratio is $0M$ and its productivity KM. In no event does this technique fail to ensure the development of production branches with highest capital-output ratio provided they are comprised in the national income increment. Point K represents techniques with the lowest capital-output ratio in every branch; if, however, any branch has only a single technique, even with relatively high capital-output ratio, then it is included by definition in the techniques represented both in point K and in point L. The relatively low value of the capital-output ratio for the whole aggregate is obtained because of the low level of mechanization in those branches where it can be low. Thus low capital-output ratios in some branches are combined with high capital-output ratios in others, and provide a whole range of capital-output ratios for the unit increment of national income.

Aggregated techniques in point L do not represent technical progress in comparison with techniques in point K. The two points, like all the others on the curve, are obtained for the given period of time as a sum total of techniques resulting from technical progress in the past to put it simply, those that have survived as efficient techniques. In choosing, say, K instead of L we do not disclaim technical progress; we simply decide to use, wherever possible, techniques with low capital-output ratio and, consequently, relatively low productivity. Again, if we choose L instead of K this does not mean that we acclaim technical progress: it means only that we seek high productivity, for which we are ready to pay in terms of high capital-output ratio. Contrary to what is commonly believed, the choice of a point on the production curve does not involve the problem of applying or not applying technical progress, but only the problem of choosing the degree of mechanization of production at a given level of technical know-how.

(b) *Technical progress*

The level of technical know-how rises continually because of scientific advances and new inventions. Technical progress leads to the discovery or adaptation of new production techniques which may consist in eliminating hard or harmful work or reducing investment per unit of output without affecting productivity. If more than two factors of production are considered—if we also take land into account—technical progress may be revealed in an increase of crops per hectare of arable land without any increase of labour productivity. But the most important fact in the long run is that new techniques lead to higher productivity. In any case, in this paper technical progress is unequivocally related to new techniques leading to higher productivity. If the new technique entails a capital-output ratio not exceeding that which accompanied the original techniques, then these latter become inefficient and are replaced by the new one.[9]

Thus technical progress results in shifting the production curve upward: through technical progress, productivity can be raised with an unchanged capital-output ratio. If, as a result of progress in aggregated production techniques, productivities rise at the same rate under any given capital-output ratio, then this type of technical progress may be called neutral. Naturally, non-neutral types

[9] If the new technique leads to higher productivity but requires a higher capital-output ratio, then it is added to the existing gamut of techniques.

of progress may exist as well, but we shall not concern ourselves with them in the present study.

The production curve for the year $t+1$ represents neutral technical progress in comparison with the production curve for the year t. This is demonstrated in figure III.

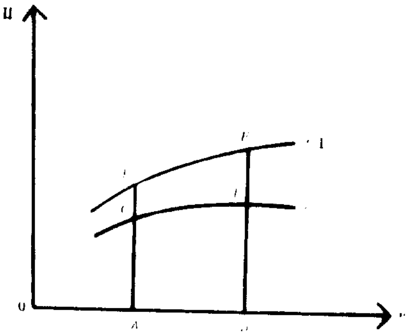


Figure III

Thus

$$EC/CA = FD/DB$$

which means that the rate of productivity increase (as a percentage) $\alpha = EC/CA$ and $\alpha = FD/DB$ is the same for production techniques with the same capital-output ratios in the year t and the year $t+1$ ($0A$ and $0B$). From this point of view, therefore, the value of the capital-output ratio does not matter; the type of technical progress we are discussing is called neutral precisely because it neither encourages nor discourages changes in the capital-output ratio. But from the point of view of the level of productivity, the value of the capital-output ratio does matter; for, of course, the higher the capital-output ratio, the higher is the level of productivity.

Note also that, with constant capital-output ratio and with technical progress, the capital-labour ratio will not remain constant but will increase proportionately with the increase of productivity. Indeed, k is equal to the area of the rectangle whose sides are $0A$ and AC in the year t, and $0A$ and AE in the year $t+1$. Thus the ratio k has increased in the year $t+1$ in comparison with the year t in the proportion $EA/CA = 1+\alpha$, i.e. a proportion equal to the increase in productivity.

Technical progress does not eliminate the problem of choosing the degree of mechanization, but produces the proper framework for examining it. Note that the problem of choosing between production curve t and production curve $t+1$ does not occur. Indeed, in the year t production curve $t+1$ does not yet exist (though it may be anticipated) and thus cannot serve as a basis for current investment decisions, while in the year $t+1$ production curve t can have an historical importance only, since in choosing the degree of mechanization we are guided by present and not by past techniques.

Hence, to postulate technical progress, right and proper as that is, does not mean to resort every time to the highest capital-output ratio and productivity; it only means to use at any given time the newest production curve, taking into account the latest achievements of technology and not only those of yesteryear. But once the production curve is given, the problem arises of choosing an efficient production technique, bearing in mind the existing labour reserves and the desired goals in the near and distant future.

3. MAXIMUM INCOME OR MAXIMUM ECONOMIC SURPLUS?

(a) *Maximum economic surplus and the level of current and future consumption*

To choose the best degree of mechanization is a problem in any economic situation, but especially in the presence of surplus labour. Indeed, with a given investment fund I, more or less labour can be employed, depending on the lower or higher degree of mechanization accompanied by a lower or higher capital-labour ratio k. In other words, with a given I employment varies inversely with k.

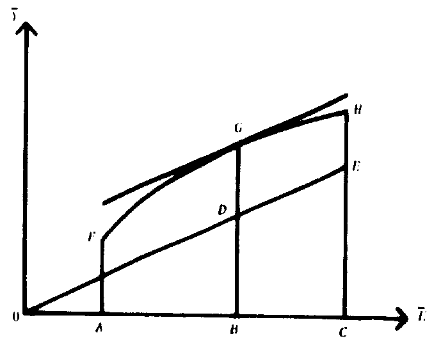


Figure IV

In figure IV employment $\overline{E}$ is plotted as an abscissa and national income $\overline{Y}$ as an ordinate.[10] The two values (and all the other values on the diagram) are related to a certain isolated economy that has been created by the initial investment fund I. As employment $\overline{E}$ increases (which is quite possible in view of the presence of redundant labour) productivity will decrease with decreasing capital-labour ratio k. But national income $\overline{Y}$,

[10] See Z. DOBRSKA, *Wybór technik produkcji w krajach gospodarczo zacofanych* (Choice of Production Techniques in Developing Countries), Warsaw, 1963, p. 51.

being the product of employment and productivity, will grow, because the increase in employment is more rapid than the decrease in productivity. Of course, if national income is growing with a given I this means that the capital-output ratio—like the capital-labour ratio—will diminish as $\bar{E}$ increases. Thus by raising employment to $\bar{E}_{max} = 0C$ we obtain the highest possible national income $Y_{max} = HC$. These are accompanied by the lowest possible capital-labour ratio $k_{min} = I/\bar{E}_{max}$ and the lowest possible capital-output ratio $m_{min} = I/\bar{Y}_{max}$.

Many economists have hailed this solution as the only acceptable one and have postulated that k be diminished until the available labour is employed. But this is an obvious over-simplification, since k cannot diminish below a certain minimum, and therefore even the lowest degree of mechanization will not result immediately in full employment if the supply of surplus labour is very large in relation to available investment. In any case, this solution aims at maximization of income; we shall call it the maximum-income solution.

The maximum-income solution has been questioned by several contemporary economists, including Galenson and Leibenstein, Dobb and Sen.[11] In particular, Dobb and Sen have brought to light a new and most relevant element, not considered previously. They have assumed the existence of an initial level of real wages which cannot be reduced. In this connexion they have proved that economic surplus, understood as the difference between national income and consumption equal to the real wage fund, varies in a peculiar way that justifies a fairly high degree of mechanization even in the presence of redundant labour. This solution—we shall call it the maximum-surplus solution—can be described diagrammatically in the following way. With real wages equal to the gradient of $0E$, the line $0E$ represents consumption, equal to real wage fund, as a linear function of employment. G is the point of tangency of the straight line, parallel to $0E$, with the curve FH. Hence, economic surplus $S_{max} = GB - DB$ is the highest. It is obtained when employment $\bar{E} = 0B$ and national income $\bar{Y} = GB$, where $\bar{E} < \bar{E}_{max}$ and $\bar{Y} < \bar{Y}_{max}$; this means, of course, that capital-labour ratio k and capital-output ratio m are in this case higher than k_{min} and m_{min}. In spite of the loss in income and consumption (for $DB < EC$) this solution has one important value: the maximization of economic surplus gives in the subsequent period (disregarding factors a and u) the highest possible rate of income growth.

[11] See W. GALENSON and H. LEIBENSTEIN, "Investment Criteria, Productivity and Economic Development", *Quarterly Journal of Economics*, Vol. 8, 1955; M. DOBB, *An Essay on Economic Growth and Planning*, London, 1960; and A. K. SEN, *Choice of Techniques*, Oxford, 1960.

Note that as $\bar{E}$ increases, the investment rate diminishes more and more rapidly, since with the wage fund rising proportionately to $\bar{E}$, national income $\bar{Y}$ is growing more and more slowly. At the same time the increase of $\bar{E}$ means a decrease of capital-output ratio m. In the interval between A and B the rate of income growth increases as $\bar{E}$ increases; indeed, the investment rate in this interval is decreasing more slowly than the capital-output ratio, bringing the rate of income growth to r_{max} when $\bar{E} = 0B$. Having passed point B, in the interval between B and C the rate of income growth decreases as $\bar{E}$ increases; in this interval the investment rate is already decreasing more rapidly than the capital-output ratio, and consequently, when $\bar{E} = 0C$, the rate of income growth is lower than r_{max}.

Since the rate of growth is decisive in the last analysis, maximization of surplus can be expected to liquidate surplus labour more rapidly than maximization of national income; considering that real wages remain stable it can also be expected to give a higher level of general and *per capita* consumption.

Denote the rate of growth of national income and consumption under the maximum-income solution by r, and the one under the maximum surplus solution by r_{max}; changes in general consumption and, assuming stability of real wages, also in employment will then appear as in figure V.

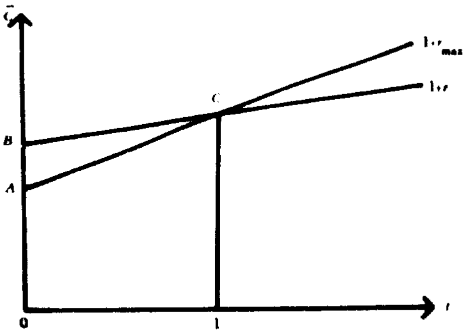


Figure V

On the ordinate, consumption $\bar{C}$ is plotted (in logarithmic scale); in the year 0 the consumption is $0B$ in the maximum-income solution and $0A$ in the maximum-surplus solution. In the latter case, though consumption is lower, a higher rate of growth is obtained, as is evidenced by the gradient of AC, $1 + r_{max}$, which is greater than the gradient of BC, $1 + r$. Hence, in a certain moment (year)

1, consumption (and employment) in the maximum-surplus solution will equal consumption (and employment) in the maximum-income solution, and in the following period the superiority of the former will be fully revealed. Indeed, in this case it must lead more rapidly to full employment coupled with higher productivity.

Without going into the details of the reasoning presented above let us consider the essential question: how much time will be needed for the maximum-surplus solution to reveal its superiority? We shall judge it differently if the time needed is, say, four years than if it is twenty years. Given the planner's attitude to sacrificing the present for the future, the nearer the moment (year) 1 to the moment (year) 0, the more acceptable to him will be the maximum-surplus solution. I shall try to prove that the time interval between 1 and 0 is quite long for two reasons: first, actual development does not correspond to an isolated economy, which is what we have examined so far; second, there is not only a gamut of techniques but also technical progress.

(b) Dependent and independent surplus

However low the initial rate of income growth and however small the fixed production assets in comparison with surplus labour, never do we face a situation equivalent to an isolated economy. Specifically, instead of a unique investment fund I, the existing apparatus of production yields each year a new investment fund which must be used. This might be called an independent fund, because for a long time it does not depend on the level of mechanization at which it is being used. Conversely, the economic surplus obtained from I might be called dependent, because it does depend on the level of mechanization. Thus, with the exception of the first year, in each subsequent year and for a very long time we shall have a joint investment fund comprising the independent as well as the dependent portion. This fact will greatly delay the moment when the maximum-surplus solution can reveal its superiority in terms of consumption. We shall now examine the problem somewhat more closely, assuming for the time being that there is no technical progress.

The diagram in figure VI follows the pattern of that in figure I. Curve HF demonstrates how the rate of growth r is dependent upon investment rate i and capital-output ratio m; since we have assumed that real wages remain stable, investment rate i is a function of capital-output ratio m and is increasing at a diminishing rate. The shape of curve HF results from an interpretation of the dia-

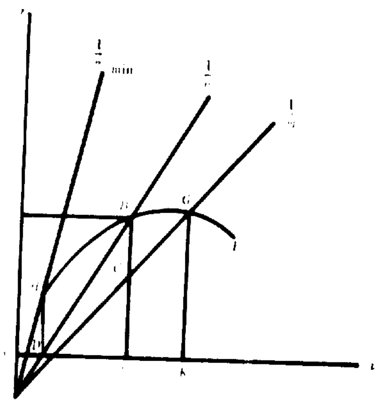


Figure VI

gram in figure IV. It ascends until it reaches its maximum, and then begins to descend. At point H the rate of growth is $r_{min} = DH$, investment rate $i_{min} = 0D$ and capital-output ratio is m_{min}; this point corresponds to the maximum-income solution. Point G corresponds to the maximum-surplus solution; here the rate of growth is $r_{max} = KG$, investment rate $i = 0K$, and capital-output ratio is m. Finally, point B shows the initial state in the year 0. Suppose that until and including the year 0, national income was growing at a rate $r_0 = EB$, with investment rate $i_0 = 0E$, and capital-output ratio m_0. Suppose also that $r_0 = \beta$, β denoting the rate of increase in labour supply, employment, and surplus labour. Because of the existence of a certain initial state, especially an initial rate of investment resulting from the existing apparatus of production, a shift from one point to another along the curve HF is a laborious operation lasting many years. Assuming that the life-span of industrial plants is n years, any modification of capital-output ratio will bring about respective changes in the whole apparatus of production only after n years, i.e. once this apparatus has been completely replaced.

Accordingly, if we decide to raise capital-output ratio from m_0 to m in year 1, we shall have to do it with the initial investment rate $i_0 = 0E$; the investment rate will increase only in year 1, as a result of higher capital-output ratio. The rate of income growth in year 1 is thus indicated by the ordinate of point C, that is, $r_1 = EC$; indeed, $r_1 = (1/m) \cdot i_0 - a + u$, where $r_1 < r_0$ when $m > m_0$.

Strange as it may seem, the maximum-surplus solution in the very beginning does not result in acceleration but in deceleration of growth; the greater the increase in capital-output ratio the more painful is the deceleration. Notice one more important phenomenon: in year 1, following the rise in capital-output ratio and in spite of the absence of technical progress, there occurs a certain rate of increase in productivity equal to a. Hence

$$r_1 = a + \beta_1$$

where $$\beta_1 = \beta - [\alpha + (r_0 - r_1)]$$

which means that the new rate of employment increase β_1 is much lower than β. It is lower because of the decrease of the rate of income growth from r_0 to r_1 and also because of α. At the same time, from year 1 onwards the investment rate begins to climb; indeed, with income growing at the rate r_1 in the year 1, consumption—always assuming stability of real wages—will rise at a rate equal to the rate of employment increase, i.e. β_1 and hence investment will increase at a rate higher than r_1. Consequently, from year 2 onwards the rate of income growth will be climbing because of increased productivity with stable real wages. But the increase in productivity is not constant: as the economy is saturated with new capital-output ratio, i.e. as it is recast under the new and higher capital-output ratio m, the rate of productivity increase withers away from α in year 1 to 0 in year $n+1$. This year will mark the end of the process of recasting and withering away; with capital-output ratio equalized for the whole economy, the investment rate will reach $i = 0K$ and the rate of income growth $r_{max} = KG$ where $r_{max} = \beta_{max}$; this will lead sooner or later to full employment, unless that has been achieved even before the year $n+1$.

Let us now concentrate on the fact that the rate of employment increase in the investigated variant grows gradually from β_1 in year 1 to β_{max} in year $n+1$. The different components of the rate of income growth are depicted in figure VII.

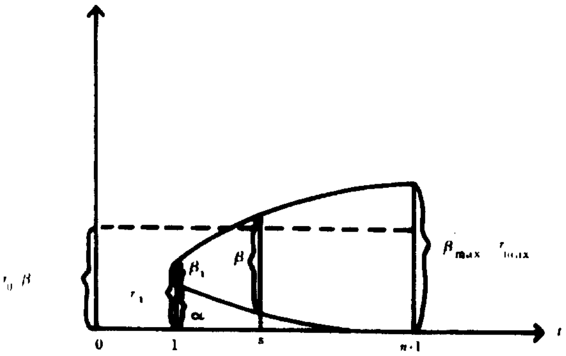


Figure VII

As the rate of productivity increase withers away, the rate of employment increase rises to reach the initial value β in moment (year) s. Notice that this moment occurs when the rate of income growth has surpassed $r_0 = \beta$. Furthermore, the average rate of employment increase calculated for the period between 1 and s is smaller than β and consequently the level of employment—and consumption—in moment (year) s is still lower in the variant examined than it might have been in the same year if initial capital-output ratio were maintained. Only in the subsequent period (not necessarily before year $n+1$) will the maximum-surplus solution at last reveal its superiority.

When the facts that growth does not begin from a zero point and that it is related to dependent as well as independent surplus are taken into account, the time needed to reveal the superiority of the maximum-surplus variant becomes very much longer. One might say, nevertheless, that this shows a way to escape from the state of underemployment while respecting the rule that the initial level of real wages must not be reduced. True enough; yet notice that respect for this rule greatly reduces the rate of consumption increase in the beginning of the process because of the lowered rate of employment increase. Thus real wages remain stable but surplus labour increases more rapidly than in the initial situation. If such sacrifices in general consumption were permissible, then the investment rate could be raised without increasing the capital-output ratio, though this would entail a violation of the rule that real wages must remain stable. Thus our reasoning has brought us back to subsection (e) of section 1, where such a variant is examined.

(c) Technical progress

Let us now introduce technical progress into our analysis. Under the neutral type of technical progress, if capital-output ratio remains unaltered, productivity will rise at the annual rate α. Hence if capital-output ratio between the years 1 and $n+1$ remains constant while real wages are stable (i.e. consumption increases at a rate equal to the rate of employment increase) then the ratio of consumption to national income diminishes $1+\alpha$ times each year or $(1+\alpha)^n$ times throughout the period under study. The ratio of consumption to national income is $1 - i^{(0)}$ in year 0 and $1 - i^{(n)}$ in year n. Hence

$$\frac{1 - i^{(n)}}{1 - i^{(0)}} = \frac{1}{(1+\alpha)^n}$$

$$1 - i^{(n)} = \frac{1 - i^{(0)}}{(1+\alpha)^n}$$

$$i^{(n)} = \frac{1}{(1+\alpha)^n}\, i^{(0)} + \left(1 - \frac{1}{(1+\alpha)^n}\right).$$

The investment rate in year n is thus a linear function of the investment rate in the year 0. Hence at the given α and n the rise in investment rate is less than proportional; for example, as figure VIII shows, while the investment rate $i^{(0)}_{min} = 0D$ increases at the segment DU, the investment rate $i_0^{(0)} = 0E$ will increase at the segment EW and the investment rate $i^{(0)} = 0K$ at the segment KS.

In this way we can find investment rates in year n corresponding to respective capital-output ratios $i^{(n)}_{min} = 0U$, $i_0^{(n)} = 0W$, $i^{(n)} = 0S$, and the

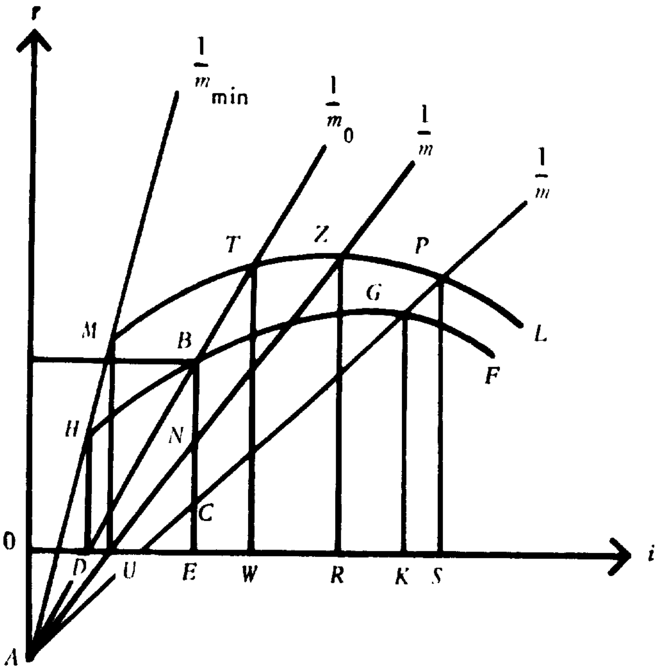


Figure VIII

resulting rate of income growth; now we can plot the curve *ML*. The curve depicts the relationship between the rate of growth of national income r and the investment rate i in the year $n+1$.

In the year $n+1$, as in year 1, the investment rate i is of course a function of capital-output ratio m and is increasing at a diminishing rate. The result is that, as i and m increase, the rate of income growth also increases in the beginning; this is illustrated by the sector *MZ* of the curve *ML*. In point Z the rate of income growth reaches maximum, whereupon it begins to fall because, once this point is passed, capital-output ratio rises more rapidly than the investment rate.

But the most important thing is that the capital-output ratio at maximum point on the curve *ML* is much lower than at maximum point on the curve *HF*. This is evidenced by the gradients of *AZ* and *AP*. It means that the capital-output ratio maximizing the rate of growth in year $n+1$ is not m but $m^1 < m$. Notice that the higher the rate of technical progress measured in α, the lower is the capital-output ratio maximizing r in year $n+1$. From this it follows that, if technical progress exists, the maximum-surplus solution does not maximize the rate of income growth in the long run. In such a situation, if the goal is to achieve the highest rate of income growth in year $n+1$ while real wages are kept stable, it is advisable to have recourse to a capital-output ratio lower than m. Then the dilemma "maximum surplus" versus "maximum national income" becomes less acute, because the capital-output ratio that in the long run maximizes the rate of income growth in the presence of technical progress is in any event lower than the capital-output ratio that maximizes surplus in the absence of technical progress. (It is not inconceivable that, given a high rate of technical progress, the lowest capital-output ratio, i.e. $m_{\min}$, will prove in the long run to maximize the rate of growth.)

Besides, when the factor of technical progress is taken into account much more time will be needed for the variant envisaging higher capital-output ratio to reveal its superiority in terms of consumption. Indeed, if capital-output ratio is raised from m_0 to m' in the year 1, then with the investment rate $i_0 = 0E$ the rate of income growth in the same year will equal $r_1 = EN$. Thereupon the investment rate will begin to rise gradually (as a result of increasing productivity with stable real wages) and the rate of growth will climb gradually to reach $r^{(n)}_{\max} = RZ$ in year $n+1$. It will be noted, however, that in year 1, due to the raising of capital-output ratio from m_0 to m', the rate of productivity increase rises from α to α_1, while the rate of income growth drops from the initial $r_0 = EB$ to $r_1 = EN$. Accordingly, the rate of employment increase declines from β to $\beta_1 = \beta - [(\alpha_1 - \alpha) + (r_0 - r_1)]$; the greater the decrease in the rate of growth of national income on the one hand and the greater the increase in the rate of growth of productivity on the other, the greater is also the decline in the rate of employment increase. In the following period the rate of employment increase will grow because of the rise in the rate of income growth from r_1 to $r^{(n)}_{\max}$ and of the simultaneous withering away of the rate of productivity increase from α_1 to the initial α in year $n+1$. The components of the rate of growth are presented in figure IX. Only in moment (year)

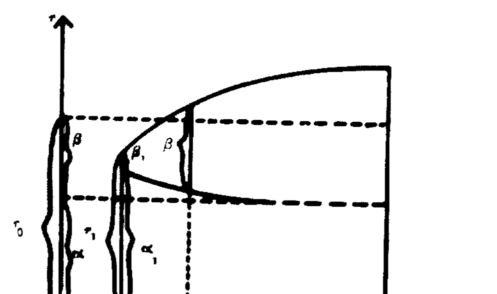


Figure IX

s will the rate of employment increase reach the initial β. But the average rate of employment increase calculated for the whole time from 1 to s is lower than β; consequently, the level of employment, and hence consumption, in moment (year) s is still lower than would be the case if initial capital-output ratio m_0 were maintained. Indeed, in the latter event we would also have an increase in the investment rate resulting from the increase in productivity at the rate α with stable real wages. Accordingly, the average rate of employment increase and of consumption increase in the period between 1 and s in this variant would be higher than β. This being the case, the superiority of the variant envisaging increased capital-output ratio might be revealed after the year s or perhaps even after the year $n+1$; meanwhile, in the short run, by limiting the level of employment this variant will adversely affect the level of consumption. The time needed to reveal the superiority of this variant will therefore be far longer than in the case when technical progress is non-existent. Nor is the variant maintaining the initial capital-output ratio completely helpless in regard to the elimination of unemployment while wages are kept stable. Indeed, it will raise the rate of income growth from $r_e = EB$ in year 1 to $r^{(n)} = WT$ in year $n+1$. Although this rate is lower than $r^{(n)}_{max} = RZ$, it is not inconceivable that the level of employment it gives in the year $n+1$ will still be higher than under the variant envisaging a rise in capital-output ratio. Even if the superiority of this variant is finally revealed (as it inevitably will be unless the supplies of labour force are exhausted earlier) the argument will still hold good that long-term advantages have been bought at the price of painful sacrifices in current consumption.

(d) *The role of the rate of productivity increase*

So far it has been assumed that real wages remain stable throughout the period of liquidation of surplus labour. If this period is relatively long, it may prove very difficult to stick to this policy; it may be necessary instead to allow for a rise in real wages slower than the rise in productivity. In such an event we shall have an annual increase in consumption corresponding both to the rate of employment increase and to the rate of increase in real wages, while the growth of national income will correspond to the rate of increase in employment and productivity. As a consequence, the relation of consumption to national income will diminish at a rate lower than that resulting from the increase in productivity. In simple terms, this corresponds to technical progress with a lower α, which means in turn that the capital-output ratio maximizing the rate of income growth will differ less in the long run from the capital-output ratio maximizing economic surplus. The whole of the previous reasoning will therefore remain valid, even though the time needed to reveal the superiority of the solution envisaging a rise in capital-output ratio over the solution envisaging a maintenance of the initial capital-output ratio will be shorter than in the case of a higher α. But in spite of these details the essential critique of the variant envisaging a relatively high level of mechanization in the presence of surplus labour still holds good.

(e) *Physical constraints on growth*

So far we have completely abstracted from the physical constraints that may hinder or prevent acceleration of growth. Yet they are of material importance; for, although to sacrifice the present for the future (which is the subject of our study in this section) is a necessary condition in accepting the solution which maximizes the rate of growth in the long run, it is not a sufficient condition. Indeed, bottlenecks in domestic production and in foreign trade may very much reduce the interval within which we can choose the rate of income growth, and deprive any conception beyond the boundaries of this interval of practical value. But even within them, the presence of bottlenecks and difficulties in foreign trade will put limitations on the acceleration of income growth. The problem is considered in more detail below.

4. DIMINISHING CAPITAL-OUTPUT RATIO

(a) *Acceleration of growth with constant investment rate*

We now turn to a solution which in our view merits careful consideration. It involves capital-output ratio that is neither increased nor maintained at the same level but, whenever possible, is diminished in order to accelerate the growth of national income in the presence of surplus labour. This is postulated not because of any dislike for those production branches that have a relatively high capital-output ratio or for technical progress, but simply because we seek a solution adapted to available labour supply. The problem consists of finding out whether the capital-output ratio that prevails initially in countries with surplus labour can be reduced, especially in view of necessary structural changes. Although the question can hardly be answered without detailed studies, this possibility is not inconceivable *a priori*, considering that initial capital-output ratio in the situation described is the product of spontaneous development. Even in countries where the initial level of capital-output ratio cannot be diminished it is important to understand th. advantages of such a diminution in the presence of surplus labour. For if this is understood it will not only counteract the myth – rather harmful under the circumstances—of "superior techniques" (which in practice means "the highest capital-output ratio") but also stimulate inventiveness in seeking techniques specially adapted to the situation in developing countries. For we must always bear in mind that existing production techniques have been developed in advanced countries, in accord with the relationships between factors of production obtaining in advanced countries.

If it is possible to diminish initial capital-output ratio then it will also be possible to accelerate income growth without placing a burden on current consumption. Figure X indicates that at

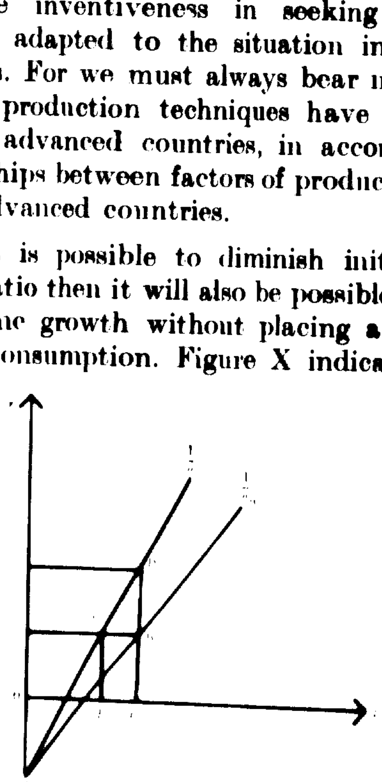


Figure X

the initial investment rate $i_0 = 0C$ the rate of income growth increases from the initial $r_0 = BC = \alpha + \beta$ to $r = DC = \alpha_1 + \beta_1$ in year 1 if capital-output ratio is diminished from the initial m_0 to m.

Acceleration of growth with an unaltered investment rate gives the same rate of growth in consumption and national income. As a result, from the very beginning actual consumption rises more rapidly than hypothetical consumption. In particular, there is no hindrance to the increase in real wages throughout the period of liquidation of unemployment, and the initial deceleration of employment increase that characterizes the solution envisaging a rise of capital-output ratio does not occur. On the contrary, in the case we are now examining the rate of employment increase will climb from the initial β to β_1 in the beginning of the process. This will occur for two reasons. First, acceleration of employment increase follows acceleration of income growth; the rate of employment increase will therefore grow by $r - r_0$. Second, because of the lowered level of mechanization of production the rate of productivity increase in year 1 will drop from α to α_1, i.e. by a value equal to $\alpha - \alpha_1$; this reduction in the rate of productivity increase is compensated for by employment. Thus the rate of employment increase in the year 1 will be $\beta_1 = \beta + [(r - r_0) + (\alpha - \alpha_1)]$, as depicted in figure XI.

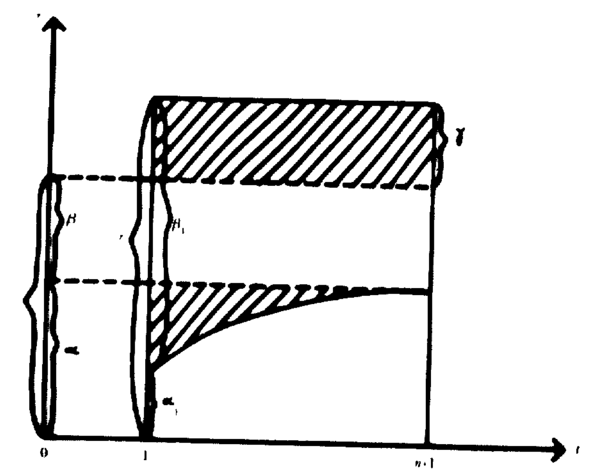


Figure XI

The hatched areas represent additional increase in employment in the interval between year 1 and year $n+1$. After the year $n+1$ the higher rate of growth may be maintained if surplus labour is still available and as long as it is available, while the rate of employment increase will be $\beta + \gamma$. Once surplus labour is no longer available the rate of income growth will drop to $r_0 = \alpha + \beta$ and the investment rate to $i = 0F$.

Instead of reducing the rate of income growth because of the unavailability of surplus labour one can consider the possibility of returning to the initial capital-output ratio or even raising it to exceed m_0. Illogical as it may seem, there is good logic in raising the capital-output ratio after its previous diminution. It is logical, because we diminished the capital-output ratio on account of the availability of surplus labour, and now we raise it on account of the unavailability of surplus labour. This brings out in full relief how the level of the capital-output ratio is subordinated to labour supply.

(b) *The condition limiting reduction of m*

Note moreover that, in the presence of surplus labour, the capital-output ratio cannot be diminished too far even though there are technical conditions for doing so. Specifically, the necessary initial deceleration of productivity increase, due to the lowered level of mechanization in new investment projects, should not result in a decreased level of productivity. Indeed, with $\alpha_1 > 0$ real wages could not be kept even at the initial level; hence the condition $\alpha_1 = 0$ must be regarded as a *sui generis* limit below which the level of mechanization cannot be reduced. If, on the other hand, $\alpha_1 > 0$, then the whole operation is accompanied not only by a rise in consumption but also, and from the very beginning, by a certain (though not very great) increase in real wages corresponding to the rate of productivity increase.

(c) *The role of factors other than investment*

Up to now the assumption has been made that the coefficient of improvements u remains constant. But there are reasons to expect that in the initial period of development in a socialist economy this coefficient might be increased. Indeed, if the economy concerned has just emerged from a non-socialist form of production, then it has some reserves which can be used rather easily by increasing employment. For in capitalist countries on a low and medium level of development, in addition to unemployment caused by shortage of working places, there is usually unemployment caused by incomplete use of the existing apparatus of production. This latter type of unemployment is fairly easy to eliminate because no previous investment is needed for the purpose. If the acceleration of growth faces us with a rapid increase in domestic demand, one way of meeting it, at least in part, is to introduce a full working week, more shifts per day, and other measures to increase employment in the existing plants. Such measures are usually profitable from the point of view of the whole national economy, even though from the point of view of a single enterprise they may not stand the test of profitability, because of the relatively low productivity of the extra employed labour. Nor is it immaterial that these measures, in contrast with investment, yield rapid results and hence increase the national income in which the share of investment must be raised.

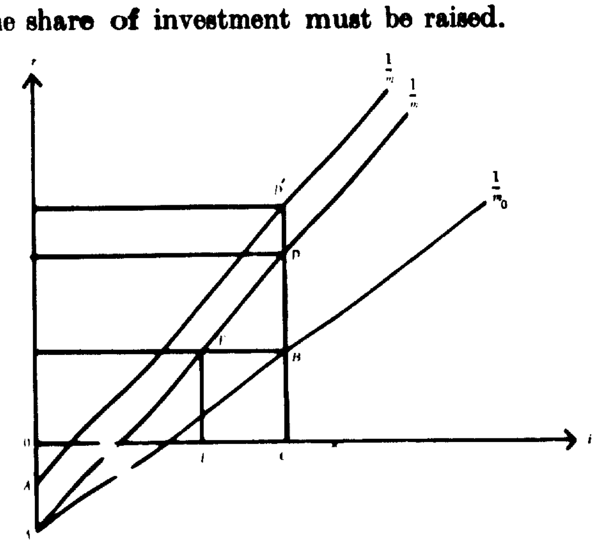


Figure XII

The smaller the degree to which productive capacities were used previously, the greater are the possibilities of raising the coefficient u in the case now under study. Thus, by replacing capitalist relations of production by socialist relations of production, opportunities are created for reducing or eliminating under-employment. Note that this was extensively used in the initial stages of industrialization in socialist countries.

An increase in u implies of course an increase in the rate of income growth. In figure XII, line $A'D'$ is drawn parallel to line AD but is shifted upward by the distance Δu equal to AA'. This distance depicts the average effect of the increase in u throughout the time when the effect occurs. As a consequence, with the investment rate $i_0 = 0C$ and the capital-output ratio reduced from m_0 to m, we obtain the rate of growth $r' = CD' = \alpha_1 + \beta_1 + \delta$ which exceeds the rate of growth r by δ representing additional increase in employment due to Δu.[12] Thus unemployment is liquidated more rapidly than would be the case if the factor Δu did not come into play.

Notice that the extra increment of national income thus obtained will include capital goods rather than consumer goods, because agriculture has no extra reserves of productive capacities of the type we have mentioned. Thus investment is increased not at the expense of consumption but at the expense of productive capacities that had previously remained idle. If the chance of tapping these resources were not used, then investment would be smaller and so would national income.[13] The factor Δu can of course be resorted to regardless of the decrease in capital-output ratio. Moreover, in the event of a relatively small surplus of labour it may also present an efficient alternative to a reduced level of mechanization, and therefore it certainly deserves careful attention.

We have seen that the effect of Δu is transitory. Once extra reserves are exhausted, the improvements coefficient u should regain its regular value.

5. CONSTRAINING FACTORS AND THE ROLE OF FOREIGN TRADE

(a) *Bottlenecks*

The only constraint on the increase of the rate of income growth we have considered so far was related to sacrifices in current consumption. Its importance is obvious, but it is not the sole con-

[12] In actual fact, the additional increase in employment is greater than δ since the rate of productivity increase in this case will be smaller than α_1, and the resulting gap will have to be filled by a higher rate of employment increase.

[13] See Józef PAJESTKA, *Zatrudnienie, inwestycje a wzrost gospodarczy* (Employment, Investment and Economic Growth), Warsaw, 1961.

straint, especially in countries on a low or medium level of development. Various physical constraints and bottlenecks usually occur in those countries upon surpassing a certain rate of growth. They include—to name but a few—limited capacities in capital goods production, especially in the engineering industry; limited possibilities, especially in the short and medium run, of expanding raw material production, agricultural production most of all; limited resources of explored mineral deposits; and a long gestation period of investment projects in certain branches. Were it not for foreign trade these bottlenecks would soon enough kill any effort to accelerate growth of national income.

(b) *The foreign trade barrier*

By foreign trade or, to be more precise, by imports, nearly all the bottle-necks can be removed. But in any case, with an accelerated growth of national income the growth of imports also will have to be accelerated. To speed up the growth of imports, especially in relation to the growth of income, requires an equivalent increase in exports so as to keep foreign trade in balance. There are barriers, however, both in demand and in supply, to the expansion of exports. Because of limited demand in foreign markets, export prices must be reduced (particularly when the exporter represents the bulk of the supply of the given item), less favourable markets must be sought, or less profitable goods must be exported in place of more profitable ones. Contraints may occur at the same time on the supply side, since it may prove difficult to expand the production of items with a more favourable relation between world prices and production costs: as a result it may be necessary to expand exports of those items with a less favourable relation between prices and costs. Finally, if attempts at expanding exports fail to yield sufficient results, recourse may be found in replacing imports by domestic goods.

Pro-export and anti-import investment usually entails a higher capital-output ratio and a lower productivity per unit of foreign currency gained in exports or saved in imports in the event of difficulties in foreign trade than would otherwise be the case. Leaving aside the drop in productivity (the gap it accounts for may be filled by means of additional employment), the situation will essentially deteriorate in regard to the rate of income growth. The impact of difficulties in foreign trade upon the rate of growth of national income is depicted in figure XIII.

If we abstract from foreign trade or if there are no difficulties in foreign trade, then the relationship between r and i with capital-output ratio

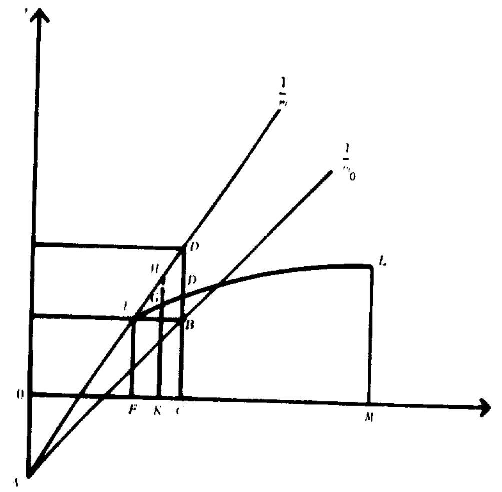


Figure XIII

m is represented by the straight line ED. If, while accelerating the growth of income, there are difficulties in foreign trade balance (which is usually the case) and the capital-output ratio must be raised to overcome them, then the relationship between r and i is represented by the curve EL. As the rate of income growth increases, difficulties in foreign trade also increase and so does the cost of alleviating them (in the form of a rising capital-output ratio). Finally, a point comes where no further increase in the capital-output ratio can help to surpass the maximum rate of growth, depicted in the figure by the ordinate of point L equal to $r_{max} = LM$.

This brings us to the important conclusion that the rate of growth of national income can be freely chosen only within the bounds of the interval $[r_0, r_{max}]$. Specifically, if difficulties occur in foreign trade, point D (mentioned before in connexion with diminishing the capital-output ratio from m_0 to m with the initial investment rate $i_0 = 0C$) will be unattainable not only with capital-output ratio m but even with the highest capital-output ratio. The rate of growth accompanying the investment rate i_0 in the event of difficulties in foreign trade is shown by the ordinate of point D', i.e. $r' = CD'$. Advantages derived from the reduction of capital-output ratio are thus smaller than they would be if there were no difficulties in foreign trade.

(c) *The impact of difficulties in foreign trade upon income growth*

If such difficulties are very hard to surmount and the curve EL is very flat, then the ordinate of point D' will but little exceed the ordinate of point B, i.e. the initial rate of growth $r_0 = BC$; it may then be advisable to keep to this rate with capital-output ratio reduced to m rather than to stick to the initial investment rate $i_0 = 0C$. Indeed, in such an event the investment rate may be cut from $i_0 = i = 0F$ without cutting the rate of income growth. This rate is $r_0 = \alpha_1 + \beta_1$ where $\beta_1 = \beta + (\alpha - \alpha_1)$, which means that while the rate of productivity increase drops at the beginning of the process from α to α_1, the rate of employment increase climbs from β to β_1. Later, because of changes in equipment related to a lower capital-output ratio, the rate of productivity increase will grow from α_1 to α while the rate of employment increase will drop from β_1 to β at the end of the process. Thus the operation brings a double advantage: first, at the very beginning it promotes a rise in consumption because of the reduction of the investment rate (the rate of income growth remains as given), after which consumption continues to rise at the initial rate; second, owing to the changed relationship between productivity and employment, the rate of employment increase is greater than β. If the resulting acceleration of employment increase is sufficient to liquidate surplus labour in a relatively short time, then the described variant will be accepted. If, on the other hand, it might take too long to eliminate unemployment, then the rate of income growth in the presence of difficulties in foreign trade will probably be fixed above $r_0 = EF$ and below $r' = CD'$, depicted by the ordinate of point G with the abscissa $i' = 0K$.

This analysis also discloses in a more general way the impact of difficulties in foreign trade upon the choice of the rate of income growth. It implies that in the presence of such difficulties the investment rate should be fixed at a lower level (e.g. $i' = 0K$ where $i' < i_0 = 0C$) than in their absence, and that the given investment rate (e.g. $i' = 0K$) is accompanied by a lower rate of income growth (e.g. $r'' = GK$ with $GK < HK$).

6. Marginal recoupment period: the instrument of choice between comparable investment projects

(a) *Factors determining the marginal recoupment period*

Suppose that the decision regarding the degree of mechanization and the rate of growth of national income has been made. It is mainly a political decision, because any choice between current and future consumption is beyond the bounds of purely economic analysis. The question is, what are the repercussions of this decision in the practice of enterprises and production branches, especially from the point of view of investment? A detailed answer to this question would exceed the scope of this essay; we can only try to shed light on the major points of the issue.

First of all, from the macro-economic decision mentioned above we derive the basic parameter used in calculating economic effectiveness of investment. It is $T = \frac{\Delta I}{\Delta K}$, the marginal recoupment period denoting the time (in years) in which additional investment (ΔI) in one of the two variants compared is to be completely recouped by means of annual savings (ΔK) in current costs.

The marginal recoupment period determines how far, from the point of view of the needs of the national economy as a whole, mechanization of production can and ought to be advanced. While envisaging certain investment projects and a certain increment in employment in a long-term plan, the planner sets the parameter T at a level which would help to achieve the stipulated targets.

Suppose there are two variants of the five-year plan with the same investment, one envisaging a reduction of the initial capital-output ratio (i.e. a relatively high increment of employment in the period under plan) and the other envisaging a rise in the initial capital-output ratio (i.e. a relatively low increment of employment in the period under plan). The marginal recoupment period will of course not be the same in both variants. It will be shorter in the variant with a higher increase in employment. The reciprocal of the marginal recoupment period, $1/T$, represents the shadow price of capital and will increase as T decreases. A short marginal recoupment period will thus induce the investor to choose production techniques with relatively low capital-output ratio and (consequently) relatively low productivity. As a result, employment increase will be relatively large. In a long marginal recoupment period the reverse will be true.

The marginal recoupment period is determined according to the supply of the labour force and the resultant decision regarding the desired level of mechanization. Consequently, the decision regarding the degree of mechanization determines the marginal recoupment period, and not vice versa.

(b) *Simplified formula of the economic effectiveness of investment*

We have said before that marginal recoupment period T plays an important part in calculating economic effectiveness of investment. Its simplified formula is

$$E = 1/T\, I + K = \text{minimum}$$

where I = integrated investment per given effect, and

K = integrated current costs (exclusive of depreciation) per given effect.

In the simple variant described in section 1 above, we apply the formula to two (or more) investment projects where the same goods are to be made by means of competing production techniques. It can also be applied in the case of investment projects that are expected to produce substitutional goods and effects, if their substitutional value can be measured in quantitative terms. Finally, it can be applied to investment related solely or mainly to foreign trade, i.e. pro-export or anti-import investment; the comparable effect in this case is a unit of foreign currency gained in exports or saved in imports. In each case preference should be given to the investment project with lowest E. Thus by setting the level of T the planner induces the investors to choose those production techniques (i.e. that degree of mechanization) which he considers to be desirable from the point of view of the national economy as a whole, and especially from that of the exisitng relationship between the investment fund and the labour force.

The formula for E is, of course, simplified. It assumes that the gestation period and the life-span are equally long in each of the investment projects compared. In actual fact they are not equal, and formula E becomes in practice much more complicated, including the freezing of resources resulting from different gestation periods as well as the time distribution of production and costs of production resulting from different life-spans.[14]

7. Some conclusions for mixed economies

(a) *Raising the investment rate in mixed economies*

In spite of the quantitative nature of many relationships analysed in this paper the statements it contains cannot be applied mechanically to every economic system. To be more specific, the basic conflict involved in the choice of techniques in the presence of surplus labour—the conflict between current and future consumption—occurs only in economies with comprehensive planning. In mixed economies, where the wealthy, propertied classes exist, it is always possible to reduce their consumption in the short run; it will not necessarily be very painful, since this consumption is usually quite high. But as far as the great majority of the population, town workers and small peasants, are concerned, any reduction in their consumption would entail real sacrifices; in no case can it be taken into consideration as long as patterns of affluent or even luxury consumption are tolerated.

One other significant aspect of the problem deserves attention. The question of choice of techniques, of how to achieve the highest effectiveness of investment in developing countries, though important, is secondary to the problem of institutional conditions of growth, and especially to the problem of sources of accumulation. Indeed, the crucial question in the countries concerned is who (which classes of population) will finance economic growth. Will it be the working people, with their notoriously low living standards, or the wealthy classes—feudalists, capitalists, merchants, usurers—whose consumption standards, copying the pattern of advanced countries, are very high not only in a relative sense? To think only in terms of maximum effectiveness of investment while forgetting about the portion of it that is wasted on luxury consumption or destined for investment projects with small social priority (such as luxury housing) constitutes a real danger in non-socialist developing countries.

It is often argued that luxury consumption accounts for only a small portion of the national income and that therefore its reduction would in no way help to raise the living standard of the whole population. But this is not the case. What is more, the argument ignores the fact that, especially in the case of a low initial rate of investment, each percentage of national income that can be additionally used for investment is materially important. It is from this angle that we must examine any measures, mostly in the form of taxation, intended to reduce luxury consumption. Besides, the problem quite often consists not so much in reducing the level of luxury consumption as in stabilizing it, or even allowing for some increase in it, though a slower one than that of the other components of national income, especially investment.[15]

(b) *Difficulties of ensuring the postulated level of mechanization in private economy*

A characteristic feature of mixed economies prevailing in non-socialist developing countries is the co-existence of the public sector, the capitalist

[14] For a more detailed description of this method, see M. Rakowski, ed., *Efficiency of Investment in a Socialist Economy*, Pergamon Press – PWE, Warsaw, 1966.

[15] See I. Sachs, "The Determination of Targets for Domestic Savings and the Inflow of External Resources". Paper presented at the Second Interregional Seminar on Development Planning, Amsterdam, Sept. 1966.

sector, and the small-holding (traditional) sector, especially in agriculture. In each of these the capital-output ratio is chosen in a different way.

The small-holding (traditional) sector, whose main purpose is to cover the needs of the family, obviously tends to minimize the capital-output ratio so as to maximize the volume of output. Somewhat more complicated is the situation in the capitalist sector, where the direct goal of economic activities is to maximize profits. If the market is unlimited the capitalist will decide to expand production up to the point of maximum economic surplus, paying no heed to profit per unit of output. Note that his decision cannot be affected by altering the rate of interest, which would only result—and here we refer to the diagram in figure IV—in shifting the wage line $0E$ upward by a distance equal to the value of the rate of interest. But the gradient of $0E$, which is equal to average wages, would remain unaltered and consequently so would the method maximizing economic surplus.

If, on the other hand, the market is limited, then maximization of profits entails highest profit per unit of output, i.e. lowest production costs with the given prices. The technique that fulfils this condition is related, *ceteris paribus*, to the rate of interest. Higher rates of interest will discourage the choice of a high level of mechanization, and lower rates of interest will encourage it. But the State can influence the rate of interest only to a limited extent; consequently this rate can by no means be identified with the shadow price of capital, which has to be used in the calculus of effectiveness of investment. To apply the rules of this calculus (explained in section 6 above) to the operations of capitalist enterprises generally seems to be fairly difficult.

All things considered, it is not always in the planner's power to ensure in the private sectors such a level of mechanization as is desirable for the whole economy. Public investment therefore—which in mixed economies in any case supplements usually insufficient private investment and corrects its structure to suit the requirements of growth—must be given a capital-output ratio which, in conjunction with the capital-output ratio in private investment, will bring about the average level of mechanization desired for the whole economy.

(c) Inflationary pressures

So far we have disregarded the problem of inflationary pressures usually occurring during acceleration of income growth. The problem is very important, especially in mixed economies. Indeed, inflationary methods are a most unfair way of financing investment and economic growth. They affect the working people and fill the pockets of landowners and merchants, encouraging not investment but parasitic consumption. It is little wonder that inflation, especially in its galloping form, leads to grave social tensions and political instability.

Inflationary pressures accompany acceleration of growth, more particularly acceleration of employment increase, when the supply of high-priority consumer goods remains constant or rises at an insufficient rate as compared with the rate of increase in employment and demand. The demand exceeds the supply at given wages and prices, and prices climb in relation to nominal wages until demand and supply are equalized. A rise in prices in relation to wages means, of course, a drop in real wages; and this is the most important effect of inflation.

To avert the danger of inflation in a developing mixed economy while liquidating surplus labour is, to put it mildly, quite a complicated task. Under these circumstances, anti-inflationary measures must consist of accelerating the growth of income and employment step by step, so as to accelerate the increase in demand gradually and not violently and uncontrollably. It is as essential, on the other hand, to step up the increase in output of high-priority consumer goods, partly at the expense of low-priority consumer goods. Hence the necessity to invest from the very beginning in expanding the productive capacities of the sector that makes high-priority consumer goods as well as to take other measures with a view to using the existing capacities to a maximum.

High-priority consumer goods mean mainly food, and the primary source of food is agriculture. The problem of inflation is thus in practice the problem of food and agriculture. Acceleration of growth in agricultural production is a difficult matter because the produce depends on biological processes and weather and also because the area under cultivation is often (though not always) strictly limited. Another difficulty consists in the fact that agricultural production is fragmented among a great many small producers. For these reasons a spectacular rise in the rate of growth of agricultural production can hardly be expected in practice.

And yet the barriers of nature and organization are of secondary importance when compared with the institutional barriers to the growth of agricultural production. An elaborate system of feudal and semi-feudal conditions of property, a system of tenancy with ruinous rent, and a system of usurious loans entangling the poor peasants in an iron web of growing debts—these are often the reasons why agricultural production is either stagnant or grows so slowly that it cannot meet the demand caused by accelerated economic growth and population explosion. It is therefore obvious that the prerequisite of real economic growth is a radical land reform which liberates the peasant from his triple subjugation to the landowner, the merchant and the usurer. A land reform coupled with aid for poorer peasants is thus the point of departure for the policy of accelerated growth of national income and the uninflationary financing of such growth.

TECHNOLOGICAL KNOWLEDGE AND ECONOMIC GROWTH

Karl Shell, Department of Economics, Massachusetts Institute of Technology, Cambridge, United States of America

EMPIRICAL LITERATURE on the sources of economic growth has convinced the contemporary economist of the important role played by "technical progress" in the process of economic development.[1] Only to have models of economic growth in which such an important factor is treated as exogenous is certainly unsatisfactory, and it was because of this that the models of Kaldor and particularly of Arrow were introduced.[2] Both these models may be thought of as positing that the production of new technical knowledge (invention) and its transmission (innovation) are social by-products of the production and adoption of new capital goods.

While it is no doubt true that technical change is related to gross investment both as a by-product of capital goods production and as a vehicle for embodying new techniques in new capital equipment, it is also true that the rate of production of technical knowledge can be increased by increasing the allocation of economic resources explicitly devoted to inventive activity. Elsewhere,[3] I have treated models in which the level of technical knowledge is increased by the explicit allocation of economic resources to inventive activity. My model is much like a heterogeneous capital-goods model except that for the enterprise economy the stock of technical knowledge enters as a pure public good of production. Such a specification is suggested by the very low cost of transmission of technical knowledge with respect to its production cost.[4] For the enterprise economy, therefore, the specification of the form of the production functions which is consistent with the usual competitive hypothesis is altogether different in the inventive activity model from the consistent specification in the ordinary heterogeneous capital-goods model.

As I see it, endogenous technical change models of the heterogeneous capital-goods type represent one of the promising first steps in this area. The currently available models of this type, however, suffer from two severe short-comings: *(a)* in none of them does uncertainty enter in an intrinsic fashion; *(b)* the manner in which technical knowledge enters production functions is specified in advance in these models, no economic choice being left between say labour-saving or capital-saving inventive activity.

There are probably two distinguishing qualities of the commodity "technical knowledge". The first is its lack of appropriability: it can be used by many economic units without altering its character. It is this quality which makes social intervention in the enterprise economy on behalf of inventive activity so desirable. This quality of technical knowledge and its implications for social policy are stressed in my two papers just mentioned. The second distinctive quality of technical knowledge is the riskiness of its production. This uncertainty is treated in my papers in a way that removes all the inherent difficulties by assuming that, given factor allocations to the inventive sector, the dispersion of aggregative benefits from invention about its mean is zero, so that under social planning no risk remains.

Recently there have been a number of contributions to the literature of economic growth employing a construct such as the invention pos-

[1] See R. W. SOLOW, "Technical Change and the Aggregate Production Function", *Review of Economics and Statistics*, Vol. 37, 1957; J. W. KENDRICK, *Productivity Trends in the United States*, Princeton, 1961; and E. F. DENNISON, *The Sources of Growth in the United States and the Alternatives Before Us*, Supplementary Paper No. 13, Committee for Economic Development, New York, 1962.

[2] N. KALDOR, "A Model of Economic Growth", *Economic Journal*, Dec. 1957, pp. 591–624; and K. J. ARROW, "The Economic Implications of Learning by Doing", *Review of Economic Studies*, June 1962, pp. 155–173.

[3] K. SHELL, "Toward a Theory of Inventive Activity and Capital Accumulation", *American Economic Review*, Vol. 56, May 1966, pp. 62–69; and "A Model of Inventive Activity and Capital Accumulation", in K. SHELL (ed.), *Essays on the Theory of Optimal Economic Growth*, M.I.T. Press, forthcoming.

[4] In a provocative unpublished paper, "A Theory of Invention in the Firm", W. D. NORDHAUS has extended the analysis to include the case in which, although "spill-overs" of technical information are present, the firm is able to internalize some of the returns from inventive activity.

sibility set (or the innovation possibility set).[5] In these models the invention possibility set is given at every instant of time and is independent of economic variables. From feasible points in the invention possibility set, firms or planners are free to choose optimal combinations of capital-augmenting and labour-augmenting technical progress.

As a prologue to the theory of endogenous technical change the next section deals with models of stylized enterprise economies and planning models in which there is exogenous technical change. In section 2 I treat three different models of education and technological change, drawing inspiration from the work of Uzawa, and Nelson and Phelps. The first model of education specifies that changes in labour-force efficiency are dependent upon the fraction of the labour force engaged in educational activity. The second model specifies that changes in labour force efficiency are dependent upon the gap between exogenously determined "available technology" and "technology in practice" and upon the "educational attainment" of the society. These two views are then integrated with the specification that changes in educational attainment are dependent upon the fraction of the labour force employed in the educational sector.

In section 3 I question the rigid assumption that technical change affects the production function in a pre-specified way that is not subject to economic calculation. I examine a planning model inspired by Samuelson and Nordhaus, in which the bias of technical change is open to choice by the planning authority. Certain turnpike properties are exhibited. The difficulties inherent in extending the analysis to enterprise economies are discussed.

1. GROWTH MODELS WITH EXOGENOUS TECHNICAL CHANGE

In a classic paper Robert Solow[6] studied the long-run dynamic behaviour of a simple economy in which the current rate of production of homogeneous output $Y(t)$ depends upon the current stock of physical capital $K(t)$ and the current size of the labour force $L(t)$ inelastically offered for employment,

$$Y(t) = \varphi\,[K(t), L(t); t], \tag{1.1}$$

or in the particular case of Hicks-neutral technical change

$$Y(t) = A(t)\,F\,[K(t), L(t)], \tag{1.1'}$$

where $A(t)$ may be thought of as a measure of the current stock of technical knowledge. Solow assumes that there is no depreciation in physical capital, so that current output can be split into current consumption $C(t)$ plus current investment $Z(t)$, and that

$$Y(t) = C(t) + Z(t) = C(t) + \dot{K}(t). \tag{1.2}$$

If a constant fraction $0 < s < 1$ of output is saved and invested, then the differential equation of capital accumulation is

$$\dot{K}(t) = s\,Y(t). \tag{1.3}$$

Solow further assumes that the labour force grows at the constant relative rate n so that

$$\dot{L}(t) = n\,L(t). \tag{1.4}$$

If lower-case letters denote quantities per worker then the system (1.1)—(1.4) can be rewritten as

$$y(t) = A(t)\,f\,[k(t)] \equiv A(t)\,F\,[k(t), 1], \tag{1.1*}$$

$$y(t) = c(t) + z(t) = c(t) + \dot{k}(t) + nk, \tag{1.2*}$$

$$\dot{k}(t) = sA(t)\,f\,[k(t)] - nk, \tag{1.3*}$$

if F is positively homogeneous of degree one (constant-returns-to-scale). First assuming the absence of technological change, $A(t) = \bar{A} > Q$, constant, it is easily shown that the Inada conditions

$$\begin{cases} f(k) > 0,\ f'(k) > 0,\ f''(k) < 0,\ 0 < k < \infty \\ f(0) = 0,\ f(\infty) = \infty \\ f'(0) = \infty,\ f'(\infty) = 0 \end{cases} \tag{1.5}$$

ensure that the economy (1.1)—(1.5) develops in such a way as to tend to the unique long-run balanced capital-labour ratio independent of initial conditions. If capital depreciates at the given exponential rate μ, and gross saving is a constant fraction of gross income,

$$\dot{k} = sAf(k) - \lambda k, \tag{1.6}$$

where $\lambda \equiv \mu + n$. Or if net saving is a constant fraction of net income then

$$\dot{k} = sAf(k) - \lambda' k, \tag{1.7}$$

where $\lambda' \equiv n/s + \mu$. Again (1.5) ensures that both the system (1.6) and the system (1.7) are globally stable in the sense of Lyapunov when s and A are given quantities independent of time.

For the special case that the exogenously given relative rate of increase of technical knowledge is constant

[5] See W. D. NORDHAUS, "The Optimal Rate and Direction of Technical Change", to appear in *Essays on the Theory of Optimal Economic Growth*, op.cit.

[6] R. M. SOLOW, "A Contribution to the Theory of Economic Growth", *Quarterly Journal of Economics*, Vol. 32, 1956, pp. 65—94.

$$\dot{A} = \varrho A, \tag{1.8}$$

and the production function given in (1.1′) is Cobb-Douglas in capital and labour, so that

$$y = e^{\varrho t} k^{\alpha},\ 0 < \alpha < 1, \tag{1.9}$$

then long-run growth tends to a balanced capital labour ratio measured in efficiency units (K/AL) when net (gross) saving is a fixed fraction of net (gross) income.[7]

Next consider the problem of planning economic development in a centrally-directed economy where Hicks-neutral technical change proceeds at a constant given rate ϱ. Assume that technology and labour-force growth are as given in (1.1)–(1.5) except that at every instant the savings fraction $s(t) \varepsilon [0, 1]$ is subject to control by the planning board. As an exercise, I consider the problem of maximizing the integral of discounted per worker consumption over a given (finite or infinite planning) period.[8]

The problem is to maximize the functional

$$\int_0^T c(t)\, e^{-\delta t}\, dt \tag{1.10}$$

subject to the constraints:

$$\dot{k}(t) = s(t)\, y(t) - \lambda k(t) \tag{1.11}$$

$$y(t) = e^{\varrho t} f(k(t)) \tag{1.12}$$

$$0 \leq s(t) \leq 1 \tag{1.13}$$

$$k(0) = k_0 \text{ and } k(T) \geq k_T \tag{1.14}$$

where δ, $\lambda \equiv n + \mu$, k_0, k_T are given constants and $s(t)$ is some measurable control (or policy) variable to be chosen. Units of measurement have been chosen such that $A(0) = 1$ and therefore $A(t) = e^{\varrho t}$. k_0 is the historically given capital-labour ratio, k_T is the "target" capital-labour ratio, while $T > 0$ is the length of the planning period.

The above problem is solved by employing the "maximum principle" expounded in *The Mathematical Theory of Optimal Processes.*[9] Introduce the Hamiltonian form

$$e^{-\delta t} \{(1 - s)\, e^{\varrho t} f(k) + q\, [s e^{\varrho t} f(k) - \lambda k]\} = \\ = e^{-\delta t} \{[(1 - s) + qs]\, e^{\varrho t} f(k) - q \lambda k\}.$$

The application of theorem 3 of the work mentioned yields the result that if a programme $[k(t), s(t) ; 0 \leq t \leq T]$ is optimal, then there exists a continuous function $q(t)$ such that

$$\dot{k}(t) = s(t)\, e^{\varrho t} f(k(t)) - \lambda k(t) \tag{1.15}$$

with initial condition $k(0) = k_0$,

$$\dot{q}(t) = (\delta + \lambda)\, q(t) - [(1 - s(t)) + \\ + q(t)\, s(t)]\, e^{\varrho t} f'(k(t)), \tag{1.16}$$

$s(t)$ maximizes

$$[1 - s(t) + q(t)\, s(t)] \text{ subject to } 0 \leq s(t) \leq 1 \tag{1.17}$$

and s is a piece-wise continuous function of t,

$$e^{-\delta T} q(T)\, [k(T) - k_T] = 0. \tag{1.18}$$

For convenience set

$$\gamma = \max_{0 \leq s \leq 1} [(1 - s) + qs] = \max(1, q).$$

Notice that $q(t)$ has the interpretation of the social demand price of a unit of investment in terms of currently foregone unit of consumption. Therefore, differential equation (1.16) may be interpreted as the requirement of perfect foresight. In a competitive economy, for example, the change in the price of a unit of capital should compensate a *rentier* for loss due to depreciation and for "abstinence", net of any rewards from the employment of that unit of capital. Transversality condition (1.18) states that at the target date either the target requirement (1.14) must hold with equality or the target demand price of investment must be zero.

Next it is required to study the singular solutions of differential equations (1.15) and (1.16). Notice that $\dot{q} = 0$ if and only if

$$q = \frac{\gamma e^{\varrho t} f'(k)}{\delta + \lambda}. \tag{1.19}$$

(1.19) reduces to

$$e^{\varrho t} f'(k_t) = \delta + \lambda \qquad \text{for case } q \geq 1, \text{ and} \tag{1.20}$$

$$q_t = \frac{e^{\varrho t} f'(k_t)}{\delta + \lambda} \qquad \text{for case } q \leq 1. \tag{1.21}$$

If the production functions satisfy (1.5) it is well known that for any instant of time, equation (1.20) is uniquely solvable in k_t. Call the solution to (1.20) k_t^*. Determination of k_t^* is shown in figure I. $\tilde{k}_t$ is the maximum sustainable capital-labour ratio when technology is held fixed.

[7] This is natural because in the Cobb-Douglas case Hicks-neutral technical change is also Harrod-neutral and thus technical change can be thought of as labour augmenting. See H. UZAWA, "Neutral Inventions and the Stability of Growth Equilibrium", *Review of Economic Studies*, Vol. 28, No. 2, pp. 117–124.

[8] This simple example is based upon the more complicated analysis appearing in K. SHELL, "Optimal Programmes of Capital Accumulation for an Economy in which there is Exogenous Technical Change", in *Essays on the Theory of Optimal Economic Growth*, op. cit.

[9] L. S. PONTRYAGIN, V. G. BOLTYANSKII, R. V. GAMKRELIDZE, and E. F. MISCHENKO, *The Mathematical Theory of Optimal Processes*, New York and London: Interscience Publishers, 1962. *(Theorem 3 appears on p. 63.)*

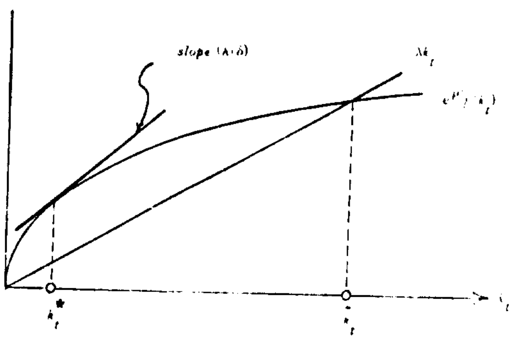


Figure I. Determination of k_t^* and $\tilde{k}_t$

It is shown that for fixed t, equation (1.19) describes a continuous curve in the (k, q) plane with a kink at $(k = k^*, q = 1)$. Differentiating (1.21) yields

$$\left.\frac{dq}{dk}\right|_{\dot{q}=0} = \frac{e^{\varrho t} f''(k)}{\delta + \lambda} < 0, \text{ for } q < 1. \qquad (1.22)$$

First we study the case of no technical change ($\varrho = 0$). The appropriate phase diagram is given in figure II. Condition (1.17) implies that for optimality it is necessary that

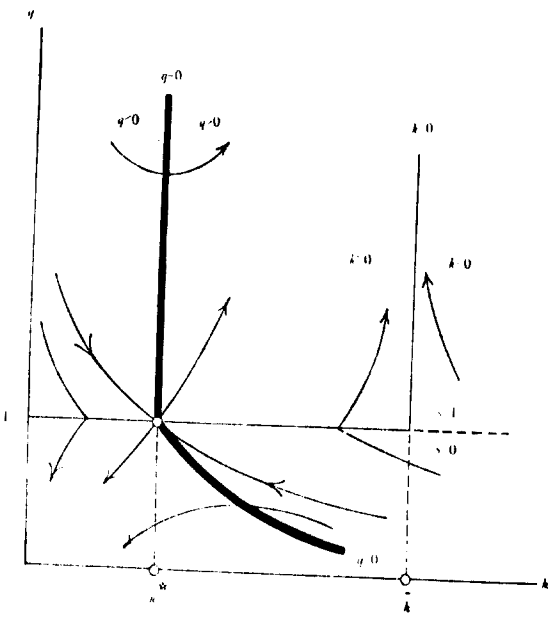


Figure II. Phase diagram for case $\varrho = 0$

$$\left|\begin{array}{ll} s(q) = 1 & \text{when } q > 1 \\ 0 \leq s(q) \leq 1 & \text{when } q = 1 \\ s(q) = 0 & \text{when } q < 1 \end{array}\right| \qquad (1.23)$$

Then on any given trajectory not passing through the point $(k^*, 1)$, k can be written as a continuous function of q.[10] In fact a trajectory $[k(t), q(t); t]$ not passing through $(k^*, 1)$ is uniquely determined by the specification of initial conditions $[k(t_0), q(t_0); t_0]$.

Assume for purposes of exposition that the initial capital-labour ratio is the balanced capital-labour ratio k^*, i.e. $k(0) = k^*$. Assume that the planning period is infinite, $T = \infty$, and that the target capital-labour ratio is left free. Then a programme of capital accumulation satisfying the necessary conditions is that of fixing $q(t) = 1$ for $0 \leq t \leq \infty$ and maintaining the balanced capital labour ratio $k(t) = k^*$ for $0 \leq t \leq \infty$.

For the case $\delta = 0$, the above programme

$$\left(k = k^*, \quad s = \frac{\lambda k^*}{f(k^*)}; \quad 0 \leq t \leq \infty\right)$$

is what both Phelps and Robinson[11] have dubbed the golden rule of capital accumulation. For $\delta \neq 0$, this may be called the modified golden rule of capital accumulation.[12]

If $k(0) \neq k^*$, the planning board would assign initial price q_0 such that the point (k_0, q_0) lies on a trajectory that passes through $(k^*, 1)$. Let $0 \leq t^* < \infty$ be the time required for such a programme to achieve $(k^*, 1)$. Then the optimal programme is

$$\left(k = k^*, \quad s = \frac{\lambda k^*}{f(k^*)}; \quad t^* \leq t \leq \infty\right).$$

The initial savings ratio is zero or one, depending upon whether the initial capital-labour ratio is greater or less than k^*.

The analysis is easily modified to handle the general case where $k(T) \geq k_T \geq 0$ and $T \leq \infty$. The

[10] By assigning the value $s(q) = 1$, the *RHS* of differential equations (1.15) and (1.16) are seen to be continuously differentiable functions of their arguments, k, q, and t, on the domain defined by $k > 0, q \geq 1, t \geq 0$. Further, by assigning the value $s(q) = 0$, the *RHS* of (1.15) and (1.16) are seen to be continuously differentiable functions of k, q, and t on the domain defined by $k > 0, q \leq 1, t \geq 0$. Thus, when the control $s(t)$ is appropriately assigned, the system (1.15) and (1.16) is shown to be trivially Lipschitzian over the respective domains of definition. By classic theorems of ordinary differential equations (see L. S. PONTRYAGIN, *Ordinary Differential Equations*, Reading, Addison-Wesley Publishing Company, 1962, pp. 159–167) we have that for a system satisfying (1.15)–(1.17) and (1.23) that specification of the parameters $(k(t_0), q(t_0); (t_0)$ uniquely determines the entire trajectory for trajectories not passing through the locus of points defined by $\{(k, q, t) \mid k = k^*(t), q = 1, t \geq 0\}$. In fact, the solutions to the system (1.15)–(1.17) vary continuously when the initial parameters $(k(t_0), q(t_0); t_0)$ are allowed to vary (see ibid., pp. 192–199).

[11] E. PHELPS, "The Golden Rule of Accumulation: A Fable for Growthmen", *American Economic Review*, Vol. 51, 1961; and J. ROBINSON, "A Neoclassical Theorem", *Review of Economic Studies*, Vol. 29, 1962.

[12] Or perhaps, "the adulterated golden rule". For $\varrho = 0$ and $T = \infty$, it is required that $\delta > 0$ in order that the value of the definite integral (1.10) be finite for all feasible programmes. For $T < \infty$, the requirement that δ be positive is too strong. Even for the case with non-zero technical change, if $\delta > f'(k_t) - \lambda$ for $t \geq 0$, then $k_t > k_t^*$. T. Koopmans, *On the Concept of Optimal Economic Growth*, Cowles Foundation (CF-30918), 1963, argues that if the ethical principle that all men are to be treated equally (independent of the size of their generation or its "timing") is held, then δ should be chosen equal to $(-n) < 0$, for the case of positive population increase. As long as $T < \infty$, our analysis is congenial to this interpretation.

initial point (k_0, q_0) is chosen on a trajectory leading to the point $(k^*, 1)$, if feasibility permits. The Pontryagin programme

$$\left(k = k^*, \quad s = \frac{\lambda k^*}{f(k^*)}\ ; \quad t^* \leq t \leq t^{**}\right)$$

is followed, where t^{**} is the time at which the backward trajectory of the system (1.15)–(1.16) starting at $(k = k_T; t = T)$ passes through $(k = k^*, q = 1)$. If, however, $q(t) < 0$ for all backward trajectories to $(k^*, 1)$ starting at k_T, then t^{**} is defined to be the time at which a backward trajectory starting at time T and demand price $q(T) = 0$ intersects the point $(k^*, 1)$. Figure III illustrates a programme satisfying Pontryagin's necessary conditions.

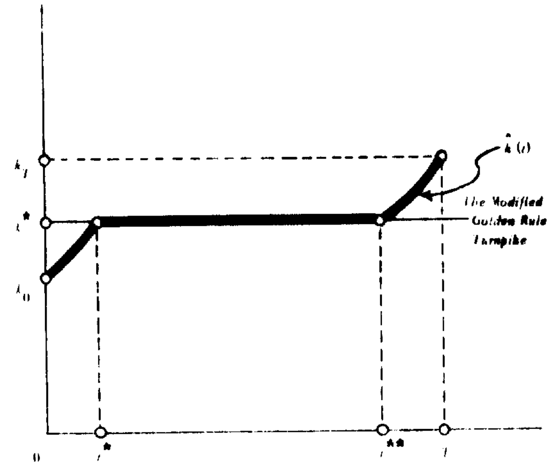


Figure III. $\hat{k}(t)$, the Pontryagin path for case $\varrho = 0$

Important assumptions are implicit in the construction of figure III. First, it is assumed that it is feasible for the economy with initial endowment $k(0) = k_0$ to achieve the target k_T in the specified time T. Even stronger, figure III assumes that in fact

$$T > t^{**} > t^* > 0. \tag{1.24}$$

If it is feasible to achieve the target during the planning period but (1.24) fails to hold, then the Pontryagin path is the appropriate envelope of a forward trajectory from (k_0, q_0) to $(k^*, 1)$ and the backward trajectory from (k_T, q_T) to $(k^*, 1)$. In the degenerate case in which only one feasible path exists, the Pontryagin path is, of course, a programme either of zero savings or of zero consumption. Since optimal programmes do not permit the demand price of investment to become negative, if no trajectory is found with $k(T) = k_T$ and $q(T) \geq 0$, then the Pontryagin problem will yield $q(T) = 0$ and $k(T) > k_T$.

Some observations are in order here. The linearity of the objective function (1.10) implies a kink in the graph of the stationary solutions to equation (1.16). Extending the argument presented in footnote [10], the backward solutions to the point $(k^*, 1)$ are unique. In general, however, q_0 will not be uniquely determined by (k_0, k_T, T). For the degenerate Pontryagin paths that are everywhere specialized to production of the same good, there is a family of trajectories satisfying (1.15)–(1.18). None the less, the Pontryagin programme of capital accumulation

$$[\hat{k}(t); 0 \leq t \leq T]$$

is uniquely determined by (1.15)–(1.18), if a feasible programme exists.

To summarize the Turnpike Property: For the case of neoclassical production without technical change, following the Pontryagin programme of capital accumulation requires the planning board to adopt the modified golden rule of capital accumulation for all but a finite amount of time. As the length of the planning period increases, the fraction of time spent on a programme not satisfying the modified golden rule approaches zero.[13]

Next, examine the case with positive technical progress ($\varrho > 0$). Notice that if ϱ is non-zero, differential equations (1.15) and (1.16) are non-autonomous and thus the appropriate phase diagram must be drawn in three-dimensional space, (k, q, t). Time differentiation of equation (1.20) yields

$$\dot{k}_t^* = \frac{-\varrho(\delta + \lambda)\, e^{-\varrho t}}{f''(k_t^*)} \gtrless 0 \ \text{ as } \ \varrho \gtrless 0. \tag{1.25}$$

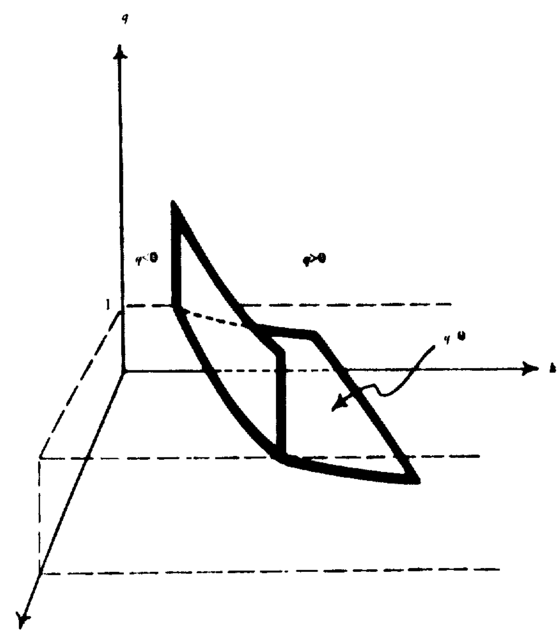


Figure IV. The manifold of solutions to $\dot{q} = 0$ for case $\varrho > 0$

[13] If $\delta \leq f'(\tilde{k}) - \lambda$, then the Pontryagin programme $[\hat{k}(t), 0 \leq t \leq T]$ is arbitrarily close to the ratio $\tilde{k}$ for all but a finite amount of time.

In general, stationary solutions to the differential equation

$$\dot{q}(t) = (\delta + \lambda)\, q(t) - \gamma e^{\varrho t} f'(k_t)$$

are shown to lie on a manifold embedded in (k, q, t) space. The manifold of solutions to $\dot{q} = 0$ is illustrated for ϱ positive in figure IV. The recollection that, given t, equation (1.20) has the unique solution k^*_t, suggests a programme satisfying the necessary conditions (1.15)–(1.18). Consider for ease of exposition the case when the initial condition is $k(0) = k^*_0$ and the target requirement is $k(T) = k^*_T$. A programme of capital accumulation that follows the modified golden rule turnpike is illustrated in figure V. This programme, though clearly satisfying the necessary conditions (1.15), (1.16) and (1.18), does not guarantee condition (1.17). In other words, it is not guaranteed that a programme of capital accumulation lying on the turnpike of figure V will have for $0 \leq t \leq T$, a feasible savings ratio $0 \leq s_t \leq 1$.

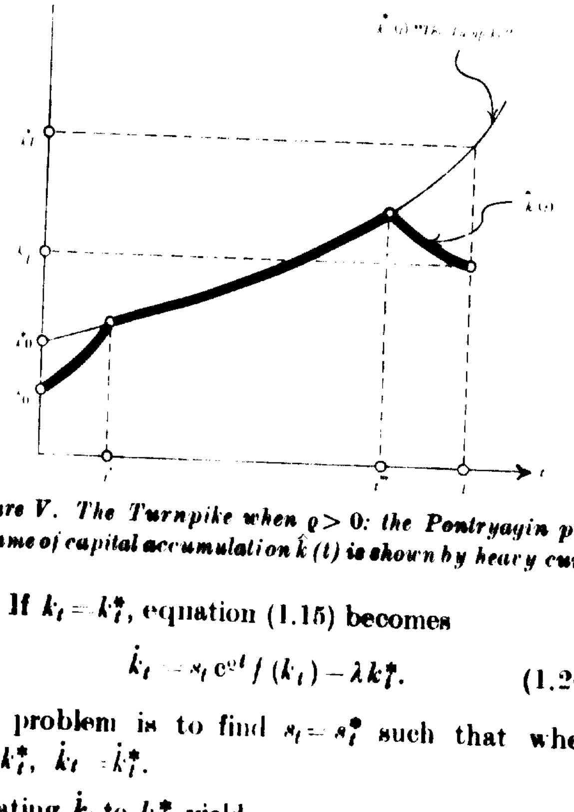


Figure V. The Turnpike when $\varrho > 0$: the Pontryagin programme of capital accumulation $\hat{k}(t)$ is shown by heavy curve

If $k_t = k^*_t$, equation (1.15) becomes

$$\dot{k}_t = s_t e^{\varrho t} f(k_t) - \lambda k^*_t. \qquad (1.26)$$

The problem is to find $s_t = s^*_t$ such that when $k_t = k^*_t$, $\dot{k}_t = \dot{k}^*_t$.

Equating $\dot{k}_t$ to $\dot{k}^*_t$ yields

$$s^* e^{\varrho t} f(k^*_t) - \lambda k^*_t = \frac{\varrho(\delta + \lambda) e^{-\varrho t}}{f''(k^*_t)}$$

from (1.25) and (1.26). Or re-writing

$$s^*_t = \frac{\lambda k^*_t}{e^{\varrho t} f(k^*_t)} - \frac{\varrho(\delta + \lambda)}{e^{2\varrho t} f(k^*_t) f''(k^*_t)} > 0 \text{ for } \varrho > 0. \qquad (1.27)$$

This is the common-sense result that to achieve a programme of positive capital accumulation requires a positive savings fraction. However, (1.27) does not guarantee that $s^*_t \leq 1$ for $\varrho > 0$. To see this, consider the case where the production function is linear-logarithmic in capital and labour, $y_t = e^{\varrho t} k^a_t$. Let $0 < a < 1$ so that a is capital's share of output in a competitive economy and the production function is Cobb-Douglas. For the Cobb-Douglas case

$$k^*_t = \left[\frac{a e^{\varrho t}}{\delta + \lambda}\right]^{1/b},$$

and

$$\dot{k}^*_t = \frac{\varrho}{b}\left[\frac{a e^{\varrho t}}{\delta + \lambda}\right]^{1/b},$$

where b is defined by $b = 1 - a$. For the Cobb-Douglas case, therefore,

$$s^* = \frac{a m}{b(\delta + \lambda)},$$

where m is defined by $m = \lambda b + \varrho$. For the Cobb-Douglas case s^* is independent of time and greater than zero, but whether s^* is less than, equal to, or greater than one depends upon the values of the parameters $a, \varrho, \lambda, \delta$.[14]

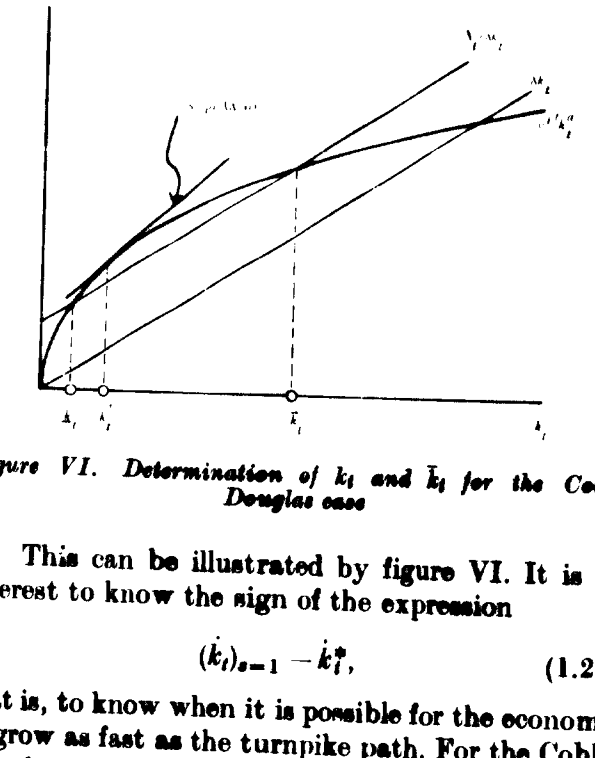


Figure VI. Determination of k_t and $\bar{k}_t$ for the Cobb-Douglas case

This can be illustrated by figure VI. It is of interest to know the sign of the expression

$$(\dot{k}_t)_{s=1} - \dot{k}^*_t, \qquad (1.28)$$

that is, to know when it is possible for the economy to grow as fast as the turnpike path. For the Cobb-Douglas case (1.28) reduces to

$$e^{\varrho t} k^a_t - [\lambda k_t + A_t],$$

where $A_t = \frac{\varrho}{b} k^*_t$. Figure VI illustrates the case where $0 < s^* < 1$. In that case setting expression

[14] Consider the "familiar economy" where $a = 0.30$, $\lambda = n + \mu = 0.10$, and $\varrho = 0.03$. If the planning board's rate of discount $\delta = 0.05$, then $s^* = 2/7 < 1$. Hence, if the "familiar economy" achieves the capital-labour ratio $k^*(t)$ at time t, then it can maintain the turnpike capital-labour ratio. It is not surprising that s^* is independent of t for Cobb-Douglas functions. Since technical change is labour-augmenting in this case, to remain on the turnpike it is required that the capital-labour ratio measured in efficiency units be held constant.

(1.28) equal to zero and holding t fixed yields an equation with exactly two positive solutions $\underline{k}_t$ and $\bar{k}_t$. If $k_t < \underline{k}_t$ the maximum (current!) growth rate for the economy is less than k_t^*.

It is important to establish that if $k_0 < k^*(0)$, then $0 < t^* < \infty$. For the special Cobb-Douglas case with $0 < s^* < 1$, t^* can be calculated and shown to be finite. For the special case, (1.15) is integrated to yield

$$k = e^{-\lambda t}\left\{k_0^b - \frac{bs}{m} + \frac{bs}{m}e^{mt}\right\}^{1/b}, \qquad (1.29)$$

when $k_0 > 0$. When $k_0 \leq k^*(0)$, t^* is the root to the equation $(k)_{s=1} = k^*$. That is, solve

$$\left[\frac{b}{m} - k_0^b\right]e^{-\lambda bt} = \left[\frac{b}{m} - \frac{a}{\delta+\lambda}\right]e^{\varrho t}$$

to yield

$$t^* = \frac{1}{m}\log\left[\frac{1 - \frac{mk_0^b}{b}}{1 - s^*}\right], \text{ when } k_0 \leq k^*(0). \qquad (1.30)$$

Since $(1 - s^*)$ is assumed to be positive, t^* will be real if and only if

$$\frac{mk_0^b}{b} \leq 1.$$

But t^* will be non-negative if and only if

$$\frac{mk_0^b}{b} \leq s^* < 1. \qquad (1.31)$$

(1.31) can be re-written as

$$k_0 \leq \left[\frac{a}{\delta+\lambda}\right]^{1/b} = k^*(0). \qquad (1.32)$$

Since the logarithm is a single-valued function, (1.32) says that $t^* = 0$ when $k_0 = k^*(0)$ and that if $k_0 < k^*(0)$, then $0 < t^* < \infty$ is the unique solution to (1.30). Of course, if $k_0 > k^*(0)$, (1.30) has no non-negative solutions.

Returning to the case of general neoclassical production, an example of a Pontryagin programme of capital accumulation is presented in figure V. In drawing this figure it is implicitly assumed that $0 < t^* < t^{**} < T$ and therefore that $s^*(t) \leq 1$ for $t^* < t < t^{**}$. It is further assumed that $\hat{q}(T) \geq 0$ when $\hat{k}(T) = k_T$.

The general case where s^* changes with time presents a sophisticated mathematical difficulty. If the number of switches from $s^* < 1$ to $s^* > 1$ and vice versa is sufficiently large it may be impossible to find a piece-wise continuous control $s(t)$ satisfying (1.15)–(1.18). If no such control exists, then no maximum to (1.10) exists.[15]

[15] If the class of admissible controls $\{0 \leq s(t) \leq 1;\ 0 \leq t \leq T\}$ is restricted to be piece-wise continuous, then a maximum to (1.10) exists if and only if the number of such switches in $[0, T]$ is finite. Therefore if s^* is an analytic function of t, then a maximum to (1.10) exists.

In the previous sections programmes satisfying necessary conditions (1.15)–(1.18) are referred to as Pontryagin programmes. It remains to show that the necessary conditions are also sufficient, and that such programmes are indeed optimal.[16]

Let $\{\hat{c}(t), \hat{z}(t), \hat{k}(t), \hat{q}(t), \ldots\}$ be a programme satisfying conditions (1.15)–(1.18). Let $\{c(t), z(t), k(t), q(t), \ldots\}$ be any feasible programme, i.e. any programme satisfying (1.11)–(1.14). It is required to show

$$\int_0^T (\hat{c} - c)\, e^{-\delta t}\, dt \geq 0. \qquad (1.33)$$

The LHS of (1.33) can be rewritten in the form

$$\int_0^T e^{-\delta t}\, dt\, \{(\hat{c} - c) + \\ + \hat{\gamma}[(e^{\varrho t} f(\hat{k}) - \hat{z} - \hat{c}) - (e^{\varrho t} f(k) - z - c)] + \\ + \hat{q}\,[(\hat{z} - \lambda\hat{k} - \dot{\hat{k}}) - (z - \lambda k - \dot{k})]\},$$

which reduces to

$$\int_0^T e^{-\delta t}\, dt\, \{(1 - \hat{\gamma})(\hat{c} - c) + (\hat{q} - \hat{\gamma})(\hat{z} - z) \\ + \hat{\gamma} e^{\varrho t}[f(\hat{k}) - f(k)] + \hat{q}\,[\lambda(k - \hat{k}) + (\dot{k} - \dot{\hat{k}})]\}. \qquad (1.34)$$

Notice that

$$(1 - \hat{\gamma})(\hat{c} - c) \geq 0 \text{ and } (\hat{q} - \hat{\gamma})(\hat{z} - z) \geq 0.$$

Therefore (1.34) is not less than the following expression

$$\int_0^T e^{-\delta t}\, dt\, \{\hat{\gamma} e^{\varrho t}[f(\hat{k}) - f(k)] + \hat{q}\,[\lambda(k - \hat{k}) + \\ + (\dot{k} - \dot{\hat{k}})]\}. \qquad (1.35)$$

But since $f(\cdot)$ is a concave function, (1.35) is not smaller than

$$\int_0^T e^{-\delta t}\, dt\, \{\hat{\gamma} e^{\varrho t}[(\hat{k} - k) f'(\hat{k})] + \\ + \hat{q}\,[\lambda(k - \hat{k}) + (\dot{k} - \dot{\hat{k}})]\}.$$

By collecting terms the expression above yields

$$\int_0^T \hat{q}\, e^{-\delta t}(\dot{k} - \dot{\hat{k}})\, dt + \int_0^T e^{-\delta t}\, dt\, (\hat{k} - k)\{\hat{\gamma} e^{\varrho t} f'(\hat{k}) - \hat{q}\lambda\}. \qquad (1.36)$$

[16] It is essential to impose some measurability requirement upon the set of admissible controls $\{0 \leq s(t) \leq 1,\ 0 \leq t \leq T\}$. If, as implied by (1.17), attention is restricted to those controls which are piece-wise continuous, then integration performed in (1.10) and (1.33)–(1.38) is to be interpreted in the sense of Stieltjes. On the other hand, if attention is restricted to Lebesgue measurable controls, then the integration in (1.10) and (1.33)–(1.38) is to be interpreted in the sense of Lebesgue.

Integrating the first term in (1.36) by parts yields

$$\hat{q}(T)\,e^{-\delta T}\{k(T)-\hat{k}(T)\}-\hat{q}_0\{k(0)-\hat{k}(0)\}-$$
$$-\int_0^T (k-\hat{k})(\dot{\hat{q}}-\delta\hat{q})\,e^{-\delta t}\,dt. \qquad (1.37)$$

Transversality condition (1.18) says that the first term in (1.37) is non-negative. Since every feasible path must satisfy the given initial condition k_0, the second term in (1.37) is identically zero. Hence

$$\int_0^T \hat{q}\,e^{-\delta t}(\dot{k}-\dot{\hat{k}})\,dt \geq -\int_0^T (k-\hat{k})(\dot{\hat{q}}-\delta\hat{q})\,e^{-\delta t}\,dt. \qquad (1.38)$$

Hence (1.36) is not smaller than

$$\int_0^T e^{-\delta t}dt[(\hat{k}-k)\{\hat{\gamma}e^{\varrho t}f'(\hat{k})-\lambda\hat{q}\}+(\hat{k}-k)(\dot{\hat{q}}-\delta\hat{q})]=$$
$$=\int_0^T e^{-\delta t}dt\,(\hat{k}-k)\{\dot{\hat{q}}-(\delta+\lambda)\hat{q}+\hat{\gamma}e^{\varrho t}f'(\hat{k})\}$$

which by (1.16) and (1.17) is identically zero. Hence optimality requirement (1.33) is established. In fact, if $k\neq\hat{k}$ on some interval then inequation (1.33) is strict.

2. Models of economic growth and education

In the previous section some of the simplest descriptive and planning models of economic growth with exogenous technical change have been treated. The shortcoming of such models is that one of the quantitatively most important ingredients of growth is left unexplained and thus is ostensibly beyond the control of policy makers. In this section I shall critically examine two models of growth in which technical progress is the endogenous result of improving labour force quality.

The first model is that of Hirofumi Uzawa.[17] He postulates that current productive output $Y(t)$ depends upon the current level of the capital stock $K(t)$, the current allocation of workers to production $L_P(t)$, and the current efficiency $A(t)$ of the labour force:

$$Y(t)=F[K(t),A(t)L_P(t)]. \qquad (2.1)$$

It is merely for convenience of analysis that the improvements in labour quality appear in (2.1) in a (Harrod neutral) labour-augmenting manner. There is, of course, no *a priori* reason to identify improvements in labour quality due to education with labour augmenting technical progress.

Next assume that improvement in labour force quality depends upon the ratio of educators to the labour force

$$\dot{A}/A=\varphi(L_E/L), \qquad (2.2)$$

where L_E is the number of educators and $L\geq L_P+L_E$ is the size of the total labour force. It is assumed that the higher the proportion of the labour force employed in education the higher the improvement in labour force efficiency.

$$\varphi'(L_E/L)\geq 0,\ \varphi''(L_E/L)\leq 0 \text{ for } (L_E/L)\in[0,1]. \qquad (2.3)$$

as before

$$\left|\begin{array}{c}\dot{L}=nL,\\ Z+C=Y,\\ \dot{K}=Z-\mu K.\end{array}\right| \qquad (2.4)$$

The planning board inherits at time zero stocks $K(0)$, $L(0)$, and $A(0)$. As before define:

$$y=Y/L,\ k=K/L,\ u=L_P/L,\ s=Z/Y. \qquad (2.5)$$

The optimal accumulation problem (over the infinite planning period) is to maximize the functional

$$\int_0^\infty (1-s)\,y\,e^{-\delta t}dt, \text{ where } \delta>0, \qquad (2.6)$$

subject to:

$$\dot{k}=sy-\lambda k, \qquad (2.7)$$
$$\dot{A}=A\varphi(1-u), \qquad (2.8)$$
$$y=Auf\left(\frac{k}{Au}\right), \qquad (2.9)$$
$$s\in[0,1],\ u\in[0,1], \qquad (2.10)$$

where δ, $\lambda=n+\mu$, $k(0)=(K(0)/L(0))$ are given constants and u and s are piece-wise continuous controllers.

The Hamiltonian for this problem is

$$e^{-\delta t}\left\{(1-s)Auf\left(\frac{k}{Au}\right)+q\left[sAuf\left(\frac{k}{Au}\right)-\lambda k\right]+\right.$$
$$\left.+vA\varphi(1-u)\right\}. \qquad (2.11)$$

Thus the optimal programme must be such that

$$\dot{v}=(\delta-\varphi)v-\gamma u\left[f\left(\frac{k}{Au}\right)-\frac{k}{Au}f'\left(\frac{k}{Au}\right)\right], \qquad (2.12)$$
$$\gamma=\max(1,q), \qquad (2.13)$$
$$\lim_{t\to\infty} qe^{-\delta t}=0=\lim_{t\to\infty} ve^{-\delta t}. \qquad (2.14)$$

Uzawa shows that (2.7)–(2.13) imply that the

[17] H. Uzawa, "Optimal Technical Change in an Aggregative Model of Economic Growth", *International Economic Review*, Vol. 6, No. 1, Jan. 1965, pp. 18–31. Although the formal model discussed here is that of Uzawa, the economic interpretations of it are not necessarily his.

unique optimal trajectory tends to the balanced state given by the starred variables which solve:

$$\left.\begin{aligned} &\varphi(1-u^*)+u^*\varphi'(1-u^*)=\delta, \\ &f'\left(\frac{x^*}{u^*}\right)=\delta+\lambda, \\ &f\left(\frac{x^*}{u^*}\right)-\frac{x^*}{u^*}f'\left(\frac{x^*}{u^*}\right)=v^*\varphi'(1-u^*), \\ &\frac{s^*f\left(\frac{x^*}{u^*}\right)}{\frac{x^*}{u^*}}=\lambda+\varphi(1-u^*), \end{aligned}\right\} \quad (2.15)$$

where $x^* \equiv \frac{k^*}{A^*}$.

Now that the formal educational planning model has been examined, let us re-examine its basic premises. Apart from the usual difficulties that come from the one sector production formulation (2.1) and the "vulgar" maximand (2.6) the Uzawa model above does not allow for the substitution of capital for labour in the education sector. Perhaps this is appropriate for planning in the context of underdeveloped societies; it is certainly a very limiting assumption for planning educational effort in the so-called advanced economies. Further, the above formulation assumes that although transmission of knowledge (education) to the labour force is costly, there is no way available to produce new technological knowledge.[18]

The second model of education and economic growth that I will treat in this section is due to Nelson and Phelps.[19] In their model the role of education is thought to be primarily that of facilitating the flow of technological information. My interpretation of education in the Uzawa model is the process of transmitting already known technological information to the labour force. The distinction between this view and that of Nelson-Phelps is rather subtle. Nelson-Phelps thinks of education as the process of training the productive actors in the economy to receive and "decode" the technological information that is being transmitted by other sectors in the economy.

In the Nelson-Phelps model production is given as in (2.1) except that the entire labour force is engaged in production, i.e. $L_P = L$, or

$$Y = F(K, AL). \quad (2.1^*)$$

The notion of the theoretical level of technology at time t, $R(t)$, plays an important role in the model. If all "best practice" technological knowledge were available to all economic agents then $R = A$. When this is not the case $A < R$.

In its most interesting formulation the Nelson-Phelps model has

$$\dot{A} = (R - A)\,\psi(h), \quad (2.16)$$

where h is a measure of the educational attainment of society and $\psi(0) = 0$, $\psi'(h) > 0$ for $h > 0$. According to hypothesis (2.16) the rate of increase of the technology in practice is an increasing function of educational attainment and is proportional to the "gap" $(R - A)$.

Following the Schumpeterian hypothesis that inventions do not depend upon other economic variables it can be assumed that R grows at the constant relative rate $\varrho > 0$,

$$\dot{R} = \varrho R. \quad (2.17)$$

If h is a positive constant, then the system (2.1*), (2.16) and (2.17) has the solution

$$A = \left(A_0 - \frac{\psi}{\psi+\varrho} R_0\right) e^{-\psi t} + \frac{\psi}{\psi+\varrho} R_0 e^{\varrho t}. \quad (2.18)$$

Therefore the long-run equilibrium path of technology in practice $A^*(t)$ is given by

$$A^*(t) = \left(\frac{\psi(h)}{\psi(h)+\varrho}\right) R_0 e^{\varrho t}, \quad (2.19)$$

so that the gap between A and R tends to a long-run constant for constant h.

In the Nelson-Phelps model not only is "technical progressiveness of the economy" (the time path of R) left outside the model but (even more important) the determination of the level of technical education h (or its time path) is left as a datum.[20] In what follows I construct an educational planning model that requires scarce resources to be devoted to the educational sector in order to increase educational attainment h. The model may be thought of as a synthesis of the Nelson-Phelps and the Uzawa models.

Assume that productive output[21] per worker can be written as

$$y = A u f\left(\frac{x}{u}\right), \quad (2.20)$$

where $u \in [0, 1]$ is the fraction of the labour force to be employed in production, A is the "digested"

[18] Production of new technological knowledge in enterprise and planned economies is the theme of two papers by the present author, K. SHELL, "Toward a Theory of Inventive Activity and Capital Accumulation", *American Economic Review*, May 1966, pp. 62–69; "A Model of Inventive Activity and Capital Accumulation", *Essays on the Theory of Optimal Economic Growth*, op. cit.

[19] R. R. NELSON and E. S. PHELPS, "Investment in Humans, Technological Diffusion and Economic Growth", *American Economic Review*, May 1966, pp. 69–75.

[20] In an unpublished Cowles Foundation discussion paper Phelps solves for the golden rule level of educational attainment.

[21] Assuming, of course, that there is no curvature to the production possibility frontier in consumption-investment space.

stock of technical knowledge, and x is the capital-labour ratio in labour efficiency units. Assume that labour force growth is zero so that we can choose units such that $L = 1$.

Assume further that increase in the educational attainment of the labour force is an increasing function of the fraction of the labour force engaged in education.

$$\dot{h} = \varphi[(1 - u) L] \tag{2.21}$$

with $\varphi' > 0$, $\varphi'' < 0$, and $\varphi(0) < 0$. Capital accumulation follows

$$\dot{K} = sF(K, AuL) - \mu K, \tag{2.22}$$

where $\mu > 0$. The law (2.16) governing the growth of technology in practice can be rewritten as

$$\frac{\dot{A}}{A} = \left[\frac{R - A}{A}\right] \psi(h). \tag{2.23}$$

Suppose that the planning board desires to maximize the functional

$$\int_0^\infty U\left[(1 - s) A u f\left(\frac{x}{u}\right)\right] e^{-\delta t} dt. \tag{2.24}$$

(2.24) is merely the discounted integral of utility of *per capita* consumption, since x is defined by $x = K/AL$. $\delta > 0$ is the planners' subjective rate of ime discount. Suppose further that $U' > 0$, $U'' < 0$, and $U'[0] = \infty$ so that consumption will always be positive along an optimal programme. It is convenient to consider the Hamiltonian H defined by

$$He^{\delta t} = U\left[(1 - s) A u f\left(\frac{x}{u}\right)\right] + q\left\{s A u f\left(\frac{x}{u}\right) - \mu k\right\} + v\{\psi(h)(R_0 e^{\varrho t} - A)\} + w\varphi[(1 - u)]. \tag{2.25}$$

Choosing utility as the *numéraire*, q is the social demand price of investment, v is the social demand price of technology in practice, and w is the demand price of educational attainment as measured by h. H is therefore the present social value of net national product at time t. Maximization of GNP with respect to the controllers $s(t) \varepsilon [0, 1]$ and $u(t) \varepsilon [0, 1]$ yields

$$U' \geq q, \text{ with equality when } s > 0, \tag{2.26}$$

and

$$U' \geq wq, \text{ with equality when } u < 1. \tag{2.27}$$

A programme of development maximizes the integral (2.24) subject to the technological constraints (2.4), (2.20)–(2.23) if there exist continuous prices $q(t)$, $v(t)$ and $w(t)$ such that

$$\dot{q} = (\delta + \mu) q - f'\left(\frac{x}{u}\right) U' \tag{2.28}$$

$$\dot{v} = (\delta + \psi) v - u\left\{f\left(\frac{x}{u}\right) - \frac{x}{u} f'\left(\frac{x}{u}\right)\right\} U' \tag{2.29}$$

$$\dot{w} = \delta w - v\psi'(h)[R - A] \tag{2.30}$$

while (2.4), (2.20)–(2.23), and (2.26)–(2.27) hold.

Condition (2.26) says that when investment in physical capital is positive, the marginal utility of consumption must equal the social demand price for investment. Condition (2.27) says that when educational effort is positive, the marginal utility of consumption must be equal to the social demand valuation of the marginal contribution to increase in educational attainment due to added educational effort.

Differential equation (2.28) says that the demand valuation of physical capital must change in a way so as just to compensate for losses due to depreciating the "waiting" net of the social demand value of physical capital's marginal product. Differential equation (2.29) says that the demand valuation of technical knowledge in practice must change so as just to compensate for losses due to narrowing the gap between available technology and technology in practice plus "waiting" net of the value of the marginal product of available technical knowledge. The path of the shadow valuation $v(t)$ is inconsequential in the sense that all allocation decisions are independent of the value assigned to $v(t)$. This is because, given h, R, and A, the value of $\dot{A}$ is uniquely determined.

On the other hand, as evidenced by condition (2.27), $w(t)$ plays an essential role in allocation. Differential equation (2.30) says that the social demand valuation of education attainment must change in order to just compensate for "waiting" less the value of the marginal contribution to increasing technological knowledge in practice.

To the above system we must append the boundary conditions

$$x(0) = x_0,\ R(0) = R_0,\ A(0) = A_0,\ h(0) = h_0. \tag{2.31}$$

That is, that the initial values of stock variables are given to the planning board. In addition we must append the necessary terminal transversality conditions

$$\lim_{t \to \infty} q e^{-\delta t} = \lim_{t \to \infty} v e^{-\delta t} = \lim_{t \to \infty} w e^{-\delta t} = 0. \tag{2.32}$$

That is, we require for optimality that the present value of all stocks tend to zero.

Next we observe that the necessary system of differential equations possesses a unique stationary solution provided production satisfies the Inada conditions.

$$f(x) > 0,\ f'(x) > 0,\ f''(x) < 0 \text{ for } 0 < x < \infty$$

$$f(0) = 0,\ f'(0) = \infty,$$

$$f(\infty) = \infty\ f'(\infty) = 0$$

Remembering that $L=1$, let $u^\dagger$ be the unique stationary to (2.21), i.e.

$$\varphi(1-u^\dagger)=0. \qquad (2.33)$$

For $u=u^\dagger$ there is one and only one value x that yields a stationary to (2.28) with $U'=q$. Define $x^\dagger$ by

$$f'\left(\frac{x^\dagger}{u^\dagger}\right)=\delta+\mu. \qquad (2.34)$$

Given $u^\dagger$ and $x^\dagger$, then $h^\dagger$ is the unique value for which (2.29) is stationary when $U'=v$,

$$\delta+\psi(h^\dagger)=u^\dagger\left\{f\left(\frac{x^\dagger}{u^\dagger}\right)-\frac{x^\dagger}{u^\dagger}f'\left(\frac{x^\dagger}{u^\dagger}\right)\right\}. \qquad (2.35)$$

Again for $q=v=w=U'$, and given $x^\dagger, u^\dagger$, and $h^\dagger$, we can solve for $[R-A]^\dagger$ as the unique stationary to (2.30), i.e.

$$[R-A]^\dagger=\frac{\delta}{\psi'(h^\dagger)}>0. \qquad (2.36)$$

Thus for the above economy the optimal trajectory is such that it tends to the capital-labour ratio $x^\dagger$ (in efficiency units) independent of initial endowments. In long-run optimal growth the gap $[R-A]$ between the theoretical technology and the available technology remains constant while the capital-labour ratio in natural units declines.

3. THEORIES OF THE INDUCED BIAS OF TECHNOLOGICAL CHANGE

In section 1, naive models of Hicks-neutral exogenous technological change were treated, and in section 2, models of education in which the induced technological change was specified to be labour-augmenting (and thus Harrod-neutral).[22] I have posited elsewhere[23] that technological change induced by inventive activity is of the Hicks-neutral form.

This specification of how the volume of inventions, the education of labour, or the learning-by-doing of entrepreneurs affects production functions is a rigid carry-over from capital theory. Certainly if there is an economic choice as to how much technological change a society should seek, there must be an economic choice amongst different types of technological change. A planner or an entrepreneur must be faced with a choice between "labour-saving" and "capital-saving" technological change.[24] This choice must be crucial both in explaining the direction of progress in enterprise economies and in planning research and development, educational policy, etc. in centrally directed economies.

Recently there have been a number of contributions to the theory of economic growth that are addressed to this point.[25] Underlying these models is a construction like the invention possibility frontier (IPF). If output is given by

$$Y=F(BK, AL) \qquad (3.1)$$

then society (or, as some authors have claimed, the entrepreneurs) faces an IPF characterized by g (.) where

$$\frac{\dot B}{B}=g\left(\frac{\dot A}{A}\right) \qquad (3.2)$$

with $g'<0$ and $g''<0$. This means that between labour-augmenting and capital-augmenting technical change a trade-off exists independent of other economic variables. In particular it is assumed that the rate of technical progress is independent of the economic resources devoted to invention and education. As before,

$$\dot K=sY-\mu K \qquad (3.3)$$

with $\mu>0$. Define the ratios:

$$\begin{cases} y=Y/L, \\ k=K/L, \\ x=BK/AL. \end{cases} \qquad (3.4)$$

Then (3.1) reduces to

$$y=Af(x) \qquad (3.5)$$

[22] The main reason that certain specifications of the bias (or neutrality) of technological change are made is for their convenience in modelling. There is, for example, no *a priori* reason to expect that the technological progress resulting from increased education is labour augmenting. This may be the case, but it may also not be the case. Of course, if labour comes in "vintages" it may be natural to specify that educationally induced technological change is labour embodied.

[23] K. SHELL, "Towards a Theory of Inventive Activity and Capital Accumulation", *American Economic Review*, May 1966, pp. 62–69, and K. SHELL, "A Model of Inventive Activity and Capital Accumulation" in K. SHELL (ed.), *Essays on the Theory of Optimal Economic Growth*, op. cit.

[24] Such a choice between "labour-saving" and "capital-saving" change is crucial to the theories due to Hicks and Fellner of innovation in enterprise economies (J. R. HICKS, *The Theory of Wages*, Macmillan, 1932 [Ch. 6]; W. J. FELLNER, "Two Propositions in the Theory of Induced Innovations", *Economic Journal*, Vol. 71, June 1961).

[25] See C. KENNEDY, "Induced Bias in Innovation and the Theory of Distribution", *Economic Journal*, Sept. 1964; P. A. SAMUELSON, "A Theory of Induced Innovation along Kennedy-Weizsäcker Lines", *Review of Economics and Statistics*, Vol. 47, No. 4, Nov. 1965; E. M. DRANDAKIS and E. S. PHELPS, "A Model of Induced Invention, Growth and Distribution", Cowles Foundation Discussion Paper No. 186; W. D. NORDHAUS, "The Optimal Rate and Direction of Technological Change", in K. SHELL (ed.), *Essays on the Theory of Optimal Economic Growth*, op. cit. The treatment that follows has benefited from Nordhaus' paper and discussions with him.

and (3.3) reduces to

$$\dot{k} = sAf(x) - \lambda k \tag{3.6}$$

where $\lambda = \mu + n$, where $n = \dot{L}/L$ is the relative rate of growth of the labour force.

In treating such a model for the representative firm in a competitive economy, one is skating on thin ice. In the enterprise economy it seems that the most important feature of technical knowledge as a commodity is its inexpensive re-use. Therefore, in treating enterprise economies the fact has to be faced that most of the firm's technical knowledge will be "imported" at typically very low cost.

The planning problem is, however, much easier to specify. Assume that it is desired to maximize a functional of the form

$$\int_0^\infty U\,[(1-s)\,Af(x)]\,e^{-\delta t}\,dt \tag{3.7}$$

where $\delta > 0$ and $U' > 0$, $U'' < 0$, $U'(0) = \infty$. That is, it is desired to maximize the discounted integral of utilities of *per capita* consumption.

In order to apply the maximum principle, construct the Hamiltonian H which is defined by

$$He^{\delta t} = U\left[(1-s)\,Af\left(\frac{kB}{A}\right)\right] + q\left\{sAf\left(\frac{kB}{A}\right) - \lambda k\right\} + \\ + ve^{zt} g(\beta)\,B + w\beta A \tag{3.8}$$

where

$$\beta = \dot{A}/A. \tag{3.9}$$

If a feasible programme maximizes (3.7) then there must exist continuous prices $q(t)$, $v(t)$, and $w(t)$ such that:

$$\dot{q} = (\delta + \lambda)\,p_1 - Bf'(x)\,U' \tag{3.10}$$

$$\dot{v} = (\delta - z - g)\,v - ke^{-zt} f'(x)\,U' \tag{3.11}$$

$$\dot{w} = (\delta - \beta)\,w - \{f(x) - xf'(x)\}\,U', \tag{3.12}$$

where

$$U'\left[(1-s)\,Af\left(\frac{kB}{A}\right)\right] \geq q \tag{3.13}$$

with equality when $s > 0$. Following Nordhaus we introduce the shadow price of A in the form $ve^{(z-\delta)t}$. Maximization of GNP (3.8) implies that

$$vg'(\beta)\,Be^{zt} + wA = 0. \tag{3.14}$$

It is further required that the system satisfy the boundary conditions:

$$k(0) = k_0,\; B(0) = B_0,\; A(0) = A_0 \tag{3.15}$$

of historically given stocks and the appropriate transversality conditions

$$\lim_{t\to\infty} qe^{-\delta t} = \lim_{t\to\infty} e^{(z-\delta)t}\,v(t) = \lim_{t\to\infty} e^{-\delta t}\,w(t) = 0. \tag{3.16}$$

If we indicate the stationary value of x (etc.) by x^* (etc.) then stationaries are found by solving

$$g'(\beta^*) = -\frac{1-\alpha^*}{\alpha^*}, \tag{3.17}$$

$$B^* f'(x^*) = \delta + \lambda, \tag{3.18}$$

$$\beta^* = z, \tag{3.19}$$

$$s^* = \left(\frac{\lambda + z}{\lambda + \delta}\right)\alpha^*, \tag{3.20}$$

where α^* is the equilibrium share of capital

$$\alpha^* = \frac{x^* f'(x^*)}{f(x^*)}. \tag{3.21}$$

If the elasticity of substitution

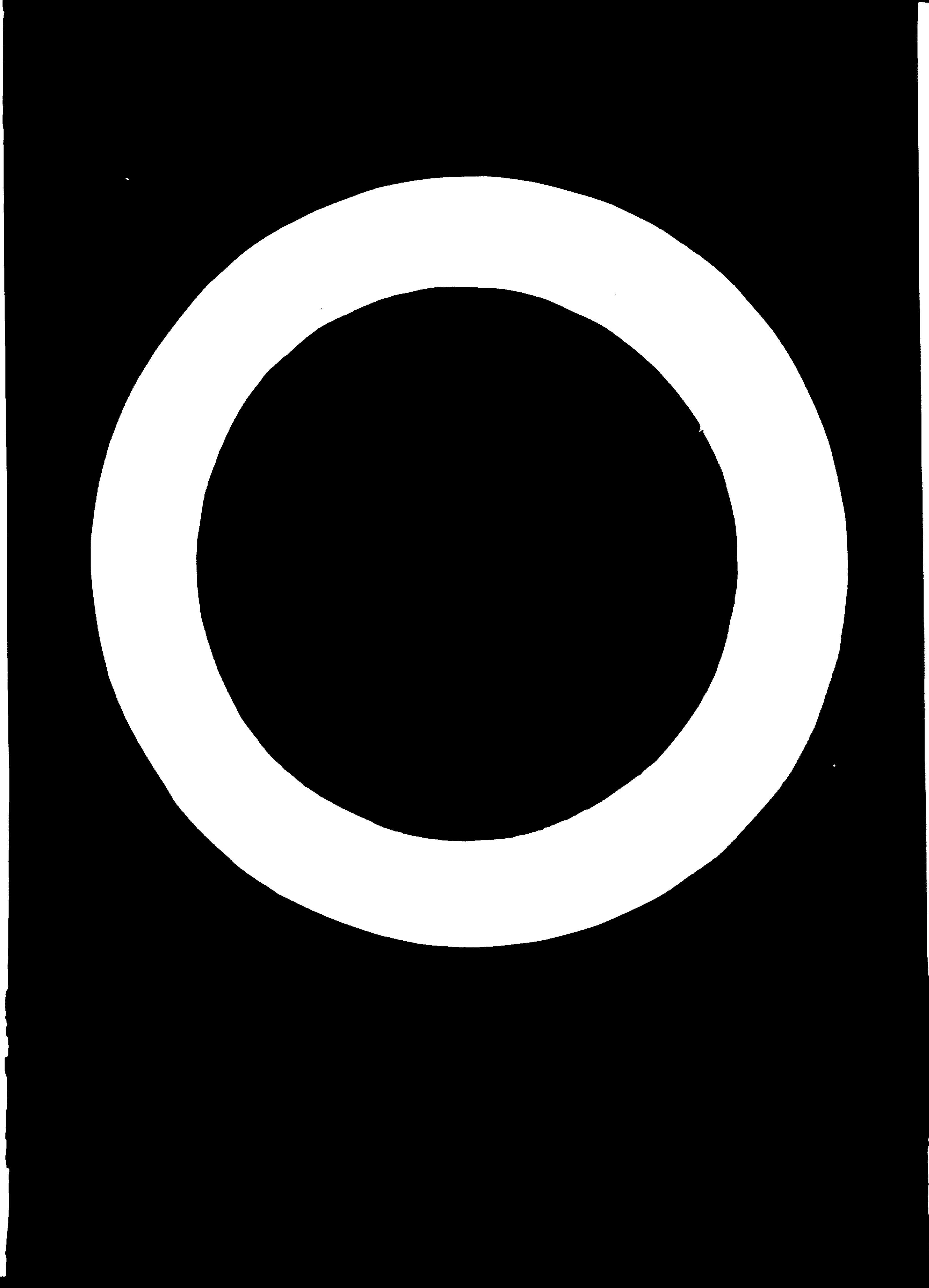
$$\sigma = \frac{-f'[f - xf']}{xff''}$$

is less than unity and if $\delta > z$ then a (forever) stationary programme is seen to satisfy all necessary and feasibility conditions.

In concluding this section, some comments are in order. We have sketched out some basic properties of the planner's optimal programme of capital accumulation and choice of the bias of technical change. We are thus left with only a partial analysis, since we have not investigated the possibility of simultaneous acceleration of technological progress by way of devoting economic resources to inventive activity. It is toward such an integration that future research in this area should proceed.

Part Three

INDUSTRIAL MANPOWER PLANNING



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PLANNING METHODS FOR SKILL REQUIREMENTS AND PRODUCTIVITY CHANGE

George Cukor, Institute of Economics, Budapest, Hungary

1. PLANNING AND INDUSTRIALIZATION IN OVER-ALL ECONOMIC GROWTH

ECONOMIC GROWTH is at present a major preoccupation of governments and of public opinion. Growth in the developing countries is, in particular, a central issue in the history of our period. The importance of economic development is not limited to the countries of Africa, Asia and Latin America, for the socialist countries, with social ownership of the means of production have set economic development (and even a high rate of economic development) as one of their basic goals. It is—perhaps viewed from a somewhat different angle—also a cardinal question for industrially developed "western" countries, where the economy is based on private ownership of the means of production.

Industrial development is an indispensable part—at the same time a precondition and a consequence—of economic development. Its importance appears, however, in a different manner in each of the three groups of countries mentioned above. The developing countries are, in general, at an initial stage of industrialization. Together with the diversification and technical development of their whole economy, one of the very conditions of their economic growth is industrialization and, in particular, the development and the increase of the share of manufacturing industries. (The greater part of industrial development in the Soviet Union took place after the 1920's and in the other European socialist countries after the late 1940's. Industry, however, still receives particular attention in these countries both for the material goods it is expected to deliver and for its impact on the technical development of the economy as a whole.) The developed western countries had already achieved high levels of industrial development at the beginning of this century. Industry (or more exactly certain industrial sectors) however is still the most dynamic part of their economy.

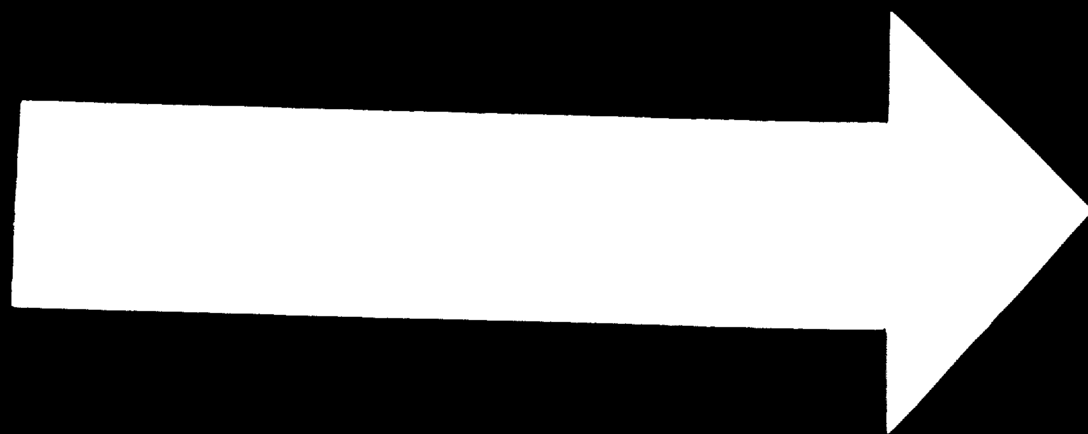
The general recognition of this central role of industrialization, in particular as far as the developing countries are concerned, is rather recent. It used to be widely held that the economic growth of the less-developed countries would be brought about not so much by modernization and structural change of their economy—an important part of which is industrialization—as by "comparative advantage" operating through the international division of labour. According to this school of thought it was advisable for the developing countries to specialize in the production of agricultural and mineral raw materials, where they had particular advantages, and to purchase industrial goods—for the production of which their situation was not favourable—as a counterpart of exported raw materials. There was therefore no need for any particular industrialization policies; the market and the free play of prices would lead in the shortest time to the best economic structure within any country, as well as internationally. This type of reasoning, however, is scarcely sustained today (anyhow not in its pure form) and industrialization has come into its full rights.

Only fairly recently has there been some unanimity not to leave economic growth, at least in the less developing countries, to the spontaneous operation of economic forces, but to work out and implement well-defined development policies through economic planning. Economic planning is not limited to the developing countries; the economic development of socialist countries is based on planning, and more or less detailed plans are worked out also in an increasing number of western countries.

Economic development, industrialization and economic planning are therefore closely interrelated. In the course of practical planning and theoretical research in this field, the chief emphasis is placed on the planning of the main aggregated economic indicators such as the national income and its principal components, production and consumption of the main sectors, investments, foreign trade etc. More recently there has been an increased interest in computations concerning the rational allocation of resources: project evaluation, mathematical programming of industrial sectors etc.

2. MANPOWER PLANNING, PRODUCTIVITY AND SKILLS

The importance of manpower planning has only recently come to the fore, together with the recognition that the principal source for the de-



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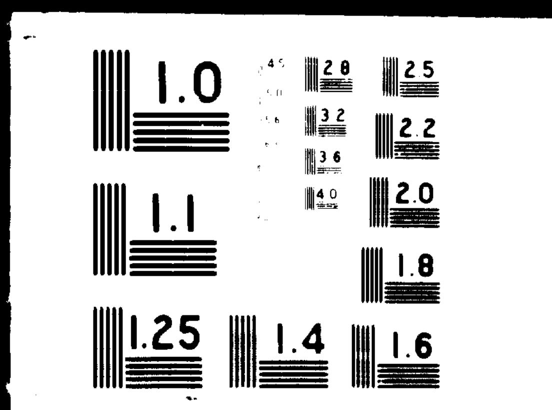

velopment of every country lies in its "human resources".

Economic thinking tended previously to consider investment as the principal moving force of development. Such an attitude is reflected, for example, in growth models like the Harrod-Domar model or in the neoclassical Cobb-Douglas type production functions. In these latter, production appears as a function of capital and labour, increases in productivity being the result only of increases in capital per head. History has not confirmed the validity of this line of thinking on economic growth. Production increased in the long run much faster than could be predicted on the basis of the standard Cobb-Douglas functions. The real change could be better described by more sophisticated production functions, having a residual term in addition to labour and capital. This residual term can be considered as reflecting the increase of skills, technical development, over-all productivity change or the like; it still remains to be precisely described. The importance of the change in the human factors of production is however indisputable and has largely been accepted, like the importance of "human investment", for every country and particularly for those that are developing.

Manpower planning—like every type of planning—has both a formal, static aspect when operating mainly with accounting identities, and a dynamic aspect when dealing with qualitative changes, the substantial part of planning. The purpose of the former is to make projections of the population (including the labour force) and to compare them with manpower requirements in order to control the equilibrium of manpower needs and resources in the plans. This kind of planning is done mainly in the form of balances. It is based on demographic statistics and forecasts, and on an estimation of the changes in the number of the total population and of the population of working age, in the employment of women, in the number of students of working age, and so on.

Planning changes in the quality of manpower is more difficult, for two closely interrelated problems have to be dealt with:

(a) changes in the results of the activity of the labour force and of its efficiency; that is, changes in labour productivity measured in production per man and unit of time (hour or year);

(b) changes in the quality of the labour force, usually measured by the skill composition of manpower.

It is to be noted that the socio-economic phenomenon to be observed and planned is measured and reflected in both cases only in a very imperfect way. As far as productivity is concerned it is well known that labour productivity indicators do not reflect the effectiveness of labour very precisely. There are many statistical imperfections connected with limited comparability when dealing with change of production patterns, price changes etc., particularly for major and more aggregated economic sectors.[1]

As to the true "quality" of manpower, its precise measurement is no more feasible. What we can measure and plan is only the skill composition of the labour force; change in the number and the share within the total of persons having completed elementary, secondary or higher education, and the share of unskilled, semi-skilled and skilled workers or of engineers and technicians in the industrial labour force. Of course, in countries where illiteracy still exists, literacy is also an important indicator of the skill level of the labour force. It is well known that even the unequivocal definition and statistical measurement of illiteracy is a rather difficult task; it is even more difficult to determine with a sufficient degree of exactitude the true quality or skill content of different educational levels. Education that is nominally similar can lead to very different knowledge and skill levels, and skills are influenced not only by education but also by many other factors, including practical experience. However, statistical analyses and planning experience lead one to believe that labour productivity and skill-composition indicators are acceptable approximations of what planners are interested in, namely the efficiency of labour and the quality of manpower. This approximation is acceptable mainly because change is to be planned and the hypothesis of "other conditions being equal" is usually permitted. An increase in labour productivity indicators therefore will usually correctly reflect an increase in efficiency, as well as an increase in the share of university graduates, for example, which reflects an increase in the quality of the labour force. It has to be noted, however, that extreme caution is indicated in making international comparison, which is often necessary for planning. International comparison of productivity is a field in which subjective judgements play an unusually large role. (It cannot be expected, in a comparison of skills between different countries, that the same nominal categories of, for example, skilled workers or technicians cover groups of people having really the same skills.)

[1] Productivity measurement and comparison is a separate branch of economics and statistics, the details of which cannot be elaborated here. Many relevant problems are discussed in DUNLOP-DJATCHENKO, *Labour Productivity*, McGraw-Hill, New York, 1964.

Labour productivity, considered in the most general sense, is the volume of national income per employed person. When employment cannot be increased substantially, or can be increased only in the long run on the basis of population growth, it is evident that economic development will depend on productivity increases. This, or something very similar, is the case in very many of the developed countries. The situation of course is rather different in the developing countries which have considerable unemployment, open or latent; in them, production can also be increased through a substantial increase of employment. It would not be advisable however to raise production only or mainly by an increase of employment and to preserve low productivity levels. This would lead to losses in international competitiveness and to low levels of saving, thus decreasing possibilities of further growth. Developing countries protest—usually rightly—against the advice sometimes given to them to introduce labour-intensive, outmoded production techniques because of the prevailing scarcity of capital and abundance of manpower. (This of course does not mean that the relative scarcity of resources can be ignored and that exactly the same technologies are as appropriate for developing as for developed countries.)

In my opinion the existence of allegedly unlimited labour supplies ought not to lead to a disinterest in the increase of labour productivity and its planning. As to the qualified labour force, its central importance to developing countries is generally accepted. Educational planning is being introduced increasingly even in those developed countries which do not apply economic planning in general. The reason for this is the increasingly obvious importance of education, which can be considered as a kind of non-material infrastructure, the development of which cannot be left to short-term, spontaneous bursts of activity but has to be entrusted to deliberate and long-range government action. There are obvious and easily acceptable interrelations between skills and productivity. An increase of skills is one factor — and in the long run probably the most important—for any increase of productivity. This will hold true, whether literacy is promoted at the lower stage of development or the proportion of highly-qualified engineers and scientists is increased. In addition, higher productivity will lead to a rise in national-income, and thus in turn to the education of more people; in fact better education will be made possible by higher material wealth.

We have already seen that planning may be divided, in a very simplified manner and from the methodological point of view, into two parts. The first is the planning of proportions; that is, of the equilibrium between resources and requirements. The main tool for this planning is the preparation and utilization of balances. The second is the planning of the most rational utilization of resources; that is, the planning of the optimum. This can be done by various means, which range from simple cost-accounting to project evaluation or to the planning of the optimal investment or production pattern of certain branches (or even of the whole economy) by mathematical programming methods and with the use of computers.

In planning with balances—whether power or material balances, or even complex input-output balances—the various resources will show in different dimensions, in different balances, or different rows of the balances. The connection between the different balances will be established by technical coefficients, which thus become an essential part of economic planning.

Labour productivity can be considered as a set of special technical coefficients, which in effect establish connections between the output of different industrial branches and the most general and most important resource, labour. Productivity is the most comprehensive indicator for planners of the rate of growth and the level of the economy; it is the indicator by which comparisons are made between the rates of growth of different industrial branches within the country (taking into consideration the special problems of the different branches), and also between certain branches of industries in different countries.

From the methodological point of view a prerequisite of the planning of equilibrium is that all relevant quantities figure consistently in the plan. This means that the plans have to show the impact of the planned figures of production and employment on productivity, and those of productivity on labour and planning. The connections thus established should serve to check the consistency and realism of the complete plan. The plan of skill-requirements can be considered as containing special productivity coefficients which, depending on the volume of output and on any change in the pattern of production, reflect the requirement of particular skills rather than that of total labour.

This kind of computation is closely related to the accounting aspect of planning. The basic questions are those of planning the change in productivity and in requirements of skilled labour, and the utilization of the latter—questions to which the answers are extremely important and also extremely difficult to find. No really satisfactory method of forecasting changes has yet been found, either in theory or in practice. We know well enough all the factors that have an impact on change in productivity. It could be said in fact that there is hardly any social or economic phenomenon that has no such impact. The quantitative relationship between cause and effect, however, is not sufficiently clear at our present stage of knowledge. The extraordinary complexity of the interconnections is one of the things which impede us when trying to work with unequivocal function-like connexions between cause and effect in the course of planning change in productivity. Planning by analogies—that is, comparisons in time and space—has therefore a great importance.

The difficulties encountered in planning the requirements of skilled labour are somewhat similar; the general trends are known, but there is much uncertainty concerning the quantitative connexions.

Planning could be short-term (in most cases one year), medium-term (3 to 5 years) or long-term (10 to 15 years). The methodological and substantive problems raised by the plans will of course vary according to the planning term. In what follows we shall be dealing only with medium- and long-term plans in connection with the planning of education and training as well as of productivity. There are generally no great changes in productivity within a short period, especially in the more aggregate sectors of economy. As far as change in skilled labour is concerned, longer periods have to be considered, since short-term changes are delimited by the educational and training system in force at the time, and by demographic changes. This of course does not mean that change in productivity or in the distribution of skilled labour between different sectors should be neglected in short-term plans from one year to the next. These problems, however, affect the statistical-accounting aspects of planning rather than the dynamic-qualitative ones.

In the next section we shall discuss, not the technical aspects of planning and its full methodology, but some cardinal methods and interrelationships which it would seem useful to take into account when planning productivity and skill requirements.

3. Planning of productivity

The direct planning of productivity is theoretically possible by planning production and labour requirements, i.e. the total labour time in detail, several years ahead for industry as a whole or for its main sectors. This direct planning is, however, not practicable. The figures used in planning are average productivities. The figures for a factory are averages of several products, those for a branch of industry are averages of several factories, and those for industry as a whole are averages of the several branches. Moreover, since it is usual to operate with productivity figures for a period of a certain length, generally for at least one year, all figures for productivity are average values over a certain period of time. To plan productivity directly, it would be necessary to have full details about the structure of production over the whole planning period. Even the labour requirements of a single product cannot always be directly planned over a period of some length, for they usually depend on the whole production pattern. Moreover, labour input depends on so many technical, economic and social factors that it does not seem possible to foresee every one of them and to plan labour requirements in detail, directly.

It is feasible, however, to plan changes of productivity. It may be assumed that some of the factors affecting production will remain unchanged, or will change but slightly, and it will suffice to investigate those that change and to evaluate their effects.

Productivity plans, like economic plans, are normally based on statistics covering the past, which serve as points of departure.

The initial data are:

(i) Productivity ratios for the "base period" (generally one year), together with information concerning the circumstances under which that particular level of productivity came about, i.e. extremely detailed facts on the structure of production, the technical level, the quality of manpower etc.

(ii) The trend of productivity change for several years before the base period, together with the change of the main factors affecting the development of productivity.

The results of planning largely depend on the quality of these data.

The basic problem here is that industrial sectors are not homogeneous, and usually include products with greatly differing labour requirements. An effort must be made therefore to constitute groups within which the effects of the main factors influencing productivity are similar. This requirement is in general well enough approximated by three digit International Standard Industrial Classification (ISIC) subgroups.

A requirement easier to fulfil—though not always complied with in statistical practice—is that the content of the various groups should be identical or at least identifiable. As labour input is usually measured by plants or enterprises and not by products this means that a particular group (e.g. a branch of industry) should always include the same enterprises, or at least that the effects of changes should be taken into account.

If the development of the factors influencing productivity and the functional connexions between these factors and the level of productivity were precisely known, then changes in the level of productivity could be computed directly without particular difficulty. Unfortunately, neither of these conditions is generally fulfilled. The main factors are known, but only in so far as to whether changes in them tend to increase or to decrease productivity.

The quantitative knowledge to reveal their impact is missing.

Economic literature contains abundant discussions on the factors of change in productivity, or rather on the causes that result in changes in productivity. The following factors or groups of factors taken by and large appear to be most significant:

(a) the quantity and quality of equipment;

(b) the use made of available capacity;

(c) the skill of the workers (quality of the labour force);

(d) welfare and social factors; and

(e) natural factors.

Let us briefly consider what effect each of these factors has on productivity and how their effect on labour productivity can be determined.

(a) The quantity and quality of equipment

It is obvious that productivity is, in the first place, determined by the quantity and the quality of the instruments of production used, largely measured by fixed capital. Among the instruments of production it is the machinery and the tools directly used in production that exercise the greatest and the most direct influence on productivity, for on their technical development depends higher production with the same quantity of labour. This means that changes in labour productivity are directly determined by the development of material-transforming machinery (of machine tools in the wider sense). The development of power equipment also has an important, but indirect, effect.

Unfortunately for productivity planning, neither quantity nor quality of machinery and equipment—in so far as they affect productivity—can be measured for industry as a whole or for its sectors. From the technical points of view, machinery is not homogeneous and cannot be expressed in similar units. The number of machines can, of course, be established, but because of differing performances and different products there is no direct relation between changes in the number and sectoral productivity. The value of the capital invested in machinery could also possibly be established; but the effect on productivity of different equipment costing the same price is usually not the same. Nevertheless an analysis of the value of existing and new machinery and the subsequent development of productivity might, of course, provide useful information.

Attempts have often been made to establish connexions between productivity and power consumption and/or equipment. An increase in the volume and performance of machinery is accompanied by an increase in power requirements (amount of installed horse-power and electricity consumption), and so it is tempting to use them as a measure of the volume of productive equipment. This measure is, however, indirect and rather inaccurate when used to plan productivity. It does not take into account the up-to-dateness, age and general quality of the productive equipment, the machinery itself. Thus there is neither a close nor well-founded relationship between production per worker and the horse-power utilized for it. In a pioneering study[2] Rostas found, when comparing 28 branches of industry in the United States and in the United Kingdom, that close liaison between productivity and installed horse-power per worker could be established only in six cases.

Closer connexions exist between productivity and the horse-power per worker within industry in one particular country, but they are not close enough to be applicable in planning.

The influence of productive equipment on productivity is different for each branch of industry. There are branches, such as the chemical industry, paper milling and electric power production, where machinery more or less completely determines technology, and thus productivity. To introduce new machinery here—at least new machines that could have an important effect on productivity—takes a number of years, since equipment of this type is everywhere manufactured only to order, and delivery times are long. In such branches, therefore, a knowledge of the investment plans or of the orders already placed makes it possible to determine when the new, more modern productive capacities will become effective, i.e. when a change in productivity due to the installation of

[2] L. Rostas, *Comparative Productivity in British and American Industry*, Cambridge University Press, 1948.

new machinery may be expected. In other industries, such as engineering, textiles and shoes, new machines may very speedily be installed; here, however, not all new equipment leads to a substantial change in productivity. It is therefore necessary to find out to what extent the expected investments will change the volume, composition, quality and up-to-dateness of the machinery.

The volume and condition of the machinery and equipment does not alone determine the technical level of production. Changes may take place in the technology of the manufacturing process, and the materials used may also vary. It is obvious that productivity is most influenced, after the machines, by the material used. Changes in this are generally slower than in machinery and their effect on productivity is smaller.

Changes in material may influence the growth of productivity in two ways. First, although the material may remain the same and maintain its basic chemical, physical and technological properties, its quality may change, and this may result in increased productivity. If, for instance, a better quality of cotton is used there will be fewer stoppages on the loom. If castings are of better quality, they can be more easily worked and there are fewer rejects.

A change in material exercises a greater influence on productivity if that change is the appearance of a new material, of which the processing technology and the mechanical and physical properties differ from those previously encountered. The various synthetic materials increasingly used instead of metals or wood and in the textile industry are a case in point. The use of these materials generally involves a considerable change in the technology of production and may thus greatly enhance productivity. The general introduction of such a new material easily takes a number of years, and so its effect on productivity can easily be determined. The relation in a particular factory or branch of industry between material and productivity may be fairly clearly established, though here also this is considerably more difficult for industry as a whole.

(b) *The use made of available capacity*

Changes in the utilization of productive capacity are sometimes mentioned as an important factor in productivity changes. The theoretical basis of this assertion is partly the allegedly U-shaped cost function and the hypothesis of a similarly U-shaped functional relation between productivity and the volume of production. Furthermore, it is obvious that when demand drops, plants having higher production costs and lower productivity must shut down; however, if production is increased these plants can resume operation.

Both phenomena do exist in certain branches of industry or particular firms, but are not everywhere valid factors and are also not the only relevant phenomena. The year-by-year development of production and productivity in the United States between 1924 and 1938 shows the following picture:

Production	*Productivity*	*Years (No.)*
Decreasing	Decreasing	2
Decreasing	Increasing	2
Increasing	Increasing	6
Constant	Constant	3

Hungarian statistics for the period 1927—1943 show similar characteristics. A decline in the volume of production and the under-utilization of capacity may impede the general tendency of productivity to increase; with large drops in production, productivity may even decrease; but increasing production is usually accompanied by increasing productivity.

Unlike other important factors affecting productivity the change in the utilization of capacity can be fairly well determined quantitatively; it can be expressed in the case of homogeneous industries (like metallurgy or some branches of the chemical industry) in physical quantities, in other cases by the number of jobs. Increases in the utilization of capacity usually act favourably on the productivity of labour, at least until a point of overloading is reached that endangers the safety and continuity of production. This overloading may be of a purely technical nature, as in cases where productive equipment is overburdened so that it is damaged or where insufficient time provided for maintenance causes unexpected fall-outs. It may also be of an economic nature, when disproportionate development in the various sectors causes shortages of material or power.

(c) *The quality of the labour force*

There is general agreement that the skill of workers engaged in production is one of the most important factors of productivity. Unfortunately, the relation has not been very well established between productivity and skill indicators that can be measured statistically, such as the distribution of the three main categories (skilled, semi-skilled and unskilled); the number, or rather the proportion of technical specialists, and the number of these with engineering degrees or technician's diplomas; the age distribution, and so on. All that can be said is that increases in experience, skill etc. generally tend to enhance productivity.

(d) *Welfare and social factors*

With respect to the next, very important factors of productivity — the welfare and social factors (nutrition, health services, housing etc.) — the planner has hardly more than informed guesswork to go on in establishing their impact on productivity. The co-ordinated efforts of economists, sociologists, psychologists and others are needed to throw some light on these important, but complicated, interrelationships.

(e) *Natural factors*

Last on our list are the factors of nature, such as the climate, the raw-material deposits, the location of centres of production and consumption, etc. These factors are constant, or in any case change slowly and have only a small effect on change in productivity, although considerably influencing its level in different countries or regions. Their effect is felt chiefly in mining, especially when the conditions of extraction change, when certain deposits are exhausted, or new deposits discovered. The quantitative effects of these factors may be more or less accurately established and determined in advance. Their effect on any change in productivity of the industry as a whole will generally be moderate, at least as far as a direct effect is concerned.

International comparison of the levels of and changes in productivity can give some guidance in productivity planning. By observing productivity changes in several countries over several years the planner will acquire a good sense of what he can expect to be feasible. However, levels of productivity are too various and rates of development change too frequently and between too wide limits to serve as very solid bases for planning. Statistics show important differences even when average values of larger groups of countries are considered. For example, productivity in the engineering industries (ISIC 35—38) of the industrialized countries increased by 8.3 per cent yearly between 1948 and 1953, and only by 3.7 per cent between 1953 and 1958. In the less industrialized countries the increases were 2.9 per cent in the first period and 9.8 per cent in the second.

4. Planning of industrial skills

The planning of skills has to be performed in the framework of a certain number of skill categories. Those concerning the general level of education distinguish between persons having completed elementary, secondary, or high-level education. Within the industrial labour force, which principally interests us here, we distinguish between skilled, semi-skilled, and unskilled workers in the manual sector and between scientists, engineers and technicians in the higher-level sector. Skill categories other than industrial – accountants, lawyers etc. – as they are well known do not seem to need further elaboration here.

There exist some general tendencies of manpower development which have to be taken into account in the course of planning. Four of these are briefly mentioned below but not discussed in detail.

(i) Economic development is accompanied by structural change in the labour force. The most important feature is the decrease of the labour force occupied in the primary sector (agriculture, forestry, and mining) and the increase of the labour force in, first, the secondary sector (manufacturing industry) and, second, the tertiary sector (services).

(ii) General educational and skill levels constantly rise in the course of economic development, and skill requirements increase in every economic sector. There is a rather close correlation between the levels of economic development and those of education and skill.

(iii) Skill requirements of industry itself are constantly changing. Average skill requirements, especially, increase for highly-qualified personnel like engineers and scientists. For skilled workers there is a decrease in the share of skills based on and characteristic of traditional small-scale industries (workers such as tailors, shoemakers, bakers etc.). On the other hand, the share and number of occupations characteristic of large-scale production increases, in particular the skills of the engineering industries (workers such as fitters, toolmakers, turners and other machine-tool operators, electricians etc.). The tendency is less clear in the change in the proportions of the skilled, semi-skilled, and unskilled workers. While there is a constant increase in the skill requirements within each group, so that the average skill content of each category is now much higher than 20 or 30 years ago, the change in the proportion of any given group within the whole can differ according to the particular industry or the particular period of economic and technical development. By and large it can be said that, while mechanization tends to increase the share of semi-skilled workers, automation tends to decrease the share of this particular group.

(iv) Skill requirements vary considerably from one industry to another. In general the so-called "dynamic" industries, like the engineering

industries in general and the chemical industries, have high skill requirements, while the more traditional industries, like the textile and clothing industries, require lower average skills.

Before going further it seems worth while to diverge briefly. Education, which is the main basis of skill formation, has two aspects. It is desired for its own sake as a part of a better and fuller life; it is also a powerful tool of production for the individual as well as for society as a whole. In its first aspect education is producing consumer goods, in its second, investment goods. Only the second aspect will be considered here.

The essence of planning industrial skills concerns, on the one hand, engineers and technicians, and on the other, the skilled workers. Because of the length of the relevant educational curricula, the planning of the labour force of engineers and technicians is worked out mainly within the framework of long-term plans and that of skilled workers in medium-term plans. Although such considerations are based on Hungarian experience only, the methods now to be discussed seem to present a fairly general applicability.

The plan for qualified and highly-qualified manpower has to be closely integrated into the over-all plans for economic and social development. In particular, a close co-ordination with the production plans for individual sectors is necessary. It stands to reason that the number of weavers, opticians, or toolmakers at work is determined mainly by the development of the relevant industry. Now it is not particularly difficult to meet this requirement as regards medium-term plans because - as far as economic development plans are worked out at all - three, four or five-year plans exist anyway. The problem for long-term planning is somewhat more difficult. The 10- to 15-year plans are usually not available, or in any case not in sufficient detail to serve as a basis for manpower projections. As the projections for engineers have to be made on a 10- to 15-year perspective this circumstance presents some difficulties; they do not, however, necessarily prevent the elaboration of realistic manpower plans.

(a) Planning of high-level technical manpower

The planning of the three categories of high-level technical manpower, engineers, scientists and technicians, has to be worked out together because of the possibilities of substitution and the close interconnexions among them. The planning period is determined by *(a)* the duration of the educational curricula, *(b)* allowing for some years of practice after graduation in order that the specialists may be fully trained, and *(c)* the time (if any) necessary to establish new educational capacities. Highly-qualified technical manpower thus has to be planned about 10 to 15 years ahead.

Planning the highly-qualified skill requirements involves working out the relevant balances. This means that computations have to be made to ensure that increases of requirements over the available numbers and decreases because of death, retirement etc. are satisfied through the output of the educational system, that is through new degree holders. The establishment of such balances is not discussed here, only the planning of total requirements. It is also necessary to take into account all the requirements of the economy. Now, as engineers are employed in practically every sector, this is not an easy task. It is, however, facilitated by the fact that about 50 per cent of all engineers and scientists are employed in industry and about 70 per cent in industry and construction taken together. The percentages are even higher for technicians. These proportions are much the same in all countries and rather stable over time. Consequently it is sufficient to work out more detailed plans for industry and to deal with the other sectors in a less elaborate way.

To establish the plan itself, the following points can be taken into account:

(i) Information should be collected on past domestic and international trends concerning the number and the proportion in the total labour force of highly-qualified technical manpower. This will give an order of magnitude but not a very firm basis for planning, for international differences in this respect are very great.

(ii) There are changes in the skill composition of the highly-qualified labour force that are likely to occur in every country. For example, the proportion of civil engineers and architects has a tendency to decrease and that of electrical engineers to increase in the course of economic development. The reason is that in the early stages there is but little or no manufacturing industry, but there is construction work, which requires architects and civil engineers. Later, however, electrical engineers are required not only in the production and distribution of electricity and in the production of electrical machinery and equipment, but also increasingly in maintenance.

(iii) As we have seen, skill requirements have to be connected to economic plans. Comprehensive long-term plans for 10 to 15 years are usually not available. This difficulty can be overcome by elaborating tentative long-term manpower projections for the economy as a whole and for its major sectors. Such projections are based on demographic data (indicating the total labour force of

working age etc.) and on the general trends of economic development (decrease of manpower in agriculture versus increase in industry and services, higher increases in the dynamic industries such as the chemical and the engineering). In this respect international comparison of structural changes can be of great assistance. On the basis of these sectoral manpower projections the requirements for engineers, scientists and technicians can be established with the help of skill-intensity coefficients (proportion of the given skills in the total labour force of the sector) based on past domestic trends and international comparison. It is worth while mentioning in this respect that possible inaccuracies in the sectoral manpower projection will affect the plan of skill requirements only as far as concerns sectors having widely different skill intensities. Shifts between (say) precision engineering and telecommunication engineering—sectors having practically the same skill intensities—would not greatly change the final results.

(iv) One particular aspect of the qualified industrial labour force has been utilized in the planning of skill requirements in Hungary. There is a large occupational category, the "technical employees" who make use in their work of some kind of technical-industrial knowledge, that follows managerial and/or white-collar occupations. Only a small part of this group has completed formal secondary or higher technical education. Experience has shown that because of technical development, the proportion of these technical employees within the total labour force of the different sectors grows quite steadily. It is therefore possible to project the development of this proportion. By assuming that all new entrants to this group will hold secondary or higher-level diplomas we arrive at a kind of upper limit to what can reasonably be expected.

(v) The methods described above would be considered "macroeconomic", for they deal only with the economy or industry as a whole or with major sectors. Another possibility is the "microeconomic" approach, the basic feature of which is to work out the details past and present of home and foreign experience in every sector as a guide to the probable impact of foreseeable technical and economic development on skill requirements. With the help of such studies, it is possible to describe the total manpower by occupation and skill in hypothetic "model plants", one or more for every industrial sector. From such model plants, the total highly-qualified manpower of single industries can be built up.

The final plan for highly-qualified manpower can be worked out as a combination of the methods described above. Experience has shown that the total number of engineers, scientists and technicians should be determined mainly by the methods mentioned under *(iii)* and *(iv)*, to which the methods under *(i)* and *(ii)*—namely international comparison and general trends—serve as useful checks. The microeconomic method under *(v)* gives the most trustworthy results concerning composition by occupational categories (mechanical, electrical, chemical, engineers etc.). The method is less reliable concerning total numbers. This type of investigation can be undertaken only by specialists in the given industrial sector itself and such groups usually have innate bias towards an overstatement of sectoral requirements.

(b) Planning of skilled-worker manpower

While the number of engineers and technicians has to be planned on the long term, the planning of skilled-worker manpower, because of the shorter period of instruction and practical training of such workers, can take place in the framework of medium-term plans.

It seems, moreover, that central plans for engineers that cover a long period are more realistic than the totalling up of the requirements of each economic unit employing engineers and technicians. For skilled workers, on the contrary, it is the industrial enterprises that have the best and most detailed information for assessing the foreseeable amount and pattern of skill requirements; in addition they very often also have the requisite training facilities and employ apprentices. Central planning activity is required here in two respects. The first is to take into account the foreseeable requirements of new enterprises. The second is more complex. Enterprises with training facilities can usually forecast quite precisely their skill requirements for the basic skills of their industry; that is, for toolmakers or turners in the engineering industries, or for weavers in the textile industry. However, a very wide variety of skilled workers is required—even if only in small numbers—in the industrial and other sectors of the economy. This is the case with maintenance workers of every kind. Since it is not very desirable that each unit employing only one or two of a given skill category should try separately to assess availabilities and requirements, it is necessary to collect information and to work out additional plans centrally.

5. Conclusion

In this article only that aspect of planning which we called the planning of the equilibrium has been dealt with. The planning of the optimal utilization of resources, involving policy decisions, raises other problems. As far as productivity is concerned the alternatives are generally considered not purely in terms of productivity but as choices between different possible sectoral structures (and thus between foreign trade alternatives) or between labour- or capital-intensive production methods. The methodology of the computations involved is fairly well developed, especially of those concerning project evaluation, and does not need to be discussed here.

The profitability of education and training has been far less thoroughly worked out. This is an important problem. The costs, and in particular the investment costs, of education and training are very high and continually increasing. It would therefore seem justifiable to compare the costs and "results" of education and training with those of other sectors, whether of the type of social services (for example, health) or of material production. The existence of a choice between different types of education and training is also relevant. Decisions in this field are often made in a rather haphazard way, without a sound economic basis. This can lead to inefficiency and waste. It should be acknowledged, however, that those who take such decisions have been given no clear theoretical foundation by economists to guide their considerations.

The economics of non-material services, like those of health and education, present particular difficulties. It is not easy to measure the value or the economic results of the "goods" these sectors deliver. A very tempting simplification in the field of education is to consider general education (i.e. that provided by elementary schools and non-technical high schools) as consumer goods from which no economic return is expected and on the cost and development of which society decides on non-economic grounds. This simplification can perhaps be accepted for highly developed countries; but certainly not for the developing countries, where both the costs of such education (compared to national income) and its economic returns (for example, through the extension of literacy) are high.

The basic difficulty is to evaluate the economic results of education. Some authors suggest measuring the value of education to the individual by comparing the discounted earnings and expenditures over the lifetimes of persons having different educational levels. Without going into details we can say that this method cannot be accepted as providing an adequate statement of the costs and benefits of education from the point of view of society. Practical planning in this respect is therefore usually the result of a compromise between what educational experts require and what society can afford (or what financial and other experts think it can afford).

It is easier—and very useful in practice—to measure the costs of education. These costs are borne partly by the families (individual persons) and partly by the society (central or local governments). In most countries, the investment costs and, at least partly, the operating costs of educational institutions are borne by society; the living costs of students are borne mainly by the families (but also by society in the form of grants, scholarships etc.). There is an additional "opportunity cost" in the earnings foregone by the individual and the national income foregone by the society because of the delay in entering the working population.

The results of such computations help to clarify the relative costs of different educational levels. The relevant interrelations may, of course, be different within individual countries, according to their educational system, levels of living etc. Hungarian computations have shown that the total social cost of training skilled workers with three years apprenticeship after elementary school is about 33 per cent higher than the cost for unskilled workers having only eight years of elementary schooling. The cost of technicians (secondary educational level) is almost double and that of engineers (university level) almost four times that of unskilled workers. This fact gives additional weight to the proposals to increase the number of technicians in comparison with that of engineers and to let all tasks for which full engineering degrees are not indispensable be performed by technicians.

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PRODUCTIVITY, SKILLS AND EDUCATION IN MANUFACTURING INDUSTRIES

Manuel Zymelman, Graduate School of Education, Harvard University, Cambridge, United States of America

INTRODUCTION

IN ADDITION TO capital investment, development demands competent entrepreneurship, stable social and political institutions and a rational use of human resources. During the last decade we have experienced a renewed interest in the economies of human resources, as has been evidenced by the increased volume of publications dealing with the problems of education, manpower, productivity and economic growth.

The present study tries to focus attention on the importance of manpower in planning for the economy and for educational facilities. It supplements our previous work for UNIDO in this field.[1] We could sum up the joint results of that article and the present paper as follows:

(i) There is a systematic relationship between the productivity and the skill composition of an industry. This relationship is unique to each industry.

(ii) Occupational data by industry, available to us through the census, is usually contaminated. Information on the educational level of different occupations can assist us in determining the correct occupational distribution.

(iii) Data of the occupational composition of industries at different levels of productivity can provide values for: parameters needed for static and dynamic models of manpower planning; a feasibility test for economic plans; verification of productivity; the allocation of labour; and for manpower forecasting.

The linking of productivity to formal education ignores important variables in the causality process between productivity and human resources. A higher educational level does not automatically produce a higher level of output unless this higher level of education is a result of a higher occupational mix, such as more professionals and fewer labourers. It is therefore of little use for planning purposes to link productivity or income *per capita* directly with formal education.

This points to the necessity of research in a vital area, i.e. that of inquiring into the different ways or means of skill acquisition (especially at the level of the blue-collar skilled worker) and that of obtaining better data on the human functions involved in production. A knowledge of the different methods by which workers acquire skills and of the relationships between productivity and the skill composition of the labour force may enable planners to determine minimal formal educational levels compatible with a given structure of the economy and a given rate of growth.

1. SKILLS AND PRODUCTIVITY[2]

There is reason to believe that a high degree of complementarity exists between a certain type of production method and the kind of labour force it requires. In other words, a certain level of technology, and hence a certain level of productivity, are represented by a specific kind of organization and by a specific kind of capital equipment that are made to work by a labour force whose occupational composition is well defined.

This assumption can be formalized as follows: the productivity of an industry is linked to a specific occupational distribution of its labour force.[3] The production function in this case is of the type

$$Q = F_1 (K, L_1, L_2, \ldots . L_n) \qquad (1)$$

where Q is output, $L_1, L_2, \ldots L_n$ are the number of

[1] M. ZYMELMAN, "Skill Requirements in Manufacturing Industries", *Industrialization and Productivity Bulletin* No. 12, 1968.

[2] The model here used was originally presented in "Skill Requirements in Manufacturing Industries", op. cit.

[3] We shall assume that productivity is the output per unit of a factor of production. As we are dealing mainly with the input of labour, we shall refer in the future to the productivity of labour simply as productivity.

workers in occupations 1, 2, ... n, and K is the amount and type of capital.

We can rewrite (1) in the following way:

$$Q/L = F_2\,(K/L,\ L_1/L,\ L_2/L,\ \ldots\ldots L_n/L) \quad (2)$$

where L is the total number of workers. Furthermore, if it is also assumed that K/L is a function of the occupational distribution of L, then it follows that:

$$Q/L = F_3\,(L_1/L,\ L_2/L,\ \ldots\ldots\ L_n/L). \quad (3)^4$$

This hypothesis was tested for each of the two-digit industries, their occupational distribution and productivity data for 21 different countries being used as observations. (The data for each industry is presented in Annex I.)

The equations used in these multiple correlations were of the form

$$y_j = a + b_{1j}\,x_{1j} + b_{2j}\,x_{2j} + \ldots\ldots + b_{nj}\,x_{nj} \quad (4)$$

where y_j is value added per person engaged in industry j and x_{nj} is the proportion of occupation n in the labour force of industry j; also the following function was fitted to the data.

$$\log y_j = a + b_{1j} \log x_{1j} + b_{2j} \log x_{2j} + \ldots\ldots + b_{nj} \log x_{nj} \quad (5)$$

y and x have the same significance as in (4).

The occupational groups[5] used in the multiple correlations were:

x_1 = professional and technical workers,
x_3 = administrators and managers,
x_4 = clerical workers,
x_6 = sales workers, and
x_7 = manual workers.

The final equations (after the variables without statistical significance were dropped);[6] the multiple R^2, the multiple F ratio and its degrees of freedom, as well as the F of each of the coefficients (and degree of significance) are given in tables 1 and 2.

These tables show definitely that (*a*) variations in productivity in a given industry can be explained by differences in occupational structures; (*b*) variations in the proportion of professional and technical workers are a major determinant in almost all industries; (*c*) the importance of other variables may vary from industry to industry, depending on what type of function is chosen. The only occupational group that seems to exert no influence is that of clerical workers.[7]

[4] While this approach is an oversimplification, i.e. it leaves out the influence of the relative pricing of capital and of different types of labour and the possible substitution among occupations, we believe that this equation is a sufficient approximation if production and equipment could be measured in physical rather than monetary terms.

[5] The number of occupational groups was determined by the constraints imposed by the number of observations and by the fact that the sum of x's has always been less than 1.

[6] The dropping of variables during the correlation process is done to avoid introducing variables whose coefficient has an F-value less than critical F chosen in advance. This procedure has the advantage of narrowing the number of variables and thus increasing reliability, and of having also a number of occupational groups whose sum is well below 100 per cent, thus minimising the effect of dependency of the variables.

[7] It should be noted that the influence of a variable has no bearing on its existence. The fact that a variable does not appear in the equation does not imply that this occupation is not needed in the production process. On the contrary, all occupations may be needed, and have to be planned for. If, for example, regardless of the level of productivity, 10 per cent of the labour force is in occupation x, the variable x may not appear in the equation but may play an important role in determining the total occupational structure, an even more important role than a statistically very significant variable whose upper limit is only 0.1 per cent of the total labour force.

TABLE 1. LINEAR CORRELATIONS OF THE FORM $y = a + b_1 x_1 + b_2 x_2 + \ldots b_n x_n$

(Unadjusted data)

ISIC No.	Equation	R^2	Multiple F	DF_1/DF_2	Degree of significance 0.95	Degree of significance 0.99
Manufacturing (2–3)	$y = -2{,}991 + 82.54\,x_1 + 60.69\,x_3 + 39.44\,x_6$ (17.32) (4.44) (2.29)	0.708	13.79	4/16	3.01*	4.77*
Food and beverages (20, 21)	$y = 7{,}954 + 38.13\,x_3 + 38.67\,x_4 - 13.45\,x_7$ (3.34) (1.63) (1.42)	0.406	3.87	3/17	3.20*	5.18
Tobacco and tobacco products (22)	$y = 123{,}748 - 157.57\,x_1 - 192.00\,x_3 - 144.56\,x_4 - 120.68\,x_7$ (4.70) (4.46) (11.15) (9.03)	0.512	3.67	4/14	3.11*	5.03
Textile mill products (23)	$y = 29.158 - 31.65\,x_7$ (12.46)	0.44	12.46	1/19	4.38*	8.18*

TABLE 1. LINEAR CORRELATIONS OF THE FORM $y = a + b_1 x_1 + b_2 x_2 + \ldots b_n x_n$ *(continued)*

ISIC No.	*Equation*	R^2	Multiple F	DF_1/DF_2	Degree of significance 0.95	Degree of significance 0.99
Clothing and other fabric textiles (243, 244)	$y = -454 + 203.30\,x_1 + 41.79\,x_4 - 31.84\,x_6$ (11.68) (9.52) (2.64)	0.656	10.21	3/16	3.24*	5.29*
Leather and footwear (241, 29)	$y = -1{,}801 + 80.19\,x_1 + 32.99\,x_3 + 50.63\,x_4 - 33.26\,x_6$ (0.93) (1.56) (7.84) (1.94)	0.620	4.08	4/10	3.48*	5.99
Furniture and fixtures (26)	$y = 26{,}571 - 27.79\,x_7$ (19.17)	0.615	19.17	1/12	4.75*	9.33*
Lumber and wood products (25)	$y = -2{,}076 + 107.72\,x_1 + 119.39\,x_3 - 34.56\,x_4$ (5.05) (16.53) (2.54)	0.702	7.88	3/10	3.71*	6.55*
Lumber and wood, including furniture (25, 26)	$y = 92{,}855 - 197.81\,x_4 + 188.43\,x_6 - 95.30\,x_7$ (2.95) (1.30) (7.21)	0.404	3.84	3/17	3.20*	5.18
Paper and paper products (27)	$y = -6{,}230 + 164.24\,x_1 + 113.00\,x_3 + 19.37\,x_4$ (52.21) (8.27) (2.10)	0.799	21.22	3/16	3.24*	5.29*
Printing and publishing (28)	$y = 19{,}336 - 24.03\,x_3 - 31.23\,x_4 + 28.90\,x_6 - 17.69\,x_7$ (1.44) (2.74) (5.99) (3.67)	0.814	17.60	4/16	3.01*	4.77*
Rubber products (30)	$y = 7{,}592 + 146.21\,x_1 + 52.70\,x_6 - 12.80\,x_7$ (25.61) (1.90) (2.53)	0.772	18.07	3/16	3.24*	5.29*
Chemical and chemical products (31)	$y = -6{,}990 + 106.87\,x_1 + 63.31\,x_6$ (20.10) (6.12)	0.674	18.66	2/18	3.55*	6.01*
Petroleum and coal products (32)	$y = -3{,}782 + 87.67\,x_1 + 77.62\,x_3$ (26.92) (4.14)	0.675	15.62	2/15	3.68*	6.36*
Glass, stone and clay products (33)	$y = -3{,}344 + 166.05\,x_1 + 31.16\,x_3 + 120.20\,x_6$ (22.43) (3.35) (6.39)	0.833	26.7	3/16	3.24*	5.29*
Metal and metal products (34, 35)	$y = -2{,}326 + 94.37\,x_1 + 41.93\,x_3 + 85.46\,x_6$ (21.70) (2.68) (2.42)	0.684	11.55	3/16	3.24*	5.29*
Primary metals (34)	$y = -21{,}130 + 161.58\,x_1 + 72.22\,x_3 + 596.00\,x_6 + 16.98\,x_7$ (9.14) (2.02) (8.37) (1.65)	0.601	4.90	4/13	3.18*	5.20
Fabricated metal products (excluding machinery) (35)	$y = -1{,}814 + 70.28\,x_1 + 40.75\,x_3 + 64.42\,x_6$ (22.24) (2.85) (1.24)	0.697	12.32	3/16	3.24*	5.29*
Machinery, excluding electrical (36)	$y = -768 + 37.55\,x_1 + 42.86\,x_3$ (4.65) (2.41)	0.306	3.76	2/17	3.59*	6.11
Electrical machinery (37)	$y = -551 + 38.85\,x_1 + 75.44\,x_6$ (12.47) (1.26)	0.438	6.62	2/17	3.59*	6.11
Transportation equipment (38)	$y = -61 + 71.99\,x_1 + 67.41\,x_6$ (17.10) (2.20)	0.527	8.94	2/16	3.63*	6.23*
Miscellaneous manufacturing (including instruments) (39)	$y = -1{,}418 + 46.45\,x_1 + 44.14\,x_6$ (17.25) (12.40)	0.661	16.58	2/17	3.59*	6.11*

y = productivity
x_1 = proportion of Professional and Technical Workers in the labour force
x_3 = proportion of Administrators and Managers in the labour force
x_4 = proportion of Clerical Workers in the labour force
x_6 = proportion of Sales Workers in the labour force
x_7 = proportion of Manual Workers in the labour force
* = significant
The figures in brackets represent F-values for coefficients.

TABLE 2. LINEAR LOGARITHMIC CORRELATIONS OF THE FORM $\log y = a + b_1 x_1 + b_2 x_2 + \ldots b_n x_n$

(Unadjusted data)

ISIC No.	*Equation*	R^2	*Multiple F*	DF_1/DF_2	*Degrees of significance 0.95*	*0.99*
Manufacturing (2 − 3)	$y = 0.912 + 0.8453\,x_1 + 0.7899\,x_3$	0.666	18.02	2/18	3.55*	6.01*
	(22.20) (9.019)					
Food and beverages (20,21)	$y = 9.1314 + 0.5761\,x_1 + 0.6241\,x_3 - 2.5764\,x_7$	0.523	6.22	3/17	3.20*	5.18*
	(5.31) (3.82) (1.57)					
Tobacco and tobacco products (22)	$y = 13.8895 - 1.3466\,x_4 + 0.5347\,x_6 - 2.86\,x_7$	0.393	3.24	3/15	3.29	5.42
	(4.87) (3.64) (1.08)					
Textile mill products (23)	$y = 22.0461 + 0.39\,x_1 + 0.23\,x_6 - 5.81\,x_7$	0.484	5.33	3/17	3.20*	5.18*
	(2.95) (0.60) (2.71)					
Clothing and other fabric textiles (243, 244)	$y = 27.6422 + 0.32\,x_1 - 0.35\,x_6 - 8.26\,x_7$	0.549	6.49	3/16	3.24*	5.29*
	(5.44) (2.35) (4.97)					
Leather and footwear (241, 29)	$y = 0.88 + 0.71\,x_1 + 0.60\,x_3 + 0.53\,x_4$	0.722	9.55	3/11	3.59*	6.22*
	(18.03) (5.54) (4.39)					
Furniture and fixtures (26)	$y = 43.27 + 0.16\,x_1 - 6.80\,x_6 - 13.40\,x_7$	0.806	13.89	3/10	3.71*	6.55*
	(2.87) (9.77) (21.89)					
Lumber and wood products (25)	$y = 1.7599 + 0.43\,x_1 + 1.47\,x_3 - 0.70\,x_4$	0.880	24.48	3/10	3.71*	6.55*
	(35.63) (14.40) (4.53)					
Lumber and wood, including furniture (25, 26)	$y = 1.61 + 0.26\,x_1 + 0.93\,x_3$	0.542	10.66	2/18	3.55*	6.01*
	(7.06) (7.72)					
Paper and paper products (27)	$y = 1.1799 + 1.00\,x_1 + 0.62\,x_3$	0.706	20.49	2/17	3.59*	6.11*
	(39.31) (5.77)					
Printing and publishing (28)	$y = 17.8119 - 1.52\,x_4 - 3.94\,x_7$	0.562	11.55	2/18	3.55*	6.01*
	(3.10) (19.03)					
Rubber products (30)	$y = 11.2722 + 1.08\,x_1 - 3.27\,x_7$	0.735	23.60	2/17	3.59*	6.11*
Chemical and chemical products (31)	$y = -0.2448 + 1.23\,x_1 + 0.43\,x_3 + 0.46\,x_6$	0.665	11.25	4/16	3.01*	4.77*
	(13.38) (2.05) (4.10)					
Petroleum and coal products (32)	$y = 0.6851 + 1.18\,x_1 + 0.51\,x_3$	0.570	9.94	2/15	3.68*	6.36*
	(17.66) (2.87)					
Glass, stone and clay products (33)	$y = -1.2308 + 1.66\,x_1 + 1.26\,x_4$	0.855	50.49	2/17	3.59*	6.11*
	(48.51) (13.57)					
Metal and metal products (34, 35)	$y = 2.8860 + 0.85\,x_1 + 0.36\,x_3 - 0.81\,x_4 + 0.34\,x_6$	0.583	5.25	4/15	3.06*	4.89*
	(14.81) (1.83) (1.75) (1.84)					
Primary metals (34)	$y = 2.9625 + 1.10\,x_1 - 0.71\,x_4 + 0.30\,x_6$	0.472	4.18	3/14	3.34*	5.56
	(10.03) (1.70) (2.08)					
Fabricated metal products (excluding machinery) (35)	$y = 1.5595 + 0.75\,x_1 + 0.46\,x_3$	0.687	18.69	2/17	3.59*	6.11*
	(34.40) (5.49)					
Machinery, excluding electrical (36)	$y = 16.8501 + 0.47\,x_1 - 1.07\,x_4 - 4.20\,x_7$	0.430	4.02	3/16	3.24*	5.29
	(3.01) (3.99) (3.18)					
Electrical machinery (37)	$y = 2.0825 + 0.64\,x_1 + 0.17\,x_6$	0.344	4.47	2/17	3.59*	6.11
	(7.92) (0.37)					
Transportation equipment (38)	$y = 24.03 - 0.52\,x_4 - 6.76\,x_7$	0.320	3.78	2/16	3.63*	6.23
	(0.98) (5.22)					
Miscellaneous manufacturing (including instruments) (39)	$y = 0.84 + 0.75\,x_1 + 1.06\,x_3 - 0.32\,x_6$	0.668	10.73	3/16	3.24*	5.29*
	(19.33) (10.14) (2.19)					

* = Significant.

2. The role of education in helping to determine the correct occupational distribution

The data used in the correlations given earlier in this paper (the values of the x's and y's) come mainly from census data of various countries. Census data are notorious for their lack of accuracy[8], mainly because questions are answered by people who may not wish to give a truthful answer—someone wishing to upgrade himself, or a housewife taking pride in bestowing a higher office on her husband—but also because of the quality and training of the census interviewer.

To check and compensate for these errors, data on education, set out by occupation, can be used. For example, if we find that 5 per cent of the professional and technical workers never finished grammar school we may assume that 5 per cent of the people who proclaim themselves professionals and technicians are not what they say they are. If we find that 10 per cent of clerical workers are illiterate we may assume that they are not performing a clerical job, and so on.

To have a better idea of the occupational structure of an industry we must therefore adjust the vector of occupation by the matrix of occupation by education. Assume that in industry Y we find that the occupational structure is composed of x_1, x_2, x_3 but we suspect that the figures are not reliable. Assume also that we have the educational distribution data of each occupation 1, 2 and 3, broken down according to percentage in levels A, B and C.

Industry Y occupational structure	*Educational breakdown of occupations in percentages, i.e. 1A + 1B + + 1C = 100*		
x_1	*1A*	*1B*	*1C*
x_2	*2A*	*2B*	*2C*
x_3	*3A*	*3B*	*3C*

Multiplying row by row we have

$$\begin{aligned} x_1 \cdot 1A + x_1 \cdot 1B + x_1 \cdot 1C &= x_1 \\ x_2 \cdot 2A + x_2 \cdot 2B + x_2 \cdot 2C &= x_2 \\ x_3 \cdot 3A + x_3 \cdot 3B + x_3 \cdot 3C &= x_3 \end{aligned} \qquad (6)$$

[8] One should recall the fact that the population census of 1950 for the United States failed to account for the presence of approximately 5 million persons, and that matched returns checking the census figures with the monthly surveys for the same year for people enumerated at the same date, show that in half the cases different interviewers arrived at different results. Also, that, even if the United Kingdom and the United States cannot produce better statistics than they do, those of other countries do not in general come near their quality.

Let us further assume that occupation 1 represents professional workers, and that levels A, B, and C are elementary, secondary and university levels of education, respectively. If we decide that it is impossible to be a professional without going to secondary school we can adjust x_1 by subtracting $x_1 \cdot 1A$ from it. The same procedure can be followed with x_2 and x_3, deciding *a priori* on the minimum educational levels necessary to perform successfully in a given occupation.[9]

In our case the adjustment was made as follows: in the minor groups of professional workers, only those with some education of a university level or higher were considered professionals. In the minor groups of technical workers, only those who went beyond elementary school were considered technicians. Those classified as professionals who had only some secondary schooling were also considered technicians. Clerical workers who did not finish elementary school were considered unsuitable for clerical work.

In the case of sales workers and managers it was impossible to adjust the figures because both groups, at the national level figures, include a myriad of occupations that do not appear in manufacturing, such as proprietors of very small businesses, street vendors, and so on.

With the manual workers group there is almost no lower educational limit for unskilled workers, and elementary education seems to be sufficient minimal formal schooling for most other manual

[9] Since educational data is given on a two-dimensional basis, occupation by education, it would be erroneous to apply to major occupational groups the correction of the average national educational level for the major group. The major groups have to be reconstructed from the sum of the minor groupings. For example, we have an industry with 10 per cent professional and technical workers, and this major group is composed of 5 per cent engineers and 5 per cent technicians, both minor groups. This gives us the following percentages:

Levels	1	2	3
National average for professionals	10	50	40
engineers	–	20	80
technicians	10	60	30

The averages for professionals obtained by summing up the minor groups are respectively 5, 40 and 55 for levels 1, 2 and 3. Such an average is higher than the national level, because the national average includes in the professional and technical group such disparate occupations as physicians, practical nurses, athletes, engineers, and so on. This method of using national averages for major occupational groups is widely employed, but it underestimates the educational levels of sectors such as manufacturing and overestimates those of others such as services.

In many cases when data on occupation by education are divorced from those on occupation by industry, the consequences of using them without the next step of adjustment and without a good understanding may be very costly, since in some cases the conclusions may be reached that we need 10 per cent of engineers of whom one-third only finished grammar school.

occupations. Since most data are from countries where elementary education is compulsory, very few workers could be separated on the basis of formal education.

The adjusted figures are presented in the tables in Annex I. These adjusted figures confirm once again that productivity is a function of the occupational distribution of the labour force. Tables 3 and 4 present the correlation of productivity with major occupational groups. Table 3 shows the results of fitting to the data a function

$$y_j = a + b_{1j} x_{1j} + \ldots\ldots + b_{nj} x_{nj} \quad (7)$$

where y_j = productivity of industry j,

x_2 = proportion of professional and technical workers in the labour force, adjusted by educational levels,

x_3 = administrators and managers as a proportion of total labour force,

x_5 = clerical workers as proportion of total labour force, adjusted by educational levels,

x_6 = sales workers as proportion of total labour force, and

x_7 = manual workers as proportion of total labour force.

Table 4 is of the form

$$\log y_j = a + b_{1j} \log x_{1j} + \ldots\ldots + b_{nj} \log x_{nj} \quad (8)$$

and where y and the x's have the same meaning as in table 3. Without exception the correlations and the degree of reliability are much higher in this case than where adjustments were not made (compare with tables 1 and 2).

It is also interesting to note that the adjusted group of professional and technical workers is the major factor in explaining the productivity of almost every industry, except in the cases of tobacco and tobacco products, shoes and leather, and the printing and publishing industries.

3. Use of the tables in Annex I for manpower planning

The tables in Annex I may serve as guidelines for manpower planning. A country planning for its industrial development can choose a productivity goal to be achieved after t years. It is possible to find in these tables a country or a group of countries whose present level of productivity for a particular industry is approximately equal to the envisaged goal of another country. This gives us an occupational composition that matches this productivity goal. Extrapolating from its present position, the country planning its manpower may get an idea of the people needed in a given occupation to reach its productivity goal from

$$\Delta X_i = \sum_{j=1}^{n} (x_{ij} E_j)_t - \sum_{j=1}^{n} (x_{ij} E_j)_{t_0} \quad (9)$$

$$\frac{\Delta X_i}{\Delta t} = \text{yearly net addition of people in occupation } i \text{ needed.} \quad (9a)$$

where

$\Delta t = t - t_0$

x_{ij} is the proportion of occupation i in the labour force of industry j

E_j is the total employment in industry j

t_0 indicates that the data are taken from time period zero

t indicates that the data are taken from the final time period

ΔX_i is net addition of people needed in occupation i over the total time period.

This method assumes a linear extrapolation between the original position and the final goal. Another use of these tables is to allow the determination of parameters needed for an input-output model that includes manpower requirements.[10]

4. Use of tables for dynamic programming

Most plans do not specify a given target of productivity but merely assert that production by the sector or industry has to grow by a given percentage each year.[11] Growth of production in a given sector or industry is a combined result of the growth both of the labour force and of productivity in the same sector:

$$dQ/Q = dL/L + dP/P,$$

where L = labour force,

P = productivity.

If we assume a very simple relationship between occupation structures and productivity of the form

$$x_{ij} = X_{ij}/L_j = K_j\,(Q_j/L_j)^{b_{ij}}, \quad (10)$$

where X_{ij} = number of people in occupation i in industry j,

[10] See M. Zymelman, op. cit.

[11] This is a consequence of an attempt to satisfy political as well as economic ends; for example it is common to hear that if population grows by 3 per cent a year production must increase by at least 5 per cent so as to raise the *per capita* income by at least 2 per cent.

TABLE 3. LINEAR CORRELATIONS OF THE FORM $y = a + b_1x_1 + b_2x_2 + \ldots b_nx_n$

(Adjusted data)

ISIC No.	*Equation*	R^2	F	DF_1/DF_2	*Degree of significance* 0.95	0.99
Manufacturing (2–3)	$y = -15{,}031 + 166.00\,x_2 + 111.08\,x_3 + 9.54\,x_5 + 11.42\,x_7$ (124.4) (61.68) (3.21) (4.35)	0.973	82.02	4/9	3.63*	6.42*
Food and beverages (20, 21)	$y = -4{,}798 + 283.00\,x_2 + 67.21\,x_3 + 27.55\,x_6$ (9.06) (7.04) (1.70)	0.642	5.99	3/10	3.71*	6.55
Tobacco and tobacco products (22)	$y = 3{,}342 + 96.20\,x_6$ (0.84)	0.06	0.84	1/12	4.75	9.33
Textile mill products (23)	$y = -3{,}990 + 243.53\,x_2 + 87.99\,x_3 + 28.97\,x_5$ (14.29) (4.59) (2.89)	0.718	8.49	3/10	3.71*	6.55*
Clothing and other fabricated textiles (243, 244)	$y = -1{,}232 + 63.74\,x_2 + 149.17\,x_5 - 38.62\,x_6$ (4.69) (5.71) (2.37)	0.676	6.26	3/9	3.86*	6.99
Leather and footwear (241, 29)	$y = 45{,}638 - 61.23\,x_6 - 49.31\,x_7$ (7.41) (16.75)	0.682	9.68	2/9	4.26*	8.02*
Furniture and fixtures (26)	$y = -1{,}666 + 306.87\,x_2 + 50.81\,x_3$ (11.87) (4.50)	0.739	9.95	2/7	4.74*	9.55*
Lumber and wood products (25)	$y = -6{,}455 + 121.62\,x_2 + 167.82\,x_3$ (2.68) (19.38)	0.767	11.55	2/7	4.74*	9.55*
Lumber and wood, including furniture (25, 26)	$y = -3{,}928 + 268.65\,x_2 + 116.77\,x_3$ (2.13) (5.86)	0.443	2.65	3/10	3.71	6.55
Paper and paper products (27)	$y = -4{,}431 + 231.73\,x_2 + 208.99\,x_6$ (109.69) (19.77)	0.911	56.8	2/11	3.98*	7.20*
Printing and publishing (28)	$y = 2{,}068 - 16.82\,x_5 + 58.11\,x_6$ (3.75) (55.42)	0.865	35.28	2/11	3.98*	7.20*
Rubber products (30)	$y = -8{,}447 + 251.04\,x_2 + 95.34\,x_3 - 16.08\,x_5 + 225.32\,x_6$ (156.00) (30.50) (2.35) (17.95)	0.971	68.57	4/8	3.84*	7.01*
Chemical and chemical products (31)	$y = -7{,}027 + 157.73\,x_2 + 19.78\,x_5$ (84.75) (3.80)	0.903	51.61	2/11	3.98*	7.20*
Petroleum and coal products (32)	$y = 12{,}974 + 128.80\,x_2 - 23.72\,x_7$ (27.49) (6.28)	0.834	27.66	2/11	3.98*	7.20*
Glass, stone and clay products (33)	$y = -1{,}898 + 270.32\,x_2 - 37.01\,x_5 + 198.17\,x_6$ (47.26) (4.018) (9.30)	0.926	37.99	3/9	3.86*	6.99*
Metal and metal products (34, 35)	$y = -4{,}486 + 140.16\,x_2 + 115.35\,x_6$ (102.96) (34.51)	0.932	75.95	2/11	3.98*	7.20*
Primary metals (34)	$y = -6{,}744 + 253.97\,x_2 + 524.86\,x_6$ (35.67) (9.00)	0.833	24.99	2/10	4.10*	7.56*
Fabricated metal products (excluding machinery) (35)	$y = -3{,}219 + 92.52\,x_2 + 73.38\,x_3 + 9.51\,x_5$ (75.43) (29.46) (1.43)	0.950	57.18	3/9	3.86*	6.99*
Machinery, excluding electrical (36)	$y = -34{,}750 + 131.93\,x_2 + 306.06\,x_6 + 37.65\,x_7$ (15.72) (4.46) (2.41)	0.722	7.82	3/9	3.86*	6.99*
Electrical machinery (37)	$y = -2{,}576 + 83.85\,x_2 + 10.45\,x_5$ (35.08) (1.32)	0.767	18.17	2/11	3.98*	7.20*
Transportation equipment (38)	$y = -24{,}475 + 144.63\,x_2 + 105.21\,x_3 + 25.10\,x_5 + 23.66\,x_7$ (40.19) (6.64) (3.20) (4.72)	0.904	16.57	4/7	4.12*	7.85*
Miscellaneous manufacturing (including instruments) (39)	$y = -1{,}227 + 76.32\,x_2 + 34.99\,x_3$ (44.14) (12.45)	0.882	25.05	3/10	3.71*	6.55*

* = Significant.

TABLE 4. LOGARITHMIC CORRELATIONS OF THE FORM $\log y = a + b_1 x_1 + b_2 x_2 + \ldots b_n x_n$

(Adjusted data)

ISIC No.	Equation	R^2	F	D_1/D_2	Degree of significance 0.95	Degree of significance 0.99
Manufacturing (2–3)	$y = -6.7039 + 1.34\,x_2 + 1.07\,x_3 + 2.27\,x_7$ (71.37) (34.90) (2.26)	0.940	52.28	3/10	3.71*	6.55*
Food and beverages (20, 21)	$y = 34.85 + 0.85\,x_3 - 1.05\,x_6 - 10.84\,x_7$ (8.34) (12.68) (22.17)	0.805	13.83	3/10	3.71*	6.55*
Tobacco and tobacco products (22)	$y = -11.40 + 0.82\,x_3 + 4.80\,x_7$ (2.40) (4.92)	0.399	2.22	3/10	3.71	6.55
Textile mill products (23)	$y = 0.9080 + 1.00\,x_2 + 0.99\,x_3$ (50.15) (16.57)	0.835	27.89	2/11	3.98*	7.20*
Clothing and other fabricated textiles (243, 244)	$y = 2.3267 + 0.38\,x_2 + 1.04\,x_3 - 71.0\,x_6$ (2.99) (2.63) (5.17)	0.651	5.60	3/9	3.86*	6.99
Leather and footwear (241, 29)	$y = 1.70 + 0.75\,x_2 + 0.72\,x_3$ (21.38) (4.49)	0.715	11.32	2/9	4.26*	8.02*
Furniture and fixtures (26)	$y = 23.05 + 1.70\,x_2 - 1.56\,x_6 - 7.05\,x_7$ (4.65) (16.30) (2.38)	0.900	18.07	3/6	4.76	9.78*
Lumber and wood products (25)	$y = -1.30 + 0.40\,x_2 + 2.58\,x_3$ (25.17) (19.83)	0.929	46.29	2/7	4.74*	9.55*
Lumber and wood, including furniture (25, 26)	$y = 0.769 + 0.51\,x_2 + 1.35\,x_3$ (25.81) (23.05)	0.824	25.90	2/11	3.98*	7.20*
Paper and paper products (27)	$y = -15.7590 + 1.49\,x_2 + 0.81\,x_6 + 5.67\,x_7$ (31.03) (6.96) (1.83)	0.897	29.28	3/10	3.71*	6.55*
Printing and publishing (28)	$y = 11.2858 - 2.82\,x_7$ (11.59)	0.491	11.59	1/12	4.75*	9.33*
Rubber products (30)	$y = 0.1190 + 1.35\,x_2 + 0.65\,x_3 + 0.43\,x_6$ (78.84) (10.13) (5.01)	0.908	29.65	3/9	3.86*	6.99*
Chemical and chemical products (31)	$y = 0.0860 + 1.44\,x_2 + 0.56\,x_3$ (30.06) (3.77)	0.830	27.04	2/11	3.98*	7.20*
Petroleum and coal products (32)	$y = 8.7101 + 1.21\,x_2 - 2.58\,x_7$ (15.09) (5.57)	0.740	15.71	2/11	3.98*	7.20*
Glass, stone and clay products (33)	$y = 0.8192 + 1.73\,x_2 + 0.41\,x_6$ (16.76) (1.84)	0.787	18.56	2/10	4.10*	7.56*
Metal and metal products (34, 35)	$y = 0.6213 + 1.16\,x_2 + 0.79\,x_3$ (60.44) (15.75)	0.863	34.77	2/11	3.98*	7.20*
Primary metals (34)	$y = 0.2767 + 2.07\,x_2 + 0.26\,x_6$ (70.73) (3.23)	0.877	35.66	2/10	4.10*	7.56*
Fabricated metal products (excluding machinery) (35)	$y = 1.29 + 0.77\,x_2 + 0.54\,x_3 + 0.19\,x_6$ (224.88) (17.20) (3.15)	0.964	81.09	3/9	3.86*	6.99*
Machinery, excluding electrical (36)	$y = -21.25 + 1.98\,x_2 + 0.40\,x_3 + 1.09\,x_6 + 6.83\,x_7$ (42.58) (3.42) (5.58) (5.16)	0.879	14.57	4/8	3.48*	5.99*
Electrical machinery (37)	$y = -7.4814 + 1.59\,x_2 + 0.46\,x_3 + 2.63\,x_7$ (22.16) (1.79) (1.66)	0.737	9.36	3/10	3.71*	6.55*
Transportation equipment (38)	$y = -28.9513 + 1.95\,x_2 + 0.91\,x_3 + 0.30\,x_6 + 9.70\,x_7$ (40.51) (8.25) (8.90) (14.15)	0.886	13.70	4/7	4.12*	7.85*
Miscellaneous manufacturing (including instruments) (39)	$y = 1.0409 + 0.85\,x_2 + 0.91\,x_3 - 0.30\,x_6$ (36.84) (10.84) (1.98)	0.854	19.53	3/10	3.71*	6.55*

* Significant.

L_j = labour force of industry j,
Q_j = production of industry j,
K_j = constant.

b_{ij} becomes the elasticity of x_{ij} with respect to productivity in industry j.[12] In other words, for every per cent increase in productivity in industry j the proportion of occupation i in industry j will increase by b_{ij} per cent.

$$b_{ij} = \frac{\frac{d(x_{ij})}{x_{ij}}}{\frac{d(Q_j/L_j)}{Q_j/L_j}} \text{ from whence } \frac{d(x_{ij})}{x_{ij}} = b_{ij}\frac{d(Q_j/L_j)}{Q_j/L_j} \qquad (11)$$

$d(x_{ij})X_{ij}$ is the rate of growth of the proportion x_i in industry j; $d(Q_j/L_j)/(Q_j/L_j)$ is the rate of growth of productivity in industry j. Now, the rate of growth of X_{ij}, the number of workers of occupation i in industry j, will depend on two rates of growth: 1) x_{ij} the rate of growth of employment in industry j assuming no change in productivity; and 2) r_{pj} the rate of growth of productivity assuming no change in employment.

[12] Applying logarithms to (10) we have

$$\log x_{ij} = \log K_j + b_{ij} \log (Q_j/L_j)$$

$$\frac{d \log x_{ij}}{d \log (Q_j/L_j)} = b_{ij}.$$

Total rate of growth of $X_{ij} = r_{pj} + r_{L_j}$[13]

where r_{pj} is from (11) $= b_{ij}\frac{d(Q_j/L_j)}{Q_j/L_j}$

We can write therefore the following dynamic equation:

$$(DX_i)_t = \sum_{j=1}^{n} (X_{ij})_{t_0} \exp (b_{ij} r_{pj} + r_{L_j}) \qquad (12)$$

where $(DX_i)_t$ = demand for occupation i at time t in the economy as a whole. This demand equation can be applied to all occupations and thus provide a set of demand equations for occupations for the system as a whole.

5. THE b VALUES OF THE EQUATION

The value of the elasticity of the proportion of an occupation in the labour force of an industry with respect to a change in productivity can be derived by fitting a logarithmic expression of the equation (10) to the data of the Annexes:

$$\log x_{ij} = \log K_j + b_{ij} \log (Q_j/L_j). \qquad (13)$$

The values of b and r are presented in table 5.

[13] For the sake of simplicity we can ignore the second order influences.

TABLE 5. VALUES OF b AND r BY INDUSTRY AND OCCUPATION

ISIC No.*	(2–3)		(20, 21)		(22)		(23)		(24, 28, 244)		(241, 29)	
	b	r	b	r	b	r	b	r	b	r	b	r
Professional and technical workers	0.52	0.71	0.34	0.52	−0.16	−0.26	0.46	0.59	0.86	0.58	0.58	0.69
Professional and technical workers (adjusted)	0.58	0.85	0.55	0.69	−0.09	−0.24	0.58	0.75	0.90	0.62	0.72	0.76
Engineers	0.56	0.34	0.18	0.20	−1.18	−0.49	0.60	0.32	0.03	0.08	0.73	0.32
Engineers and scientists (adjusted)	0.58	0.74	−0.01	−0.04	−0.23	−0.30	0.74	0.70	0.02	−0.05	−0.59	−0.25
Technicians	0.94	0.42	0.22	0.13	−0.20	−0.13	0.85	0.35	0.83	0.31	0.17	−0.05
Technicians (adjusted)	0.51	0.73	0.89	0.48	0.03	−0.07	0.52	0.56	0.57	0.45	0.51	0.25
Administrators and managers	0.29	0.51	0.31	0.70	0.12	0.16	0.30	0.38	0.69	0.41	0.27	0.28
Clerical workers	0.06	0.16	0.09	0.37	−0.26	−0.49	0.13	0.30	0.69	0.32	0.32	0.41
Clerical workers (adjusted)	0.19	0.17	0.21	0.32	−0.10	−0.31	0.12	0.31	0.51	0.33	0.44	0.35
Sales workers	0.53	0.55	0.00	−0.18	0.23	0.31	0.24	0.27	0.54	0.27	−0.22	−0.28
Manual workers	−0.06	−0.64	−0.04	−0.42	0.03	0.37	−0.04	−0.62	−0.04	−0.61	−0.02	−0.14
Metal fabricators and makers	0.01	0.19	0.20	0.34	0.40	0.19	0.51	0.26	0.64	0.37	0.58	−0.35
Construction workers	−0.25	−0.13	0.00	0.27	−0.02	0.00	0.00	0.00	−1.30	−0.48	1.06	0.46
Transportation workers	0.17	0.40	0.48	0.76	−0.51	−0.29	−0.24	−0.05	0.10	0.11	−0.15	−0.02
Mechanics and repairmen	0.42	0.20	1.27	0.50	0.57	0.11	0.97	0.27	0.25	0.09	0.55	−0.02
Labourers	0.33	0.24	0.05	0.00	0.46	0.26	0.89	0.27	0.64	0.21	0.38	0.36
Service workers	−0.06	0.01	0.22	0.28	−0.13	−0.20	0.01	0.10	0.24	0.39	−0.02	−0.02
University graduates	0.62	0.62	0.44	0.28	0.23	−0.03	0.43	0.39	0.41	0.22	0.44	0.27

TABLE 5. VALUES OF *b* AND *r* BY INDUSTRY AND OCCUPATION *(continued)*

ISIC No.*	(26) b	(26) r	(25) b	(25) r	(25, 26) b	(25, 26) r	(27) b	(27) r	(28) b	(28) r	(30) b	(30) r
Professional and technical workers	0.80	0.58	0.94	0.81	0.67	0.59	0.63	0.78	0.19	0.32	0.51	0.83
Professional and technical workers (adjusted)	0.69	0.84	0.94	0.85	0.56	0.68	0.75	0.88	0.36	0.55	0.56	0.88
Engineers	1.08	0.52	0.59	0.32	0.44	0.34	0.74	0.29	−0.90	−0.19	0.50	0.23
Engineers and scientists (adjusted)	1.00	0.73	0.48	0.38	0.25	0.31	0.65	0.65	−1.30	−0.50	0.62	0.51
Technicians	0.92	0.49	1.07	0.66	0.72	0.54	1.27	0.42	0.47	0.22	1.14	0.48
Technicians (adjusted)	0.50	0.52	1.14	0.83	0.68	0.67	0.73	0.72	0.24	0.28	0.45	0.71
Administrators and managers	0.67	0.49	0.54	0.35	0.29	0.60	0.17	0.17	0.19	0.28	0.15	0.24
Clerical workers	0.42	0.58	−0.12	−0.40	0.19	0.34	0.16	0.07	0.26	0.80	0.10	0.26
Clerical workers (adjusted)	0.41	0.65	−0.18	−0.53	0.21	0.38	0.40	0.17	0.28	0.27	0.33	0.43
Sales workers	0.35	0.17	−0.15	−0.36	0.31	0.28	0.25	0.05	0.98	0.61	0.18	0.21
Manual workers	−0.06	−0.74	−0.01	−0.30	−0.03	−0.58	−0.04	−0.50	−0.21	−0.70	−0.06	−0.63
Metal fabricators and makers	0.61	0.71	−0.17	−0.09	0.38	0.55	0.77	0.31	−0.11	−0.04	0.53	0.32
Construction workers	−0.03	0.02	0.07	0.35	−0.31	0.06	0.33	0.41	0.27	0.15	0.37	0.27
Transportation workers	0.22	0.14	0.22	0.59	0.55	0.40	−0.09	0.16	−0.07	0.01	−0.22	−0.07
Mechanics and repairmen	1.22	0.52	1.20	0.54	0.91	0.47	0.85	0.25	0.84	0.27	0.54	0.13
Labourers	0.62	0.33	0.62	0.20	0.64	0.27	0.54	0.21	−0.07	−0.04	0.26	0.00
Service workers	0.39	0.44	0.15	0.33	0.31	0.25	0.09	0.05	0.00	0.10	0.04	0.14
University graduates	0.54	0.37	0.34	0.21	0.44	0.43	0.46	0.34	0.55	0.50	0.58	0.41

ISIC No.*	(31) b	(31) r	(32) b	(32) r	(33) b	(33) r	(34, 35) b	(34, 35) r	(34) b	(34) r	(341) b	(341) r
Professional and technical workers	0.32	0.71	0.48	0.70	0.39	0.86	0.55	0.66	0.25	0.51	0.05	0.12
Professional and technical workers (adjusted)	0.48	0.88	0.43	0.78	0.43	0.87	0.64	0.82	0.38	0.92	0.23	0.53
Engineers	0.50	0.24	0.52	0.68	0.79	0.41	0.81	0.65	0.47	0.29	0.43	0.55
Engineers and scientists (adjusted)	0.46	0.78	0.42	0.80	0.45	0.59	0.70	0.76	0.41	0.68	0.47	0.70
Technicians	1.02	0.31	0.71	0.20	1.11	0.56	1.12	0.40	0.96	0.43	−0.39	−0.62
Technicians (adjusted)	0.52	0.74	0.41	0.62	0.51	0.85	0.57	0.67	0.36	0.70	0.09	0.05
Administrators and managers	0.28	0.51	0.21	0.25	0.35	0.12	0.28	0.32	−0.03	−0.19	0.21	0.51
Clerical workers	0.02	−0.04	0.05	0.07	0.18	0.67	0.19	0.27	0.00	0.13	0.06	0.60
Clerical workers (adjusted)	0.28	0.27	0.14	0.11	0.32	0.55	0.34	0.26	0.19	0.08	0.39	0.78
Sales workers	0.37	0.50	0.15	0.13	0.60	0.55	0.52	0.37	0.18	−0.05	0.41	0.62
Manual workers	−0.10	−0.55	−0.10	−0.47	−0.05	−0.70	−0.07	−0.57	−0.02	−0.14	−0.01	−0.45
Metal fabricators and makers	0.31	0.22	0.25	0.19	0.46	0.31	0.24	0.20	−0.24	−0.25	−0.40	−0.71
Construction workers	0.12	0.23	0.10	0.28	−0.14	0.10	0.12	0.07	0.36	0.23	−0.34	−0.75
Transportation workers	−0.55	−0.27	−0.05	0.14	0.15	0.42	−0.13	−0.04	−0.13	−0.06	−0.32	−0.66
Mechanics and repairmen	0.80	0.24	1.60	0.53	0.80	0.21	0.50	0.11	0.43	0.02	2.74	0.79
Labourers	0.16	0.00	−0.18	−0.23	0.45	0.36	0.47	0.22	0.42	0.13	0.09	0.07
Service workers	−0.12	−0.07	−0.31	−0.22	−0.04	0.04	0.15	0.10	0.22	0.23	−0.17	−0.32
University graduates	0.55	0.78	0.25	0.23	0.52	0.53	0.67	0.61	0.46	0.61	0.74	0.86

TABLE 5. VALUES OF *b* AND *r* BY INDUSTRY AND OCCUPATION *(continued)*

*ISIC No.**	*(342)* *b*	*r*	*(35)* *b*	*r*	*(36)* *b*	*r*	*(37)* *b*	*r*	*(38)* *b*	*r*	*(383, 384, 386)* *b*	*r*
Professional and technical workers	0.22	0.75	0.73	0.77	0.45	0.53	0.54	0.57	0.66	0.49	0.52	0.88
Professional and technical workers (adjusted)	0.44	0.93	0.97	0.88	0.43	0.84	0.52	0.82	0.67	0.76	0.71	0.97
Engineers	0.57	0.63	1.09	0.71	0.79	0.39	0.77	0.31	0.91	0.33	0.57	0.68
Engineers and scientists (adjusted)	0.66	0.82	1.04	0.85	0.28	0.64	0.50	0.76	0.66	0.62	0.70	0.79
Technicians	−0.34	−0.60	0.86	0.40	0.68	0.09	1.18	0.31	1.03	0.33	0.35	0.46
Technicians (adjusted)	0.27	0.59	0.94	0.82	0.25	0.32	0.55	0.72	0.68	0.73	0.82	0.91
Administrators and managers	0.40	0.31	0.26	0.23	0.17	0.12	0.18	0.16	0.21	0.35	−0.03	−0.44
Clerical workers	0.04	0.13	0.23	0.38	0.16	0.13	0.10	0.14	0.27	0.31	0.14	0.12
Clerical workers (adjusted)	0.34	0.53	0.42	0.32	0.17	0.11	0.11	0.02	0.34	0.30	0.12	0.17
Sales workers	0.68	0.84	0.40	0.27	0.43	0.21	0.18	0.20	0.23	0.27	−0.20	−0.51
Manual workers	−0.04	−0.61	−0.0[illegible]	−0.66	0.07	−0.43	−0.09	−0.26	−0.07	−0.53	−0.04	−0.40
Metal fabricators and makers	−0.66	−0.80	−0.29	−0.32	−0.07	0.00	0.26	0.27	0.13	0.20	−0.34	−0.62
Construction workers	−0.13	−0.15	0.09	0.08	−0.23	0.00	−0.49	−0.15	−0.15	−0.23	−0.37	−0.60
Transportation workers	−0.48	−0.51	0.11	0.31	−0.24	−0.08	−0.33	−0.15	−0.07	0.03	−0.13	−0.01
Mechanics and repairmen	2.92	0.69	0.61	0.15	0.23	0.00	0.31	0.11	−0.40	−0.15	0.06	−0.17
Labourers	−0.34	−0.46	0.46	0.27	0.03	−0.04	0.12	0.08	0.12	0.17	−0.25	−0.10
Service workers	−0.42	−0.43	0.06	0.18	0.16	0.16	0.27	0.15	0.21	0.26	0.06	0.37
University graduates	0.97	0.93	0.73	0.61	0.34	0.66	0.58	0.83	0.80	0.67	0.72	0.71

*ISIC No.**	*(391, 392, 393)* *b*	*r*	*(39)* *b*	*r*
Professional and technical workers	0.55	0.82	0.67	0.68
Professional and technical workers (adjusted)	0.70	0.96	0.80	0.83
Engineers	0.55	0.60	1.01	0.29
Engineers and scientists (adjusted)	0.60	0.83	0.62	0.56
Technicians	1.05	0.48	1.00	0.29
Technicians (adjusted)	0.81	0.94	0.89	0.90
Administrators and managers	0.03	−0.07	0.29	0.51
Clerical workers	0.13	0.37	0.36	0.28
Clerical workers (adjusted)	0.16	0.40	0.44	0.38
Sales workers	0.06	−0.05	0.40	0.30
Manual workers	−0.10	−0.76	−0.11	−0.51
Metal fabricators and makers	−0.41	−0.46	0.21	0.15
Construction workers	0.00	0.19	−0.15	0.08
Transportation workers	−0.22	−0.08	0.14	0.38
Mechanics and repairmen	0.80	0.05	0.42	0.02
Labourers	−0.32	−0.16	0.39	0.24
Service workers	0.09	0.39	−0.02	0.16
University graduates	0.54	0.67	0.56	0.50

* *Manufacturing Industries*	*ISIC No.*
Manufacturing	(2−3)
Food and beverages	(20, 21)
Tobacco and tobacco products	(22)
Textile mill products	(23)
Clothing and other fabricated textiles	(243, 244)
Leather and its products (including footwear)	(241, 29)
Furniture and fixtures	(26)
Lumber and wood products (excluding furniture)	(25)
Lumber and wood products (including furniture)	(25, 26)
Paper and paper products	(27)
Printing and publishing	(28)
Rubber products	(30)
Chemicals and chemical products	(31)
Petroleum and coal products	(32)
Glass, stone and clay products	(33)
Metal and metal products	(34, 35)
Primary metals	(34)
Iron and steel	(341)
Non-ferrous metals	(342)
Fabricated metal products (excluding machinery)	(35)
Machinery (excluding electrical)	(36)
Electrical machinery and equipment	(37)
Transportation equipment	(38)
Motor vehicles etc.	(383, 384, 386)
Professional and scientific instruments	(391, 392, 393)
Miscellaneous manufacturing (including instruments)	(39)

It is interesting to note that for all major groups except that of manual workers, the coefficient is positive for most industries. This means that their proportion increases while that of manual workers decreases, as productivity rises. (This does not mean that there are no shifts among the minor groups.) Also, the only significant relationships are to be found in the professional and technical groups and the manual workers group. The statistical significance for administrators and managers, clerical and sales workers is weak.[14]

If we adjust the professional and technical group according to education (as shown above)[15] the coefficient of correlation is much larger, and also b becomes bigger. The size of the coefficient b is extremely important because it gives an idea of how fast the proportion of an occupation in the labour force has to expand if we wish to improve productivity at a given rate. If we intend to expand productivity by 3 per cent a year and the value of b is 0.8, the proportion of this occupation has to grow at 2.4 per cent; if however the value of b is only 0.1, the proportion will grow only at 0.3 per cent.

For the major group of professional and technical workers the value of b is always less than 1 in all manufacturing industries, and about 0.5 for the sector in general.

If we intend to develop the manufacturing sector at a rate of growth of about 6 per cent a year—a common assumption in many plans—of which 3 per cent is because of an increase in employment and 3 per cent due to an increase in productivity, the group of professionals and technicians in this industry has to expand at $3\% + 3 \cdot 0.5\% = 4.5\%$ a year. In other words, the number of professionals and technicians in this industry has to double in 14 years.

On the other hand, the coefficient of manual workers is generally very small and negative, the average for the manufacturing sector being -0.06, and therefore the rate of growth of productivity becomes unimportant compared with that of total employment. Using the figures given in the above example

$$3\% + (-0.06)\, 3\% = 2.82\%.$$

Very revealing also are the coefficients for some of the minor groups. The result obtained from applying corrections to the census figures according to the level of education are startling. If we correlate the unadjusted figures of the proportion of engineers and technicians in the labour force with productivity in manufacturing, the relationship is not significant—the coefficients of correlations are $r = 0.34$ and $r = 0.42$ respectively—but when we introduce the adjustments the coefficients of correlations become meaningful in a statistical sense—0.74 and 0.73, respectively. The coefficients b also become slightly higher in the correlations using adjusted figures (see table 5). In other words, when figures are adjusted for educational levels there is direct and meaningful relationship between the proportion of engineers in the labour force and productivity, and between the proportion of technicians in the labour force and productivity, but there is almost no relationship when the figures are not adjusted.

The absence of a systematic and meaningful relationship between productivity and the proportion of administrative[16], clerical and sales workers in the labour force, as well as that of some minor groups of manual workers such as construction workers, transportation workers, metal workers and labourers in all cross-country types of occupations in the labour force, is due chiefly to difficulties with the occupational classification. The demarcation line between skilled occupations and less skilled ones is blurred. In most classifications the item "other" in all these groups is too large to allow precise classification of the rest. In the case of administrators and managers, group classifications are too broad to be useful. A study of United States industries shows that as productivity goes up, the specialization of functions inside this group increases, although the total number remains constant.

We cannot rule out the possibility of substitution inside major groups although the opinion of production workers suggests that substitution among major groups is probably small.

6. A manpower planning model

The demand equation for a given occupation (see equation 12) can be used as a basis for developing a dynamic system of equations or models to allocate manpower in different industries, or to de-

[14] However, the analysis of the results of tables 1, 2, 3, 4 and 5 taken together may point to the fact that it is difficult to talk about a single variable but more appropriate to talk about structure of occupations.

[15] See section 2 above.

[16] It seems that the proportion of administrators and managers is more a function of the size of establishments than of productivity. An initial study by the author tends to show this result. The data, however, are still too limited to warrant a final statement. Another study shows that while the proportion of managers does not change with productivity, management functions do; see "Manpower Ratios in Manufacturing", *Factory*, Mar. 1965, pp. 84–91.

termine the rate at which supply of different occupations has to be available to attain goals of productivity and/or employment.

If we assume that the supply of a given occupation over time depends on the initial conditions of supply and expansion of educational and training facilities, we can write:

$$(SX_i)_t = (X_i)_{t_0} \exp (r_{gi} - r_{ai})\, t \qquad (14)$$

where

- $(SX_i)_t$ is the supply of people with occupation i at time t;
- $(X_i)_{t_0}$ is the initial stock of persons in occupation i at time t_0;
- r_{gi} is the rate of expansion of persons in occupation i (it may depend on the ability of the educational and vocational training systems to expand)[17];
- r_{ai} is the rate of attrition for persons in occupation i[18].

In the following example we shall assume the existence of three occupations, three industries, and also that demand for an occupation cannot exceed the supply.

$$(X_{11})_{t_0} \exp (b_{11} r_{p1} + r_{L1})\, t + (X_{12})_{t_0} \exp (b_{12} r_{p2} + r_{L2})\, t + (X_{13})_{t_0} \exp (b_{13} r_{p3} + r_{L3})\, t = (X_1)_{t_0} \exp (r_{g1} - r_{a1})\, t$$

$$(X_{21})_{t_0} \exp (b_{21} r_{p1} + r_{L1})\, t + (X_{22})_{t_0} \exp (b_{22} r_{p2} + r_{L2})\, t + (X_{23})_{t_0} \exp (b_{23} r_{p3} + r_{L3})\, t = (X_2)_{t_0} \exp (r_{g2} - r_{a2})\, t$$

$$(X_{31})_{t_0} \exp (b_{31} r_{p1} + r_{L1})\, t + (X_{32})_{t_0} \exp (b_{32} r_{p2} + r_{L2})\, t + (X_{33})_{t_0} \exp (b_{33} r_{p3} + r_{L3})\, t = (X_3)_{t_0} \exp (r_{g3} - r_{a3})\, t$$

The meaning of X, b, r_p, r_L, t_0, t are the same as in equation 12. This model can serve various purposes. Assuming that we fix the rate of growth of productivity and employment in each industry, it is possible to know the path that the educational system should follow (the b coefficients can be derived from table 5). Conversely, if we are better able to forecast the path of the educational system, we can solve for the rate of growth of productivity and employment for each industry and, according to the number of equations, introduce such constraints as minimum growth rates for productivity and employment, or maximization of employment rates.

7. EDUCATION AND PRODUCTIVITY

The role of education in economic development has come into prominence only in the last decade. The suggestion of Adam Smith that education and training be considered on the same basis as investment in capital[19] was completely disregarded for almost two centuries. The possession of education was considered part of the duty of a civilized citizen; more of a consumers' good than a producers' good.

From a theoretical point of view, the introduction of education as a new factor in production was virtually forced upon economists when the mere increase in capital goods and the increase in the labour force, as reflected in man-hours worked, failed to explain the actual rate of growth of the economy; and so a "residual", namely the difference between the observable rate of growth and the rate of growth derived theoretically from existing economic knowledge, made its appearance. This residual became "technological change", or the factor of technology. The next step was obvious: technological change is not a natural law but a consequence of something that was called knowledge—a function of education. Thus the education component of the labour force became a partner in the production process. The link between the production of physical goods and services and the educational system is productivity. From a production point of view, demand for education is a derived demand (the role of education as a consumption good will be considered later), because productivity is a function of the occupational distribution of the labour force (assuming that the complementary capital goods are available). Each occupation requires a certain educational level, formal or informal, and certain natural abilities; it is foolish to think that every person is capable of becoming a miner or is endowed with a mind capable of tackling higher mathematics. Hence, productivity is partly a function of different types of education. The direct linking, however, of pro-

[17] This is an oversimplification, i.e. this rate is also a function of other important variables such as wage levels, mobility and other social factors.

[18] This rate is a function of the age distribution of persons in the occupation, institutional factors and mobility between occupations.

[19] "The acquisition of talents by the maintenance of the acquirer during his education, study or apprenticeship, always costs a real expense, which is a capital fixed and realised as it were on his person. Those talents as they make a part of his fortune so do they likewise of that of the society to which he belongs. The improved dexterity of a workman may be considered in the same light as a machine or instrument of trade which facilitates and abridges labour, and which, though will cost a certain expense, repays that expense with a profit." Adam SMITH, *The Wealth of Nations*, 6th ed., Ed. Edwin Cannan, 1950, Book II, p. 264.

ductivity to formal education—an approach widely used[20]—ignores the other important variables in the causality process.

8. Relationship between productivity and education

It is extremely difficult to try to relate productivity with education. First of all, the countries that offer cross-classifications of occupation by industry and occupation by education in sufficient detail to make the figures meaningful present the data on education in such ways that it is very difficult to standardize them. Some present them in the form of years of schooling (Argentina 1960, Japan 1960, and the United States of America 1950 and 1960), others according to the type of schooling completed (France 1962, Federal Republic of Germany 1957, Japan 1960, Netherlands 1960, Norway 1960, Sweden 1960, Yugoslavia 1961). Still others present the data in broad intervals (Canada 1951 and 1961) and others according to terminal education age (the United Kingdom 1951 and 1961).

Apart from differences in the quality of education, how could we compare the classification of France, for example, with that of the United Kingdom? In France the respondent gives as an answer his terminal degree, the difference between terminal degrees being about 3 to 4 years of schooling. In the United Kingdom the respondent tells us the age at which he left school; but the age is in groups of ages; what about all those between the first and the last age in each group? Too many additional assumptions have to be made for a sound comparison.

Secondly, most countries do not report vocational training and evening studies, data very crucial for determining the levels of education of blue-collar workers. Thirdly, and most important of all, is the already-mentioned intermingling of considerations on the income-consumption effect on education with those based on production requirements or investment.

Consumption of education is a function not only of income but also of other variables, such as cultural environment, traditions and institutional settings. The best example of all is Japan, where income *per capita* is far below that of some other countries, but where the average level of education is higher. It is also a matter of knowledge that in many countries some minorities with a traditional cultural background provide a higher level of education for their children than some others with the same level of income. Legal provisions also promote differences in educational attainments. In some countries where the legal age for leaving school is 16 it is not surprising to find persons from an elementary school performing the most menial jobs; in others, where obligatory attendance ends at the fourth grade, the same job is held by fourth grade finishers or lower.

We cannot assume therefore that a higher average level of education automatically produces a higher level of output unless that higher level of education is a result of a "higher" occupational mix, such as more professionals and less labourers, and that this higher education is not the result of a minimum compulsory-level requirement.

Only by eliminating all these objections is it possible to study the interaction of education and productivity. Only one educational level was found to be free of these objections—university graduates. This level is less ambiguous than other levels of education for it requires 16 or more years of schooling and is above any compulsory level, thus reducing to some degree the institutional effect. The level is also high enough to depend less on the income-consumption effect.

The educational level of an industry is derived from the occupational distribution and the educational distribution by occupation of the labour force (see equation 6). Educational distribution of the labour force in a given industry[21] can be calculated as follows:

$$\begin{gathered}[x_1 \cdot 1A + x_2 \cdot 2A + x_3 3 \cdot A), \\ (x_1 \cdot 1B + x_2 \cdot 2B + x_3 \cdot 3B), \\ (x_1 \cdot 1C + x_2 \cdot 2C + x_3 \cdot 3C)].\end{gathered} \qquad (15)$$

If we assume that level C is university graduates, $(x_1 \cdot 1C + x_2 \cdot 2C + x_3 \cdot 3C)$ is the proportion of university graduates in the labour force of the industry. The data of the proportion of university graduates in the labour force by industry are presented in Annex I.

When fitting to the data a function of the form $\log y = a + b \log x$, where y is the proportion of university graduates in the labour force of a given industry, and x is the productivity of the same industry, the values of the coefficient of correlation and elasticity (coefficient b) show that there is a

[20] See for example TINBERGEN and CORREA, "Quantitative Adaptation of Education to Accelerated Growth", *Kyklos*, Vol. 15, 1962; TINBERGEN and BOS, "A Planning Model for the Educational Requirements of Economic Development", in *The Residual Factor and Economic Growth*, OECD, 1964; and *Econometric Models of Education: Some Applications*, OECD, 1965.

[21] This is so because the sum of the x's $= 1$ and the sum of $1A + 1B + 1C = 1$, $2A + 2B + 2C = 1$ and $3A + 3B + 3C = 1$.

good correlation between productivity and the proportion of university graduates in the labour force in most countries (see table 5).

The coefficient of elasticity for manufacturing in general is of the magnitude of 0.6. It is interesting to note that, if we disregard industries and correlate by country the proportion of university graduates with the productivity of all industries taken together, the figures are lower (see table 6). This leads us to believe that the relationship between productivity and university graduates is applicable within an industry more than across industries, and that the good relationships obtained from correlating income *per capita* with higher education, or with other types of education, are strongly biased by the consumption effect of education (multicollinearity).

TABLE 6. CORRELATION OF NUMBER OF UNIVERSITY GRADUATES PER 1000 WORKERS IN INDUSTRY WITH PRODUCTIVITY, FOR SELECTED COUNTRIES

Country		*r*	*b*
Argentina	1960	0.45	0.61
France	1962	0.69	0.90
Germany (Fed. Rep.)	1960[a]	0.44	0.78
Japan	1950	0.69	1.02
	1960	0.76	0.64
Netherlands	1960	0.69	0.84
Norway	1960	0.70	1.54
United Kingdom	1951	0.01	0.05
	1961	0.23	0.18
United States	1950	0.65	1.03
	1960	0.49	0.68
Yugoslavia	1961	0.42	0.36

[a] The data on occupations is for 1960, and on education for 1957, the latest available. The three years' difference is probably not very significant.

From a practical point of view the reason for determining the educational levels necessary to attain a given level of productivity is presumably to enable planners to develop an educational system capable of producing people with given skills and fit to perform the functions demanded by their occupations. It is, therefore, of little use to say that in order to achieve a given productivity in manufacturing it is necessary that x per cent of the working force be university graduates. This figure may help us estimate the size of the secondary school output but is useless for planning university education unless we know what type of university is needed. Two lawyers cannot be traded for one engineer and a physician cannot convert into an accountant. As we see, even if we know the percentage of university graduates necessary for a given productivity we shall have to take the whole pattern of occupational distribution into account to make the figure meaningful.

When we turn from university education to secondary education the problem becomes even more acute. Institutional settings and social traditions determine to a large extent the level of the formal education of its administrators and managers, and its sales, clerical and blue-collar workers. For example, in a country where there is a law requiring young people to stay in school until the age of 16 we may expect to find the average level of education of all workers in all industries is higher than in a country where compulsory school attendance ends at 12 years of age.

Even when productivity in the first country is higher than in the second—which is by no means certain—how much of this superiority should be attributed to a higher occupational structure (higher in the sense of having a larger proportion of people in the professions and white collar occupations), and how much to a higher formal educational level of the groups within the structure? Moreover, so far as manual work is concerned there is no simple way of assessing learning on-the-job as against learning in school and it is very doubtful that raising the average formal educational level of an industry while leaving the occupational distribution undisturbed will raise the level of productivity very much.

9. CONCLUDING REMARKS

The problems of manpower and education came to the fore when the pressure of automation and rapid technological change in developed countries caused a rapid change in occupational structures, and when the less-developed countries realized that lack of adequate manpower hindered their development. At the same time, with the available economic tools, it was not possible to explain the rapid growth of production, a growth greater than economics was able to justify solely by an increase of capital and labour. There was, so it was argued, something else: a residual or technological progress, or education.

This led to the exploration of a given direction in causality between education and productivity; that one way of increasing production (through productivity) is to raise the level of education. This conclusion may not be very helpful to developing nations because demand for education (from a production point of view) is only a derived demand and many other manpower and non-manpower variables have to be taken into account; an increase in productivity also demands generally different equipment and "human functions" to operate it.

Each human function requires a set of natural abilities as well as "learning". This learning is composed of formal schooling plus informal training and experience. Most of the more advanced human functions require more of the formal type of education, but a large majority of occupations can still do with substitutes for formal education such as on-the-job training. It is therefore of little use to try to link directly productivity or income *per capita* to formal education for planning purposes.

Pragmatically, planning for education involves three separate steps. *(i)* Given a goal for production and productivity (and consequently for employment) for each sector or industry, we have to determine the human functions or the number of people able to perform a given job who are necessary to achieve these objectives. *(ii)* We have to determine the most economic way to train these people so that they can perform these functions successfully. The way can be formal or informal education or a combination of both. *(iii)* Educators have to take into account these minimum demands (necessary to produce the planned income) when planning education for the country as a whole.

To implement the first step the tables given in Annex I, the coefficients of elasticity and the principles given in the models of this paper can be used. It is important to note that we are faced here with a problem that is not insurmountable from the point of view of methodology. But there is an uncomfortable feeling that we are testing a hypothesis with data that leave much to be desired. The fact that adjustments to educational data provide a better fit than expected, as in the case of different professional and technical occupations, points to the necessity of acquiring better data on the human functions involved in production.

The second step requires the close collaboration of economists and educators. And it is here that the greatest gains can be made. While a great deal is known about the training of professionals (although there is no doubt that great strides can be made even in this type of formal training), the training for skilled occupations is marred by institutional restrictions such as union policies, and is guided mostly by custom and tradition. It would be unwise for less-developed nations to get bogged down by the same prejudices that exist in more mature economies.

There is a great need to determine the different combinations of knowledge, ability and practice that go into every skilled blue-collar occupation independently of traditional ways and obsolete customs. Unfortunately we know little about this because educators are interested mainly in formal education, and a large percentage of persons employed in skilled occupations acquired the training for their job informally. Yet it is in this area that the developing countries will have to concentrate their efforts and develop imaginative programmes adapted to their own needs, not necessarily following the traditional path of advanced countries.

As shown in table 5, the employment effect is much larger in this group of operative skilled workers than the productivity effect; and for generations the bulk of the labour force will be in this category. The most economic way has to be found to prepare those workers for their functions — economic in terms not only of money but also of time. Failure to provide the necessary skills at a given moment of time cannot be remedied by the provision of more skills later on. In conjunction with this training, attention should also be paid to the retraining process. Here lessons can be learned from more advanced nations, where more and more effort goes into this.

The economist and manpower expert can give his view with some authority only on steps *(i)* and *(ii)*. The basic decisions with regard to step *(iii)* are political in nature. Education for a country is an all-inclusive system that flows over the boundaries imposed by production constraints. After all, the labour force is only part of the total production; more important perhaps is the fact that, while economists abstain from intruding upon the choice of consumption of physical goods, they insist in establishing themselves as arbiters in decision-making about the consumption of another good, education. Economists are no better qualified than any other citizen to decide upon consumption of education. They should only point to alternative choices.

Lastly, the successful incorporation of manpower into general planning will have to be carried out by a process of approximation. All new steps are likely to lead to pitfalls as well as to solutions, but progress can be made as long as they lead to the right question whether or not the right answer is given. In the words of John W. Tukey:

> "The most important maxim for data analysis to heed, and one that many statisticians

seem to have shunned, is this: Far better an approximate answer to the right question, which is often vague, than an exact answer to the wrong question which can always be made precise. It would be a mistake not to face up to this fact, for by denying it, we would deny ourselves the use of a great body of approximate knowledge, as well as failing to maintain alertness to the possible importance in each particular instance of particular ways in which our knowledge is incomplete."[22]

[22] J. W. TUKEY, "The Future of Data Analysis", *Annals of Mathematical Statistics*, Vol. 33, 1962, pp. 13–14.

ANNEX I

TABLES SHOWING OCCUPATIONAL DISTRIBUTION IN THE MANUFACTURING INDUSTRIES OF SELECTED COUNTRIES
(per thousand of persons engaged)

Data for the following countries include occupation by industry and education by occupation: Argentina 1960, Canada 1951 and 1961, England and Wales 1951 and 1961, France 1961, Germany (Federal Republic) 1960,[1] Japan 1950 and 1960; the Netherlands 1960, Norway 1960, United States 1950 and 1960, Yugoslavia 1961.

Data for the following countries cover only occupation by industry, since that on education is either unavailable or insufficient in detail to warrant analysis: Belgium 1960, Chile 1960, Finland 1960, Ireland 1960, Israel 1960, New Zealand 1960, Sweden 1960.

Note: The data on occupation by industry and education by occupation were calculated from tables in M. A. HOROWITZ, M. ZYMELMAN and I. L. HERRNSTADT, *Manpower Requirements for Planning, An International Comparison Approach*, Northeastern University, Boston, Mass., 1966.[2]

[1] As educational data for 1960 were not available, data on occupation by industry for 1957 were used.
[2] This publication presents manpower and education data of manufacturing industries for countries at different levels of productivity and the possible applications of these data to manpower planning.

	Argentina 1960	Canada 1951	Canada 1961	France 1962	Germany (Fed. Rep.) 1960	Japan 1950	Japan 1960	Netherlands 1960	Norwa[y] 1960
Manufacturing ISIC (2–3)									
Professional and technical workers	12	33	52	55	51	18	18	44	40
Professional and technical workers (adjusted)	10	30	42	27	37	10	16	23	29
Engineers	6	8	13	22	33	8	12	2	9
Engineers and scientists (adjusted)	5	9	14	15	21	4	7	5	7
Technicians	0.1	9	18	27	12	4	0.1	32	21
Technicians (adjusted)	4	18	19	10	15	4	7	16	18
Administrators and managers	35	56	64	48	22	37	40	36	45
Clerical workers	64	113	51	91	96	100	111	109	64
Clerical workers (adjusted)	31	94	44	20	77	72	110	88	28
Sales workers	12	28	39	22	23	27	31	20	9
Manual workers	846	723	709	751	768	782	791	743	821
Metal fabricators and makers	24	133	114	161	222	87	188	156	160
Construction workers	127	39	35	22	75	22	5	29	74
Transportation workers	19	22	36	16	23	8	15	42	28
Mechanics and repairmen	118	37	30	40	38	36	9	61	81
Labourers	17	125	85	114	63	42	58	11	29
Service workers	15	17	17	15	18	12	11	31	12
University graduates	8			29	29	14	34	12	13
Productivity (US $)	1,300	5,220	7,890	(3,300)	(3,100)	600	1,400	2,700	3,660
Food and beverages ISIC (20 and 21)									
Professional and technical workers	10	24	22	8	9	3	6	29	12
Professional and technical workers (adjusted)	8	21	18	5	6	1	6	14	10
Engineers	3	2	2	6	5	0.1	5	0.1	2
Engineers and scientists (adjusted)	4	5	4	4	4		3	2	1
Technicians	0.1	5	7	2	4	3	0.1	24	5
Technicians (adjusted)	4	15	11	1	2	1	3	11	6
Administrators and managers	43	69	74	112	27	34	53	40	49
Clerical workers	91	126	121	80	74	68	91	121	70
Clerical workers (adjusted)	45	105	105	17	60	49	89	98	31
Sales workers	22	51	57	54	118	88	105	36	14
Manual workers	794	689	694	716	646	796	731	740	839
Metal fabricators and makers	3	11	7	15	16	0.1	5	5	4
Construction workers	24	15	10	9	14	2	1	16	20
Transportation workers	62	76	148	55	53	10	36	93	76
Mechanics and repairmen	28	3	23	15	3	3	0.1	26	12
Labourers	41	160	106	141	60	41	129	16	42
Service workers	15	25	21	16	16	7	2	33	10
University graduates	9			16	7	12	33	7	6
Productivity (US $)	2,070	6,310	8,500	(3,700)	(3,750)	430	1,140	3,000	3,140
Tobacco and tobacco products ISIC (22)									
Professional and technical workers	28	12	18	38	13	53	22	8	19
Professional and technical workers (adjusted)	19	10	13	28	11	21	22	4	15
Engineers	3	0.1	0.1	12	13	6	16	0.1	2
Engineers and scientists (adjusted)	4	0.1	0.1	8	8	5	9	1	2
Technicians	1	0.1	7	22	0.1	38	0.1	6	3
Technicians (adjusted)	13	10	11	19	3	15	13	3	11
Administrators and managers	34	36	38	96	19	35	41	24	50
Clerical workers	120	142	120	69	72	268	268	93	145
Clerical workers (adjusted)	58	118	105	16	58	183	262	75	63
Sales workers	11	24	26	8	29	17	9	32	58
Manual workers	779	695	716	671	849	572	614	815	712
Metal fabricators and makers	4	12	21	46	14	6	22	2	4
Construction workers	13	12	10	2	7	6	3	8	13
Transportation workers	23	12	5	1	14	9	9	30	41
Mechanics and repairmen	37	0.1	42	7	1	15	0.1	26	22
Labourers	22	94	53	178	53	47	91	5	45
Service workers	17	12	24	22	10	58	44	26	24
University graduates	10			25	11	22	61	4	12
Productivity (US $)	2,550	8,110	11,750	(5,400)	(3,150)	700	1,200	2,500	2,530

United Kingdom 1951	United Kingdom 1961	United States 1950	United States 1960	Yugoslavia 1961	Belgium	Chile	Finland	Ireland	Israel	New Zealand	Sweden
				MANUFACTURING ISIC (2–3)*							
31	56	52	74	44	29	10	36	18	29	24	50
17	30	42	65	33							
5	13	18	27	8	9	3	29	1	7	2	28
4	8	15	24	8							
17	31	12	22	27	18	4	1	2	10	8	11
11	19	22	25	24							
39	38	47	50	14	28	31	24	31	63	49	51
109	115	116	121	32	97	52	71	87	72	83	85
95	80	100	110	30							
13	21	31	38	12	11	5	16	20	17	65	51
788	713	773	675	794	761	870	791	833	776	799	707
158	188	91	82	98	187	66	141	40	154	131	109
31	38	20	17	42	49	82	51	35	77	43	32
23	50	23	29	43	33	21	35	38	13	20	33
24	1	33	35	0.1	44	118	53	48	48	55	115
138	70	80	53	141	4	9	69	152	36	36	39
16	25	18	15	43	66	14	30	11	22	13	24
9	13	43	53	14							
2,070	2,540	7,310	10,240	1,260	2,520	1,000	2,800	2.540	2,190	4,340	4,880
				FOOD AND BEVERAGES ISIC (20 AND 21)							
14	24	25	21	26	9	12	22	14	17	13	20
9	15	21	18	21							
1	4	5	3	6	5	5	16	1	3	1	9
3	4	6	2	6							
6	9	6	7	9	4	7	5	0.1	7	4	6
5	10	13	15	14							
50	47	75	74	22	35	56	34	44	60	47	133
116	124	112	103	84	97	80	95	101	90	87	80
66	86	98	92	32							
33	68	54	68	36	29	9	51	33	63	26	19
788	660	700	683	754	742	782	740	771	712	807	666
26	28	10	8	9	13	9	9	2	36	33	1
18	21	9	6	15	19	32	16	11	21	28	6
66	96	87	149	60	124	81	78	99	57	81	75
5	0.1	29	33	0.1	17	31	18	26	9	4	22
196	111	103	74	160	16	23	44	221	65	28	37
20	30	24	21	59	84	33	43	9	26	12	52
7	12	34	35	13							
1,760	2,410	7,080	11,250	1,140	5,220	1,100	3,240	2,790	2,740	4,920	6,530
				TOBACCO AND TOBACCO PRODUCTS ISIC (22)							
11	15	9	18	49	5	45	25	22		20	
6	8	7	15	33							
0.1	0.1	0.1	1	7	2	10	19	0.1		1	
0.1	0.1	2	1	8							
8	9	0.1	6	30	1	30	3	0.1		2	
6	3	5	13	24							
28	22	37	40	18	28	22	32	25		42	
179	205	65	75	87	91	221	61	197		120	
102	147	57	68	33							
33	34	22	41	12	30	12	16	63		43	
729	674	835	754	791	804	652	823	664		755	
26	34	14	16	6	10	4	28	0.1		38	
13	13	6	3	11	8	37	21	0.1		15	
23	53	8	8	34	37	45	25	13		8	
6	0.1	20	35	0.1	35	67	43	22		4	
50	53	79	67	78	1	54	22	99		18	
28	37	23	29	48	41	52	53	0.1		22	
4	7	19	28	14							
3,560	5,480	11,390	19,510	3,220	2,450	3,200	4,510	5,290		5,370	

* Belgium – Sweden inclusive: 1960

	Argentina 1960	Canada 1951	Canada 1961	France 1962	Germany (Fed. Rep.) 1960	Japan 1950	Japan 1960	Netherlands 1960	Norway 1960
TEXTILE MILL PRODUCTS ISIC (23)									
Professional and technical workers	8	19	23	14	23	4	3	20	17
Professional and technical workers (adjusted)	7	17	17	7	16	2	3	10	13
Engineers	2	3	3	7	16	0.1	2	0.1	4
Engineers and scientists (adjusted)	3	4	4	5	10	0.1	1	1	3
Technicians	0.1	8	11	6	3	3	0.1	13	9
Technicians (adjusted)	3	12	9	2	6	2	2	8	9
Administrators and managers	36	34	44	33	23	30	35	27	41
Clerical workers	67	89	107	80	78	67	63	81	54
Clerical workers (adjusted)	33	44	93	27	63	48	62	66	24
Sales workers	14	12	18	15	12	11	15	7	10
Manual workers	853	790	760	827	831	882	868	810	860
Metal fabricators and makers	1	16	15	23	23	1	30	9	6
Construction workers	13	16	10	7	13	19	2	15	22
Transportation workers	6	6	6	7	11	3	6	33	9
Mechanics and repairmen	36	1	33	15	2	23	0.1	29	20
Labourers	10	115	70	132	68	19	27	0.1	37
Service workers	12	18	15	15	20	15	15	36	14
University graduates	13			12	15	9	19	5	7
Productivity (US $)	1,600	4,440	6,540	(2,300)	(2,350)	480	890	1,600	2,840
CLOTHING AND OTHER FABRICATED TEXTILES ISIC (243 AND 244)									
Professional and technical workers	0.1	12	13	11	7	1	2	6	4
Professional and technical workers (adjusted)	0.1	10	12	5	6	1	2	6	3
Engineers	0.1	1	0.1	2	4	0.1	0.1	0.1	1
Engineers and scientists (adjusted)	0.1	1	0.1	1	3	0.1	0.1	0.1	1
Technicians	0.1	0.1	0.1	3	0.1	1	0.1	0.1	2
Technicians (adjusted)	0.1	8	1	4	4	1	2	6	2
Administrators and managers	12	56	58	43	22	34	26	34	46
Clerical workers	12	75	78	44	49	61	49	52	36
Clerical workers (adjusted)	12	62	68	10	39	43	48	42	16
Sales workers	4	30	30	34	15	33	58	13	11
Manual workers	961	804	806	827	839	863	862	834	869
Metal fabricators and makers	0.1	2	1	2	1	0.1	6	0.1	1
Construction workers	36	2	0.1	2	1	1	1	1	5
Transportation workers	1	2	3	3	4	1	4	17	3
Mechanics and repairmen	1	0.1	4	4	2	6	0.1	7	4
Labourers	1	27	22	37	19	14	17	0.1	19
Service workers	3	12	8	28	45	5	2	9	31
University graduates	3			6	6	11	15	3	4
Productivity (US $)	710	3,800	4,430	(1,460)	(1,060)	280	600	1,100	2,360
LEATHER AND LEATHER PRODUCTS, INCLUDING FOOTWEAR ISIC (29 AND 241)									
Professional and technical workers	3	8	17	6	10	2	2		
Professional and technical workers (adjusted)	2	7	15	4	9	1	2		
Engineers	0.1	0.1	0.1	4	9	0.1	2		
Engineers and scientists (adjusted)			0.1	3	6		1		
Technicians	0.1	3	1	1	0.1	2	0.1		
Technicians (adjusted)	2	7	12	1	3	1	1		
Administrators and managers	44	47	47	41	21	34	32		
Clerical workers	36	68	90	45	55	60	69		
Clerical workers (adjusted)	18	56	78	10	44	42	68		
Sales workers	11	23	22	20	13	54	48		
Manual workers	895	828	802	873	860	843	844		
Metal fabricators and makers	2	3	5	8	8	0.1	3		
Construction workers	14	6	4	6	6	0.1	0.1		
Transportation workers	3	3	2	5	4	4	3		
Mechanics and repairmen	7	0.1	9	3	1	2	0.1		
Labourers	5	65	47	75	46	22	19		
Service workers	6	12	10	6	6	6	4		
University graduates	3			5	8	10	30		
Productivity (US $)	1,130	2,760	4,250	(2,500)	(2,600)	560	1,020		

United Kingdom 1951	*United Kingdom* 1961	*United States* 1950	*United States* 1960	*Yugoslavia* 1961	*Belgium*	*Chile*	*Finland*	*Ireland*	*Israel*	*New Zealand*	*Sweden*
					TEXTILE MILL PRODUCTS ISIC (23)						
11	15	14	17	26	10	10	24	6	22	13	19
7	9	12	15	18							
1	3	3	4	3	3	2	18	0.1	5	0.1	7
2	2	4	3	3							
6	5	4	6	9	7	7	5	0.1	14	7	4
4	5	7	11	15							
28	33	24	28	9	23	35	20	21	75	33	40
57	68	61	73	52	71	63	50	56	76	54	55
33	47	53	66	30							
6	11	9	12	11	5	4	13	9	9	15	13
880	855	860	820	856	853	845	857	863	783	845	807
18	11	12	11	5	14	4	58	0.1	48	22	2
10	10	10	6	10	11	21	12	3	13	13	10
22	47	5	6	13	13	8	13	4	5	4	13
3	1	20	30	0.1	20	62	10	18	9	21	20
125	64	48	40	82	1	6	4	107	30	27	43
11	23	21	18	19	32	22	36	7	27	25	25
6	9	20	24	8							
1,680	2,230	4,040	6,370	1,110	1,700	1,600	1,900	1,800	2,080	3,840	3,720
					CLOTHING AND OTHER FABRICATED TEXTILES ISIC (243 AND 244)						
1	3	9	10		3	2	11	1	6	8	7
1	3	7	7								2
0.1	0.1	0.1	1		0.1	0.1	10	0.1	0.1	0.1	5
0.1	0.1	0.1	1								4
0.1	0.1	7	6		3	2	1	0.1	0.1	3	2
1	3	7	5								6
40	42	46	40		29	22	24	22	44	40	43
52	63	66	72		45	17	10	39	36	47	45
30	43	56	65								9
12	12	19	24		9	2	20	9	12	18	23
826	785	842	825		885	945	879	839	862	842	806
2	7	3	3		1	0.1	1	0.1	8	2	0.1
1	3	0.1	0.1		2	0.1	1	0.1	5	1	0.1
12	29	3	3		6	0.1	2	2	0.1	2	17
3	0.1	6	8		2	2	4	2	1	4	7
26	13	11	9		0.1	4	13	18	8	11	0.1
64	71	10	11		24	7	16	58	27	41	54
4	7	16	19								
1,790	2,840	4,240	5,990		850	700	1,830	1,050	1,460	2,410	3,030
					LEATHER AND LEATHER PRODUCTS, INCLUDING FOOTWEAR ISIC (29 AND 241)						
5	5	7	8	14				4	7		7
4	2	6	6	9							
0.1	1	1	1	3				0.1	0.1		6
1	1	2	1	3							
3	1	2	3	6				0.1	1		1
3	1	4	5	6							
39	36	33	36	13				16	46		61
65	71	77	87	55				47	17		68
37	49	67	75	21							
10	9	17	18	17				9	9		2
880	850	844	811	853				902	915		772
11	9	9	8	5					6		6
7		4	2	15					6		1
14	32	3	4	8				6	1		8
2	0.1	12	14	0.1				8	3		21
71	27	32	29	83					5		41
9	11	11	10	25				83	5		7
6	6	19	19	6							
1,430	1,730	3,960	6,210	1,290				1,100	1,380		3,680

	Argentina 1960	Canada 1951	Canada 1961	France 1962	Germany (Fed. Rep.) 1960	Japan 1950	Japan 1960	Netherlands 1960	Norway 1960
FURNITURE AND FIXTURES ISIC (26)									
Professional and technical workers			13		13	2	2	12	4
Professional and technical workers (adjusted)			6		11	1	2	7	3
Engineers			1		8	0.1	2	1	1
Engineers and scientists (adjusted)			1		5	0.1	1	1	1
Technicians			5		1	2	0.1	3	2
Technicians (adjusted)			2		6	1	1	6	2
Administrators and managers			83		19	18	39	45	53
Clerical workers			90		45	28	50	43	31
Clerical workers (adjusted)			78		36	20	49	35	14
Sales workers			24		8	17	26	13	3
Manual workers			757		878	936	881	887	904
Metal fabricators and makers			52		22	3	28	11	18
Construction workers			70		593	59	8	43	114
Transportation workers			13		0.1	2	14	16	9
Mechanics and repairmen			8		1	1	0.1	2	4
Labourers			64		56	17	19	1	10
Service workers			6		5	2	3	8	1
University graduates					9	6	19	3	4
Productivity (US $)			5,180		(3,360)	250	730	1,700	2,750
LUMBER AND WOOD PRODUCTS (EXCLUDING FURNITURE) ISIC (25)									
Professional and technical workers			11		22	0.1	1	13	5
Professional and technical workers (adjusted)			7		19	0.1	1	7	4
Engineers			1		11	0.1	1	0.1	2
Engineers and scientists (adjusted)			1		7	0.1	1	1	2
Technicians			4		1	0.1	0.1	7	2
Technicians (adjusted)			5		12	0.1	0.1	6	2
Administrators and managers			69		42	38	44	53	54
Clerical workers			57		67	70	67	70	40
Clerical workers (adjusted)			49		54	50	66	57	18
Sales workers			12		12	19	27	16	4
Manual workers			813		834	866	855	821	890
Metal fabricators and makers			32		35	12	20	13	10
Construction workers			55		91	7	6	199	92
Transportation workers			43		29	22	32	38	50
Mechanics and repairmen			14		3	1	0.1	13	11
Labourers			229		145	99	119	3	19
Service workers			18		8	3	5	36	4
University graduates					15	10	20	5	5
Productivity (US $)			5,180		(2,890)	250	760	1,800	2,830
LUMBER AND WOOD PRODUCTS (INCLUDING FURNITURE) ISIC (25 AND 26)									
Professional and technical workers	2	10	10	25	16	0.1	1	11	3
Professional and technical workers (adjusted)	2	9	8	9	14	0.1	1	5	3
Engineers	1	2	1	3	9	0.1	1	0.1	1
Engineers and scientists (adjusted)	1	2	1	2	5	0.1	1	0.1	1
Technicians	0.1	2	3	11	1	0.1	0.1	4	2
Technicians (adjusted)	1	6	5	7	9	0.1	0.1	5	2
Administrators and managers	26	75	73	41	26	32	42	48	54
Clerical workers	16	55	66	43	51	58	61	55	36
Clerical workers (adjusted)	8	45	57	9	41	41	60	44	16
Sales workers	3	10	15	10	10	18	26	13	3
Manual workers	938	816	799	866	863	865	862	852	893
Metal fabricators and makers	4	32	37	19	25	9	23	10	13
Construction workers	13	70	59	18	437	22	7	114	103
Transportation workers	19	48	35	26	19	16	26	26	27
Mechanics and repairmen	6	1	12	8	1	1	0.1	7	7
Labourers	17	261	185	182	84	76	87	2	14
Service workers	5	19	16	4	5	2	5	20	3
University graduates	2			11	10	8	19	4	4
Productivity (US $)	640	3,980	5,150	(2,600)	(2,600)	260	740	1,700	2,770

	United Kingdom 1951	*United Kingdom 1961*	*United States 1950*	*United States 1960*	*Yugoslavia 1961*	*Belgium*	*Chile*	*Finland*	*Ireland*	*Israel*	*New Zealand*	*Sweden*
FURNITURE AND FIXTURES ISIC (26)												
	9	20	16	19			1	24	0.1		3	
	6	11	13	16								
	0.1	2	4	5			0.1	22	0.1		0.1	
	0.1	1	3	4								
	6	8	6	8			1	2	0.1		1	
	5	9	9	11								
	45	51	52	54			21	24	26		59	
	67	80	80	92			11	42	46		57	
	39	55	69	83								
	14	17	22	29			2	8	11		13	
	846	818	808	767			958	862	869		852	
	14	28	34	34			4	41	29		45	
	0.1	174	25	23			414	281	185		28	
	18	41	13	21			1	16	19		3	
	2	0.1	16	21			3	8	4		1	
	73	51	63	47			2	55	59		24	
	14	14	13	13			3	18			5	
	4	8	23	26								
	1,590	1,810	5,430	7,180			1,000	2,330	930		3,520	
LUMBER AND WOOD PRODUCTS (EXCLUDING FURNITURE) ISIC (25)												
	4	5	6	11			4	23			5	12
	3	3	4	7								
	0.1	0.1	0.1	1			0.1	21			0.1	10
	0.1	0.1	0.1	1								
	2	2	3	6			2	0.1			2	2
	2	3	4	5								
	42	48	63	61			43	26			48	61
	59	82	45	56			37	43			30	42
	24	57	39	51								
	6	11	8	12			3	3			3	3
	851	830	857	822			880	864			891	830
	17	28	21	24			4	35			0.1	7
	237	290	24	27			86	45			206	46
	24	45	58	55			56	81			80	70
	2	0.1	11	17			31	30			7	23
	167	126	233	210			4	335			116	29
	13	8	11	13			14	29			5	7
	4	7	16	22								
	1,330	1,900	4,390	7,180			1,200	2,330			4,400	3,800
LUMBER AND WOOD PRODUCTS (INCLUDING FURNITURE) ISIC (25 AND 26)												
	6	12	10	11	19	4	2	23	0.1	7	5	11
	4	6	3	9	16							
	0.1	1	3	1	5	1	0.1	21	0.1	0.1	0.1	9
	0.1	1	2	1	6							
	4	5	4	6	8	2	2	1	0.1	5	2	1
	3	5	6	7	10							
	43	48	59	58	13	38	34	26	15	44	51	48
	63	78	56	71	57	37	24	43	30	28	26	56
	36	54	48	64	22							
	11	14	12	19	7	7	2	5	4	3	6	13
	845	795	843	800	851	875	926	865	930	806	880	868
	14	19	25	27	21	7	3	37	12	37	36	10
	162	216	24	26	52	231	272	110	429	401	156	114
	30	42	44	41	0.1	24	25	62	16	2	31	26
	2	0.1	13	19	0.1	5	15	17	3	6	6	7
	114	81	178	141	158	1	3	250	77	17	91	13
	13	10	11	14	37	36	9	24	0.1	8	7	30
	4	7	30	22	9							
	1,500	1,600	6,230	14,210	720	1,630	700	2,340	1,100	1,520	4,250	3,700

	Argentina 1960	Canada 1951	Canada 1961	France 1962	Germany (Fed. Rep.) 1960	Japan 1950	Japan 1960	Netherlands 1960	Norway 1960
PAPER AND PAPER PRODUCTS ISIC (27)									
Professional and technical workers	14	50	60	20	24	12	8	29	43
Professional and technical workers (adjusted)	12	46	46	10	18	7	8	14	34
Engineers	7	11	13	10	18	4	7	0.1	11
Engineers and scientists (adjusted)	6	13	14	7	11	3	4	1	8
Technicians	0.1	18	26	8	5	5	0.1	20	26
Technicians (adjusted)	5	30	25	3	7	4	3	12	25
Administrators and managers	43	35	42	35	27	38	44	32	29
Clerical workers	90	106	112	89	90	114	106	109	54
Clerical workers (adjusted)	44	88	97	19	72	82	104	88	24
Sales workers	17	14	16	19	14	21	23	24	3
Manual workers	795	744	728	808	810	795	808	775	852
Metal fabricators and makers	4	53	52	32	47	11	20	15	26
Construction workers	46	60	52	16	27	14	4	19	129
Transportation workers	37	30	22	17	25	9	16	54	38
Mechanics and repairmen	54	2	31	19	2	10	0.1	36	54
Labourers	28	202	132	182	112	63	66	9	33
Service workers	12	24	20	10	17	17	11	29	13
University graduates	9			24	15	13	30	7	11
Productivity (US $)	3,070	8,080	10,530	(3,000)	(3,240)	720	1,530	2,660	3,550
PRINTING AND PUBLISHING ISIC (28)									
Professional and technical workers	59	90	89	142	42	112	101	61	99
Professional and technical workers (adjusted)	40	83	83	66	24	53	81	46	69
Engineers	3	0.1	0.1	6	7	1	3	0.1	1
Engineers and scientists (adjusted)	1	0.1	0.1	4	6	1	2	0.1	1
Technicians	3	7	6	83	17	12	0.1	6	7
Technicians (adjusted)	14	42	28	28	12	29	7	13	8
Administrators and managers	43	81	93	51	47	69	65	52	49
Clerical workers	126	199	203	159	123	187	181	209	182
Clerical workers (adjusted)	62	153	176	36	99	134	178	166	79
Sales workers	27	84	118	35	10	52	47	69	31
Manual workers	726	510	470	570	741	566	599	553	625
Metal fabricators and makers	1	3	3	12	9	2	11	1	3
Construction workers	0.1	6	4	3	6	2	0.1	4	10
Transportation workers	9	11	13	10	43	5	9	31	13
Mechanics and repairmen	9	0.1	7	7	1	5	0.1	8	3
Labourers	5	27	24	52	149	23	31	2	19
Service workers	5	14	13	13	17	6	3	16	12
University graduates	24			33	15	38	79	29	42
Productivity (US $)	2,110	4,520	7,790	(4,000)	(2,900)	780	1,490	2,070	3,320
RUBBER PRODUCTS ISIC (30)									
Professional and technical workers	14	42	46		41	15	14	25	34
Professional and technical workers (adjusted)	12	39	35		31	8	13	13	26
Engineers	5	14	4		31	8	10	3	1
Engineers and scientists (adjusted)	6	17	14		22	4	6	4	1
Technicians	0.1	14	18		7	5	0.1	16	21
Technicians (adjusted)	5	12	16		9	4	7	8	24
Administrators and managers	56	37	48		20	45	22	35	44
Clerical workers	95	138	169		121	140	110	154	78
Clerical workers (adjusted)	47	114	147		96	101	106	124	34
Sales workers	8	14	23		16	23	25	20	7
Manual workers	800	722	646		774	755	823	744	822
Metal fabricators and makers	4	24	21		62	7	25	17	17
Construction workers	29	20	17		21	8	3	12	34
Transportation workers	10	9	8		21	8	10	62	10
Mechanics and repairmen	37	0.1	26		6	12	0.1	47	27
Labourers	11	88	39		86	36	49	5	41
Service workers	11	15	16		21	20	6	21	12
University graduates	9				25	17	31	10	5
Productivity (US $)	1,600	6,390	(8,060)		2,940	670	1,360	3,320	3,170

PAPER AND PAPER PRODUCTS ISIC (27)

United Kingdom 1951	United Kingdom 1961	United States 1950	United States 1960	Yugoslavia 1961	Belgium	Chile	Finland	Ireland	Israel	New Zealand	Sweden
22	34	33	49	35	17	25	47	14		45	42
15	19	28	42	26							
2	4	8	12	9	6	5	42	0.1		8	17
4	4	13	9	9							
6	15	9	17	19	10	6	1	0.1		18	20
8	13	13	17	15							
34	41	43	44	13	33	42	16	26		45	28
106	15	114	109	71	122	105	72	52		106	62
60	10	100	99	27							
18	20	23	28	6	17	1	6	10		17	4
817	761	770	728	804	708	799	753	832		748	792
42	22	37	36	19	24	17	67	0.1		65	13
21	27	17	22	33	28	82	42	14		42	56
24	52	23	23	63	44	48	74	20		21	56
4	0.1	27	39	0.1	26	79	38	25		12	77
221	67	103	66	50	1	9	38	169		43	55
18	27	16	17	57	100	22	52	0.1		11	24
6	10	22	40	14							
2,750	3,330	8,860	10,660	3,110	2,820	2,810	3,240	2,900		8,450	5,630

PRINTING AND PUBLISHING ISIC (28)

United Kingdom 1951	United Kingdom 1961	United States 1950	United States 1960	Yugoslavia 1961	Belgium	Chile	Finland	Ireland	Israel	New Zealand	Sweden
68	67	91	90	36	55	40	91	85	142	114	121
45	80	89	81	25							
0.1	1	0.1	0.1	6	1	0.1	19	0.1	0.1	1	6
0.1	1	0.1	0.1	6							
5	6	6	10	11	11	23	2	0.1	6	10	16
15	12	38	10	11							
53	54	37	75	19	41	42	20	36	72	46	56
156	175	183	184	113	149	155	210	176	159	167	180
89	121	160	166	41							
33	31	151	204	17	26	11	16	14	32	45	29
672	640	464	414	756	701	711	565	670	581	615	545
14	9	3	2	11	2	3	2	0.1	8	5	1
6	6	4	2	6	6	21	8	0.1	2	3	1
38	54	15	15	16	25	13	12	22	9	6	14
2	0.1	10	10	0.1	7	7	7	11	3	8	7
72	24	10	11	87	0.1	6	16	76	7	7	19
13	22	12	11	43	31	23	24	8	6	10	16
25	30	83	91	17							
1,880	2,430	8,500	10,610	1,430	2,440	1,400	2,800	1,910	2,070	4,720	4,680

RUBBER PRODUCTS ISIC (30)

United Kingdom 1951	United Kingdom 1961	United States 1950	United States 1960	Yugoslavia 1961	Belgium	Chile	Finland	Ireland	Israel	New Zealand	Sweden
32	40	53	56	27	22	19	30	16	35	30	31
23	22	44	41	20							
2	6	14	20	6	3	5	34	0.1	11	2	10
5	5	16	18	6							
18	26	14	15	14	12	11	3	0.1	17	11	9
16	17	25	18	13							
32	35	34	45	13	30	48	26	20	61	40	47
137	134	135	123	77	156	118	98	141	128	115	90
77	93	116	112	28							
17	21	19	25	16	19	6	15	33	16	41	14
758	730	718	695	811	677	778	700	763	697	745	717
43	41	29	36	31	41	21	27	0.1	48	58	6
15	17	16	12	14	18	36	29	0.1	16	14	13
14	40	6	12	19	26	14	18	18	13	12	19
3	0.1	35	38	0.1	26	60	23	32	13	3	40
167	72	63	53	191	1	6	48	96	0.1	12	31
14	22	26	17	35	93	16	44	13	31	19	16
11	11	43	45	11							
2,030	3,080	8,220	9,960	1,470	2,230	1,800	2,400	1,600	2,900	5,790	4,300

CHEMICALS AND CHEMICAL PRODUCTS ISIC (31)

	Argentina 1960	*Canada 1951*	*Canada 1961*	*France 1962*	*Germany (Fed. Rep.) 1960*	*Japan 1950*	*Japan 1960*	*Netherlands 1960*	*Norway 1960*
Professional and technical workers	71	93	137	83	93	46	36	110	98
Professional and technical workers (adjusted)	57	86	110	41	57	27	35	56	78
Engineers	12	20	28	31	32	27	30	4	26
Engineers and scientists (adjusted)	37	36	47	23	32	17	17	17	22
Technicians	0.1	35	51	40	40	5	0.1	91	54
Technicians (adjusted)	19	47	52	17	14	10	18	37	55
Administrators and managers	56	74	94	40	30	50	42	44	55
Clerical workers	187	196	205	140	155	189	203	113	101
Clerical workers (adjusted)	92	162	178	30	95	136	200	78	44
Sales workers	72	84	128	39	34	28	30	42	16
Manual workers	563	455	454	658	648	656	665	590	698
Metal fabricators and makers	3	36	33	54	79	19	40	24	30
Construction workers	33	36	31	21	45	22	9	37	97
Transportation workers	25	0.1	15	24	23	12	14	67	47
Mechanics and repairmen	33	2	31	18	6	20	0.1	46	59
Labourers	18	110	59	177	63	82	118	23	47
Service workers	23	24	27	22	25	27	24	44	28
University graduates	41			29	41	24	61	24	31
Productivity (US $)	2,540	9,940	13,500	(4,000)	(4,200)	880	2,750	3,600	5,610

PETROLEUM AND COAL PRODUCTS ISIC (32)

	Argentina 1960	*Canada 1951*	*Canada 1961*	*France 1962*	*Germany (Fed. Rep.) 1960*	*Japan 1950*	*Japan 1960*	*Netherlands 1960*	*Norway 1960*
Professional and technical workers	51	120	164	155	112	28	47	199	56
Professional and technical workers (adjusted)	41	100	138	58	71	21	45	102	71
Engineers	27	42	50	78	55	16	45	11	30
Engineers and scientists (adjusted)	20	50	61	54	44	10	26	32	29
Technicians	1	36	69	61	43	8	0.1	157	44
Technicians (adjusted)	19	45	67	27	27	11	18	60	41
Administrators and managers	29	43	60	61	36	57	82	26	45
Clerical workers	267	178	179	207	183	193	230	194	87
Clerical workers (adjusted)	131	147	155	46	147	160	227	157	28
Sales workers	10	14	27	34	25	26	37	10	17
Manual workers	530	647	494	473	505	656	561	503	747
Metal fabricators and makers	5	42	31	54	111	20	40	62	30
Construction workers	83	78	57	19	55	20	20	60	148
Transportation workers	95	50	46	61	58	27	42	74	44
Mechanics and repairmen	68	7	42	33	11	11	0.1	60	34
Labourers	79	121	62	58	54	113	94	33	35
Service workers	48	14	22	28	45	31	52	67	18
University graduates	24			59	55	92	66	28	33
Productivity (US $)	7,170	9,900	19,000	(12,000)	(11,760)	900	4,880	13,000	8,000

GLASS, STONE AND CLAY PRODUCTS ISIC (33)

	Argentina 1960	*Canada 1951*	*Canada 1961*	*France 1962*	*Germany (Fed. Rep.) 1960*	*Japan 1950*	*Japan 1960*	*Netherlands 1960*	*Norway 1960*
Professional and technical workers	10	30	35	30	26		12	23	32
Professional and technical workers (adjusted)	8	27	27	14	18		12	11	26
Engineers	3	6	10	12	16		10	1	9
Engineers and scientists (adjusted)	3	8	10	8	11		8	2	7
Technicians	0.1	12	14	14	8		0.1	15	15
Technicians (adjusted)	3	17	14	6	8		8	8	16
Administrators and managers	48	65	73	34	30		37	47	55
Clerical workers	32	97	101	69	71		86	63	47
Clerical workers (adjusted)	18	80	87	14	87		64	51	40
Sales workers	4	20	27	12	8		18		4
Manual workers	892	733	733	834	839		836	825	854
Metal fabricators and makers	5	44	44	56	24		26	29	23
Construction workers	38	53	73	125	72		16	43	220
Transportation workers	21	36	77	27	55		24	60	50
Mechanics and repairmen	20	3	35	21	4		1	28	29
Labourers	21	210	142	216	103		99	10	23
Service workers	8	9	13	9	17		10	30	9
University graduates	12			21	15		26	7	13
Productivity (US $)	1,390	6,100	7,350	(5,000)	(2,550)		1,330	1,800	4,000

United Kingdom 1951	United Kingdom 1961	United States 1950	United States 1960	Yugoslavia 1961	Belgium	Chile	Finland	Ireland	Israel	New Zealand	Sweden
					CHEMICALS AND CHEMICAL PRODUCTS ISIC (31)						
90	106	117	153	86	90	63	76	59	107	82	113
57	66	110	134	67							
9	9	33	38	17	26	10	61	0.1	22	3	31
25	18	53	60	25							
41	63	25	49	45	45	35	0.1	0.1	36	27	47
28	47	54	68	40							
49	48	63	68	18	41	47	42	50	103	80	73
185	164	152	153	101	202	183	107	155	147	165	130
105	113	133	139	38							
31	39	47	56	30	36	29	34	56	18	75	32
622	555	580	516	689	465	625	636	619	570	568	546
58	58	31	25	59	42	11	38	0.1	64	61	13
31	39	32	29	43	34	28	38	4	50	27	32
34	64	22	20	57	52	33	42	43	26	26	46
4	0.1	37	46	0.1	20	41	40	26	12	3	58
187	78	95	56	144	4	26	69	281	89	39	73
24	42	28	21	64	163	28	57	4	44	17	30
27	28	90	97	35							
2,580	3,560	12,500	19,320	1,900	3,170	2,100	4,840	2,230	2,890	8,670	6,980
					PETROLEUM AND COAL PRODUCTS ISIC (32)						
92	86	141	148	90	73	82	81			54	
67	63	99	128	68							
18	16	49	41	19	28	36	70			8	
33	25	52	43	21							
42	51	31	42	51	34	25	4			22	
32	37	39	77	43							
26	41	59	58	16	38	20	29			98	
135	165	168	181	107	200	171	85			100	
77	114	147	164	41							
6	15	25	25	30	17	5	17			31	
710	632	577	543	689	489	633	673			721	
100	155	51	42	1	82	42	58			66	
52	40	50	50	74	63	137	84			33	
32	65	40	42	105	99	74	51			135	
6	0.1	39	47	0.1	44	93	56			41	
291	113	100	63	92	6	4	103			255	
21	39	20	14	105	178	46	54			4	
20	22	91	90	31							
1,780	2,490	11,600	18,460	2,500	4,940	7,000	9,400			6,910	
					GLASS, STONE AND CLAY PRODUCTS ISIC (33)						
18	30	39	47	24	19	15	38	21	26	27	34
13	17	32	41	17							
1	5	13	15	5	7	4	30	0.1	6	3	18
2	4	12	14	5							
9	18	9	13	14	10	3	0.1	0.1	10	12	9
9	12	19	25	12							
35	38	51	60	14	28	33	31	16	81	63	48
73	91	92	96	59	82	68	58	63	74	67	56
42	63	81	87	23							
6	12	16	23	6	6	2	10	4	3	11	8
856	787	776	728	835	747	839	791	837	788	820	783
43	46	36	33	30	32	20	40	0.1	79	59	12
60	77	23	22	84	84	96	64	60	117	133	64
32	67	33	73	78	45	30	60	53	25	45	77
3	0.1	32	41	0.1	21	49	26	34	15	5	30
258	160	171	125	240	19	10	60	312	49	75	56
8	19	15	11	41	111	16	34	0.1	29	6	12
6	10	35	44	9							
1,620	2,090	8,100	10,490	1,510	2,410	1,400	2,820	2,250	3,090	5,730	4,790

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	Argentina 1960	Canada 1951	Canada 1961	France 1962	Germany (Fed. Rep.) 1960	Japan 1950	Japan 1960	Netherlands 1960	Norway 1960
METAL AND METAL PRODUCTS ISIC (34 AND 35)									
Professional and technical workers	13	40	55	33	55	18	14	39	48
Professional and technical workers (adjusted)	11	37	44	16	38	11	13	19	37
Engineers	10	13	16	13	37	11	13	1	13
Engineers and scientists (adjusted)	5	14	16	9	23	4	7	3	10
Technicians	0.1	15	22	20	14	5	0.1	33	32
Technicians (adjusted)	5	19	21	7	15	7	6	15	25
Administrators and managers	40	46	57	44	16	37	41	33	38
Clerical workers	68	121	116	76	87	114	115	96	55
Clerical workers (adjusted)	33	100	101	17	70	82	113	78	24
Sales workers	8	18	22	13	7	12	31	10	3
Manual workers	855	713	715	808	801	802	801	786	838
Metal fabricators and makers	144	400	389	350	557	410	627	610	599
Construction workers	451	35	43	25	88	19	6	31	67
Transportation workers	10	15	16	13	28	11	18	32	24
Mechanics and repairmen	137	4	30	140	10	19	2	30	60
Labourers	8	119	93	118	40	56	52	7	30
Service workers	7	14	16	13	21	17	13	32	13
University graduates	7			21	27	13	32	8	14
Productivity (US $)	1,440	5,520	8,870	3,000	3,200	600	1,700	2,970	4,190
PRIMARY METALS ISIC (34)									
Professional and technical workers	23		63	52	49	27	25	61	60
Professional and technical workers (adjusted)	20		50	27	34	14	24	32	47
Engineers	18		19	25	33	15	22	3	17
Engineers and scientists (adjusted)	10		20	17	21	8	12	7	14
Technicians	0.1		25	24	14	6	0.1	45	37
Technicians (adjusted)	9		24	10	13	6	10	23	32
Administrators and managers	39		30	21	16	33	30	21	24
Clerical workers	69		105	88	97	140	141	120	53
Clerical workers (adjusted)	34		101	19	78	100	139	97	23
Sales workers	6		9	5	8	8	8	4	1
Manual workers	831		749	799	792	765	773	734	838
Metal fabricators and makers	349		360	397	538	359	532	503	564
Construction workers	292		54	31	61	24	8	36	94
Transportation workers	19		17	14	34	17	23	33	35
Mechanics and repairmen	75		29	22	10	23	2	50	57
Labourers	17		125	172	48	77	63	18	28
Service workers	12		22	21	27	25	21	68	21
University graduates	11			32	24	15	36	14	17
Productivity (US $)	1,200		10,800	(3,600)	(4,500)	740	2,150	3,440	5,400
IRON AND STEEL ISIC (341)									
Professional and technical workers					47				
Professional and technical workers (adjusted)					31				
Engineers					32				
Engineers and scientists (adjusted)					20				
Technicians					13				
Technicians (adjusted)					11				
Administrators and managers					16				
Clerical workers					94				
Clerical workers (adjusted)					76				
Sales workers					7				
Manual workers					794				
Metal fabricators and makers					536				
Construction workers					64				
Transportation workers					36				
Mechanics and repairmen					9				
Labourers					46				
Service workers					28				
University graduates					24				
Productivity (US $)					(2,900)				

United Kingdom 1951	United Kingdom 1961	United States 1950	United States 1960	Yugoslavia 1961	Belgium	Chile	Finland	Ireland	Israel	New Zealand	Sweden
METAL AND METAL PRODUCTS ISIC (34 AND 35)											
24	51	44	83	52	31	15	31	10	34	21	
17	27	36	72	39							
5	12	20	36	9	8	9	30	0.1	16	3	
5	7	16	29	9							
13	33	11	26	36	22	7	1	0.1	16	9	
11	20	18	40	29							
34	31	36	48	11	21	27	24	17	74	58	
99	97	108	125	84	92	72	57	44	72	70	
57	67	94	113	32							
4	7	13	18	9	4	3	5	3	5	10	
828	754	767	681	784	759	831	822	891	743	829	
365	383	203	196	289	611	560	636	519	604	663	
20	37	27	20	38	47	67	32	0.1	39	14	
28	45	17	13	38	19	16	30	22	7	6	
6	0.1	30	40	0.1	24	147	45	59	7	6	
209	102	133	65	144	3	5	42	198	40	46	
11	25	20	14	39	84	12	25	0.1	19	10	
11	11	37	54	13							
1,940	2,290	6,590	10,640	1,750	2,170	1,500	2,430	1,800	1,730	4,500	
PRIMARY METALS ISIC (34)											
30	52	40	55	50	32	42	45	18	58	19	
22	28	34	48	36							
6	12	18	22	7	10	25	43	0.1	25	7	
7	7	16	20	7							
15	30	9	14	34	44	11	1	0.1	27	7	
14	20	16	25	27							
26	26	24	27	9	16	8	14	26	73	50	
100	98	95	102	80	95	121	60	73	76	62	
57	68	83	93	29							
3	6	8	11	5	2	1	3		2	6	
827	767	791	754	791	957	767	804	854	737	847	
328	379	201	176	282	588	418	547	277	571	703	
36	49	35	36	52	56	115	39	0.1	45	11	
24	44	19	21	54	20	34	63	32	15	6	
3	0.1	29	38	0.1	25	158	40	82	13	1	
270	148	179	137	148	4	4	63	374	43	67	
12	26	22	18	46	96	37	34	0.1	35	7	
11	13	34	42	12							
2,220	2,550	9,750	11,530	3,140	2,500	2,900	2,900	1,200	1,300	4,790	
IRON AND STEEL ISIC (341)											
26	50	37	48	50							
19	26	31	42	37							
5	11	16	19	7							
5	9	14	18	7							
13	29	8	13	33							
13	16	15	21	28							
23	24	23	23	10							
95	92	92	99	78							
50	64	80	90	29							
2	5	7	8	5							
830	780	796	778	795							
326	369	211	187	294							
38	56	35	29	53							
23	45	19	24	50							
3	0.1	29	40	0.1							
281	159	192	159	148							
12	25	20	19	44							
7	12	32	38	12							
2,160	2,550	6,720	11,450	1,780							

	Argentina 1960	Canada 1951	Canada 1961	France 1962	Germany (Fed. Rep.) 1960	Japan 1950	Japan 1960	Netherlands 1960	Norway 1960
NON-FERROUS METALS ISIC (342)									
Professional and technical workers					60				
Professional and technical workers (adjusted)					42				
Engineers					39				
Engineers and scientists (adjusted)					25				
Technicians					17				
Technicians (adjusted)					17				
Administrators and managers					21				
Clerical workers					116				
Clerical workers (adjusted)					93				
Sales workers					10				
Manual workers					763				
Metal fabricators and makers					542				
Construction workers					45				
Transportation workers					21				
Mechanics and repairmen					13				
Labourers					57				
Service workers					26				
University graduates					30				
Productivity (US $)					(3,700)				
FABRICATED METALS (EXCLUDING MACHINERY) ISIC (35)									
Professional and technical workers	12		52	21	74	5	5	34	38
Professional and technical workers (adjusted)	11		40	10	52	2	5	17	29
Engineers	9		14	8	47	2	5	0.1	10
Engineers and scientists (adjusted)	4		13	6	30	1	3	2	8
Technicians	0.1		22	13	20	3	0.1	29	27
Technicians (adjusted)	6		20	4	21	1	2	14	21
Administrators and managers	40		80	58	15	42	51	37	51
Clerical workers	67		126	68	68	82	93	87	55
Clerical workers (adjusted)	33		110	14	55	59	91	70	24
Sales workers	8		32	20	5	18	18	11	6
Manual workers	856		682	810	812	839	825	808	833
Metal fabricators and makers	119		416	320	604	470	709	645	633
Construction workers	470		35	18	147	14	4	30	41
Transportation workers	7		12	11	11	3	13	32	13
Mechanics and repairmen	191		30	217	10	12	1	24	63
Labourers	7		65	81	24	31	43	3	32
Service workers	6		12	10	7	7	5	20	8
University graduates	8			15	35	12	27	7	12
Productivity (US $)	1,500		7,190	(2,000)	(2,700)	400	1,160	1,580	3,360
MACHINERY (EXCLUDING ELECTRICAL) ISIC (36)									
Professional and technical workers	34		83	91	96	35	24	71	71
Professional and technical workers (adjusted)	30		68	43	69	19	23	35	56
Engineers	25		27	35	72	25	22	4	23
Engineers and scientists (adjusted)	14		24	24	46	12	13	8	17
Technicians	1		29	5	22	9	0.1	62	45
Technicians (adjusted)	14		30	18	22	7	12	27	38
Administrators and managers	63		78	43	19	56	51	36	56
Clerical workers	140		190	104	123	142	141	129	64
Clerical workers (adjusted)	69		165	22	99	102	139	104	28
Sales workers	29		39	12	13	16	18	11	7
Manual workers	663		581	721	721	736	752	730	789
Metal fabricators and makers	25		294	368	514	345	630	490	460
Construction workers	190		27	30	45	15	3	33	43
Transportation workers	10		7	11	12	6	11	26	11
Mechanics and repairmen	354		63	42	59	118	2	103	206
Labourers	10		37	85	47	32	34	2	25
Service workers	23		14	13	15	17	11	19	6
University graduates	17			40	50	19	39	13	22
Productivity (US $)	2,170		7,150	(2,500)	(3,300)	580	1,520	2,600	3,900

United Kingdom 1951	*United Kingdom 1961*	*United States 1950*	*United States 1960*	*Yugoslavia 1961*	*Belgium*	*Chile*	*Finland*	*Ireland*	*Israel*	*New Zealand*	*Sweden*
NON-FERROUS METALS ISIC (342)											
43	52	51	73	51							
30	28	42	64	38							
10	12	23	29	9							
11	8	22	29	11							
23	33	11	19	33							
18	20	18	32	25							
34	36	33	42	8							
114	118	111	115	79							
64	82	97	105	37							
4	9	11	19	8							
789	727	752	706	790							
324	410	171	148	255							
24	26	27	27	52							
17	44	14	17	59							
4	0.1	28	35	0.1							
227	104	122	73	148							
16	25	26	12	46							
10	12	41	52	15							
2,470	2,550	7,110	11,780	3,400							
FABRICATED METALS (EXCLUDING MACHINERY) ISIC (35)											
15	56	46	95	54	32	13	27	15	25	22	45
10	29	38	83	41							
3	13	21	41	10	6	5	26		15	3	28
2	7	16	34	10							
9	38	13	31	37	26	8	1		12	10	12
7	22	20	45	30							
42	36	54	56	13	28	34	27	13	73	60	40
99	96	122	133	89	39	54	56	34	69	72	74
57	66	107	121	34							
6	7	23	20	10	7	3	7	4	8	13	5
823	749	737	653	782	772	861	834	851	747	825	777
408	383	209	175	293	651	615	673	592	615	606	414
14	28	19	18	31	32	51	30	0.1	39	15	26
15	44	12	12	31	21	11	16	14	5	7	31
10	0.1	32	36	0.1	24	143	47	60	5	7	183
140	67	68	45	143	1	6	34	93	40	41	34
10	25	15	13	35	66	11	23		11	11	18
6	11	39	61	16							
1,650	2,110	6,880	9,380	2,390	1,600	1,200	2,210	1,700	1,400	4,480	6,500
MACHINERY (EXCLUDING ELECTRICAL) ISIC (36)											
53	109	67	92	77	61	9	52	35	36	30	91
36	56	55	80	58							
11	32	33	42	14	14	4	50	0.1	8	9	66
8	16	24	32	14							
36	64	15	30	56	47	5	1	0.1	15	30	14
25	38	29	45	42							
38	57	49	56	10	41	12	19	50	53	60	81
122	139	137	134	96	124	34	79	138	51	97	117
70	97	120	121	37							
8	26	25	22	9	15	1	9	48	3	15	12
773	617	695	655	754	710	911	755	706	841	750	631
385	410	245	227	248	561	206	474	181	690	552	140
47	26	13	11	42	29	41	61	21	26	24	46
9	39	8	7	39	14	7	26	21	1	7	21
33	0.1	52	45	0.1	70	636	105	277	36	34	227
136	44	40	27	90	1	3	48	133	12	36	40
10	23	17	13	37	45	6	26	0.1	7	7	18
10	18	48	58	19							
1,690	2,460	8,750	9,800	2,500	3,000	1,500	2,640	1,320	2,940	4,080	4,200

	Argentina 1960	Canada 1951	Canada 1961	France 1962	Germany (Fed. Rep.) 1960	Japan 1950	Japan 1960	Netherlands 1960	Norway 1960
ELECTRICAL MACHINERY AND EQUIPMENT ISIC (37)									
Professional and technical workers	26	69	132	160	102	58	31	120	119
Professional and technical workers (adjusted)	21	65	103	72	77	30	30	62	92
Engineers	23	34	45	55	81	45	29	9	36
Engineers and scientists (adjusted)	12	32	42	38	51	22	17	18	26
Technicians	0.1	21	58	96	17	11	0.1	95	78
Technicians (adjusted)	8	30	47	30	24	8	13	42	64
Administrators and managers	30	45	58	51	16	51	31	21	48
Clerical workers	87	172	177	120	130	203	183	171	97
Clerical workers (adjusted)	43	142	154	26	105	146	180	138	42
Sales workers	12	16	25	13	15	19	14	8	8
Manual workers	824	623	582	619	708	637	733	644	716
Metal fabricators and makers	3	143	145	152	198	103	168	165	108
Construction workers	719	41	42	19	120	24	1	22	65
Transportation workers	7	7	5	10	12	5	8	27	14
Mechanics and repairmen	53	35	26	59	68	118	2	58	82
Labourers	6	57	34	70	71	25	31	5	42
Service workers	5	15	14	17	15	17	8	31	8
University graduates	13			56	57	25	45	25	33
Productivity (US $)	1,500	5,180	7,780	(5,000)	(4,500)	500	1,570	3,250	4,230
TRANSPORTATION EQUIPMENT ISIC (38)									
Professional and technical workers	10	30	65		49	40	35	34	35
Professional and technical workers (adjusted)	9	25	55		37	18	23	11	27
Engineers	9	9	23		40	23	34	2	10
Engineers and scientists (adjusted)	5	9	21		25	11	19	4	8
Technicians	0.1	8	21		8	13	0.1	25	23
Technicians (adjusted)	4	15	24		12	6	6	14	19
Administrators and managers	21	51	36		13	29	22	32	34
Clerical workers	43	98	140		88	137	153	101	43
Clerical workers (adjusted)	21	81	122		71	98	150	81	19
Sales workers	4	21	9		11	7	9	11	
Manual workers	902	776	703		808	758	764	794	873
Metal fabricators and makers	11	215	263		361	235	414	317	322
Construction workers	155	75	87		18	146	11	73	141
Transportation workers	7	15	9		16	9	12	27	9
Mechanics and repairmen	668	246	90		227	162	137	276	326
Labourers	18	99	61		61	39	44	33	22
Service workers	7	15	20		16	21	15	27	8
University graduates	6				28	15	41	8	10
Productivity (US $)	1,500	5,250	7,890		(3,600)	600	1,960	2,200	2,960
MOTOR VEHICLES, ETC. ISIC (383, 385 AND 386)									
Professional and technical workers					44	26			
Professional and technical workers (adjusted)					34	14			
Engineers					37	17			
Engineers and scientists (adjusted)					23	9			
Technicians					6	7			
Technicians (adjusted)					11	4			
Administrators and managers					14	42			
Clerical workers					91	158			
Clerical workers (adjusted)					73	113			
Sales workers					14	17			
Manual workers					807	735			
Metal fabricators and makers					325	268			
Construction workers					65	38			
Transportation workers					15	12			
Mechanics and repairmen					267	191			
Labourers					65	30			
Service workers					14	16			
University graduates					27	17			
Productivity (US $)					(3,000)	600			

United Kingdom 1951	United Kingdom 1961	United States 1950	United States 1960	Yugoslavia 1961	Belgium	Chile	Finland	Ireland	Israel	New Zealand	Sweden
				ELECTRICAL MACHINERY AND EQUIPMENT ISIC (37)							
61	113	95	149	88	90	18	60	28	57	30	
42	58	81	131	66							
16	49	50	69	17	29	9	57	0.1	26	7	
14	25	37	55	17							
36	56	22	50	64	58	9	0.1	0.1	23	11	
27	31	40	69	47							
32	31	32	43	12	23	15	16	37	79	55	
164	147	146	146	113	139	67	130	124	79	120	
94	102	127	123	62							
9	22	15	15	13	10	3	15	31	9	28	
709	612	691	604	711	662	855	708	765	761	740	
146	162	89	76	129	174	39	198	52	113	108	
27	45	20	12	80	145	518	120	34	267	109	
9	42	6	4	25	15	6	12	18	7	7	
25	6	44	33	0.1	24	233	68	91	94	57	
103	46	36	21	150	2	5	71	140	38	31	
13	20	19	13	35	71	10	15	0.1	11	12	
13	19	61	82	23							
1,600	2,190	8,820	9,750	1,450	3,500	1,300	4,000	1,770	1,940	4,080	
				TRANSPORTATION EQUIPMENT ISIC (38)							
38	93	66	119		22	4	42	13	35	9	46
26	48	55	105								
8	25	31	61		5	2	30	0.1	17	1	30
6	14	23	47								
26	59	15	30		16	2	2	0.1	13	3	4
19	32	29	52								
20	20	25	28		26	7	15	20	44	28	54
116	118	120	130		104	21	61	31	73	60	93
66	52	105	113								
2	4	7	6		1		6	11	4	30	37
806	690	753	674		794	943	801	836	805	824	696
343	347	186	164		304	64	275	90	195	225	156
59	37	41	47		64	57	135	51	95	50	49
14	47	11	11		21	7	23	14	10	6	15
29	1	71	64		346	717	287	342	392	336	314
137	51	51	32		55	22	47	166	6	34	47
14	21	24	13		42	5	34	5	19	6	16
8	15	46	70								
1,640	2,210	6,940	11,320		2,900	1,200	2,560	1,600	1,630	3,740	4,410
				MOTOR VEHICLES, ETC. ISIC (383, 385 AND 386)							
52	90	67	136								
35	52	57	120								
10	27	33	60								
7	15	24	54								
33	63	14	32								
25	35	30	50								
24	22	23	27								
148	124	122	137								
84	86	107	124								
4	4	8	6								
755	676	747	652								
321	343	171	145								
36	33	18	20								
11	49	12	11								
23	1	77	70								
90	47	46	25								
15	22	22	17								
10	16	47	73								
2,070	3,500	7,230	11,790								

	Argentina 1960	Canada 1951	Canada 1961	France 1962	Germany (Fed. Rep.) 1960	Japan 1950	Japan 1960	Netherlands 1960	Norway 1960
PROFESSIONAL AND SCIENTIFIC INSTRUMENTS ISIC (391, 392 AND 393)									
Professional and technical workers					53	33	21		
Professional and technical workers (adjusted)					35	17	20		
Engineers					30	19	19		
Engineers and scientists (adjusted)					19	10	11		
Technicians					10	9	0.1		
Technicians (adjusted)					16	7	9		
Administrators and managers					28	58	48		
Clerical workers					102	142	158		
Clerical workers (adjusted)					82	102	155		
Sales workers					13	25	28		
Manual workers					775	725	741		
Metal fabricators and makers					437	136	229		
Construction workers					38	11	3		
Transportation workers					13	4	6		
Mechanics and repairmen					39	104	0.1		
Labourers					67	18	18		
Service workers					12	10	5		
University graduates					22	20	44		
Productivity (US $)					(2,210)	400	1,140		
MISCELLANEOUS MANUFACTURING (INCLUDING INSTRUMENTS) ISIC (39)									
Professional and technical workers	15	34	74	28	47	12	10	32	18
Professional and technical workers (adjusted)	11	31	57	15	31	6	9	17	17
Engineers	3	3	11	8	28	5	7	1	4
Engineers and scientists (adjusted)	5	3	10	6	18	3	4	4	3
Technicians	1	9	19	11	8	4	0.1	22	0.1
Technicians (adjusted)	4	26	40	7	23	3	5	12	14
Administrators and managers	71	93	97	68	29	35	42	44	88
Clerical workers	71	151	158	92	99	71	90	94	62
Clerical workers (adjusted)	35	125	137	20	88	51	88	76	27
Sales workers	14	58	56	34	12	32	36	17	13
Manual workers	522	613	557	759	779	839	820	803	811
Metal fabricators and makers	2	67	81	79	405	51	117	55	70
Construction workers	21	61	42	14	41	15	12	5	47
Transportation workers	16	10	9	10	11	2	8	25	11
Mechanics and repairmen	18	0.1	23	17	37	29	1	12	20
Labourers	11	81	54	149	68	19	36	5	22
Service workers	288	9	13	10	11	4	4	16	5
University graduates	8			25	21	12	33	10	15
Productivity (US $)	1,820	4,430	6,130	(2,400)	(3,100)	290	970	2,560	3,300

United Kingdom 1951	*United Kingdom 1961*	*United States 1950*	*United States 1960*	*Yugoslavia 1961*	*Belgium*	*Chile*	*Finland*	*Ireland*	*Israel*	*New Zealand*	*Sweden*
PROFESSIONAL AND SCIENTIFIC INSTRUMENTS ISIC (391, 392 AND 393)											
93	91	97	159								
42	66	80	139								
6	28	35	66								
7	17	32	45								
49	48	26	54								
32	30	46	89								
57	47	55	52								
137	163	164	170								
77	113	143	154								
11	20	25	22								
674	626	645	556								
109	148	87	67								
16	23	13	10								
9	39	6	4								
6	0.1	32	33								
56	30	22	12								
18	20	19	11								
19	19	64	88								
1,800	3,000	5,680	11,160								
MISCELLANEOUS MANUFACTURING (INCLUDING INSTRUMENTS) ISIC (39)											
48	52	48	85	87	27	6	30		31	37	37
31	28	39	74	45							
3	13	16	33	10	0.1	1	0.1		4	2	19
4	9	15	28	11							
13	1	13	29	26	14	5	0.1		7	5	7
26	18	23	43	31							
57	54	70	64	31	34	41	42		72	63	66
121	133	130	143	110	77	25	69		81	96	92
70	92	114	130	48							
19	24	33	30	19	12	4	23		24	29	34
723	689	679	636	669	799	908	808		790	760	750
92	102	76	62	44	80	16	107		123	60	79
16	26	13	10	37	16	355	32		13	8	14
12	41	6	6	26	11	2	9		2	5	10
3	0.1	25	29	0.1	19	26	22		5	6	17
102	42	29	21	137	1	5	52		38	36	149
14	21	14	11	52	46	7	11		8	11	10
13	15	42	58	22							
1,830	2,100	5,240	7,200	2,260	1,900	1,050	2,060		1,070	4,110	4,200

ANNEX II

An input-output model including skill requirements

If we assume a country with three sectors and three types of skills (this example can be expanded easily to n sectors and m skills) we may write:

$$X_1 = a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + X_{1D} = a_{11}X_1 + a_{21}X_1 + a_{31}X_1 + rK_1 + S_{11}w_1 + S_{21}w_2 + S_{31}w_3. \qquad (1)$$

Verbally, this equation states that the product of industry j (X_1 in this case referring to industry 1) can be valued in terms of demand for outputs, i.e. final demand (X_{1D}), plus intermediate demand as inputs into all industries ($a_{11}X_1 + a_{12}X_2 + a_{13}X_3$); or in terms of supply of inputs, i.e. the value of intermediate inputs from all industries to industry 1 ($a_{11}X_1 + a_{21}X_1 + a_{31}X_1$), plus the value of capital employed in industry 1 (rK_1) plus the total wage bill to all occupations in industry (or skills) ($S_{11}w_1 + S_{21}w_2 + S_{31}w_3$).

Where X_j is the production of industry j,

- X_{jD} is the final demand for the product of industry j,
- S_{ij} is the number of people in occupation i employed in industry j,
- r is the rate of return per unit of capital for all sectors,
- K_j is the amount of capital in industry j,
- w_i is the wage paid for skill i, and
- a_{ij} is the inter-industry coefficient obtained from an input-output table.

$j = 1, 2, 3$

$i = 1, 2, 3$

Regrouping (1) we have

$$X_1(a_{21} + a_{31}) = a_{12}X_2 + a_{13}X_3 + X_{1D} - rK_1 - (S_{11}w_1 + S_{21}w_2 + S_{31}w_3). \qquad (2)$$

Dividing and multiplying certain terms by L_1, the number of people employed in industry 1, we have

$$\frac{X_1}{L_1}(a_{21} + a_{31})L_1 = a_{12}X_2 + a_{13}X_3 + X_{1D} - rK_1 - L_1\left(\frac{S_{11}w_1}{L_1} + \frac{S_{21}w_2}{L_1} + \frac{S_{31}w_3}{L_1}\right) \qquad (3)$$

where $X_1/L_1 = P_1$ is the productivity of labour in industry 1, and $s_{21} = S_{21}/L_1$ = percentage of occupation 2 in the labour force of industry 1; we now can write the whole system as follows:

$$\begin{aligned} P_1(a_{21} + a_{31})L_1 - a_{12}X_2 - a_{13}X_3 + rK_1 + L_1(s_{11}w_1 + s_{21}w_2 + s_{31}w_3) &= X_{1D} \\ [P_1(a_{21} + a_{31}) + s_{11}w_1 + s_{21}w_2 + s_{31}w_3]L_1 - a_{12}X_2 - a_{13}X_3 + rK_1 &= X_{1D} \\ [P_2(a_{12} + a_{32}) + s_{12}w_1 + s_{22}w_2 + s_{32}w_3]L_2 - a_{21}X_1 - a_{23}X_3 + rK_2 &= X_{2D} \\ [P_3(a_{13} + a_{23}) + s_{13}w_1 + s_{23}w_2 + s_{33}w_3]L_3 - a_{31}X_1 - a_{32}X_2 + rK_3 &= X_{3D}. \end{aligned} \qquad (4)$$

Also

$$\begin{aligned} L_1s_{11} + L_2s_{12} + L_3s_{13} &\le \bar{S}_1 \\ L_1s_{21} + L_2s_{22} + L_3s_{23} &\le \bar{S}_2 \\ L_1s_{31} + L_2s_{32} + L_3s_{33} &\le \bar{S}_3 \end{aligned}$$

where $\bar{S}_1$, $\bar{S}_2$, $\bar{S}_3$ are number of available people with occupations 1, 2, 3.
Assumptions 2 and 3 stated above can now be introduced, namely,
P_j is a function of the occupational composition of industry j;
K_j is a function of the occupational composition of industry j.
We also assume that X_{jD} is a function of X_j or a given parameter, and occupational wage rates and inter-industry coefficients are given.

We therefore have n industry equations and m occupational equations, and total number of equations is $n + m$, and the total number of unknown variables is $2n$; (nL's and nX's) if m (the number of occupations) is less than n (number of industries) we can introduce $n - m$ constraints. One of these constraints could be the maximization of $X_1 + X_2 + X_3$ = total production.

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PLANNING AND PROGRAMMING METHODS USED IN THE CZECHOSLOVAK SOCIALIST REPUBLIC IN RELATING SCIENTIFIC RESEARCH TO INDUSTRIAL GROWTH TARGETS

J. Chodtal, J. Nekola, L. Riha and L. Tondl, Czechoslovak Academy of Sciences, Institute for Science Planning, Czechoslovak Socialist Republic

1. Planning and programming concepts in the economic and social life of Czechoslovakia

(a) *Origin and development of the current planning and programming concept in Czechoslovakia*

When speaking about the origin and development of the contemporary conception of planning and programming in industrial and socio-economic life, we must bear in mind the fact that the idea of planning was put into effect immediately after the Second World War. Even as early as that, Czechoslovakia was an advanced country with a relatively highly developed industry (mainly in the machine-engineering branch) and with rich cultural and scientific traditions. The first steps in planning the first two-year plan for 1947-48 were taken mainly to rebuild the war-damaged economy, and to renew and normalize economic life; these steps provided a certain experience that could be further utilized. These first measures in the planning and programming of industrial and socio-economic life were based on an extensive socialization of basic components of economic life (industry, building construction, banking etc.). The socialization was realized in two stages: begun in 1945, it was completed (with the exception of agriculture) in 1948. In further development, the long-term five-year plans have become the backbone of planning.

Emphasis must be laid on the fact that the concept of planning and programming industrial and socio-economic life did not remain unchanged, but gradually developed and extended with the development of institutional and organizational means at the various stages of implementation. The development and changes in the concept of planning were based both on the results (positive as well as negative) obtained at home and on certain schemes and models worked out in other countries, primarily in the USSR. With the broadening of practical experience at home and with the working out of a number of theoretical analyses and studies in economics and other branches corresponding to progress in the scientific and research base of planning and programming, the value of this home experience and of these scientific and theoretical analyses became greater, and they served as a basis for the improvement of the planning and programming concept. Although the course of development was more or less gradual, it is possible to distinguish several stages: from the early 1950s a concept grew up which was to a considerable extent conditioned by circumstances and which laid the main stress on directive planning, on the necessity of a centrally-organized system of planning measures, on the unconditional authority of the plan, and on planning discipline. This concept was also linked with ensuring the industrialization of the country and therefore with increased attention to a priority development of the means of production, chiefly of heavy industry, metallurgy and machine-engineering. Even though this conception of planning promoted a rapid growth in the mid-1950s of some selected branches of the national economy, it could not meet the new and fast-growing demands of the entire national economy.

For these reasons the conception of planning especially where the planning and organization of the national economy is concerned—has been modified and improved in the last few years in a number of basic aspects and the role of the plan has been emphasized in relation to the long-term perspective. In the management of the national economy and its individual sectors, the role of the economic mechanism, i.e. the relations between demand and supply as well as between individuals, groups and enterprises, has been strengthened. It is to be anticipated that the changes recently taking place in the concept of planning and programming social and economic life will show themselves in two main ways. In the perspective planning these changes will lead to a strengthening of the social and economic functions of research and development, particularly in determining the target structure, the system of means to be applied and the distribution of these means. In operational management itself and in decision-making, the changes will offer a much wider scope for the exercise of initiative at all levels of management, will make fruitful emulation possible, and will contribute towards overcoming certain monopolistic elements which have had a negative effect on sectors of the national economy.

The development so far of the concept of planning and programming social and economic life in Czechoslovakia has furnished evidence that it must not be interpreted rigidly and dogmatically; on the contrary, it is vitally important to perfect, develop and modify this concept to accord with new technical, economic and social conditions and, above all, new findings of science and research. It is particularly important, when developing the conception of planning and programming, to take into consideration the most up-to-date management and decision-making methods based on the latest methods of data processing, the application of cybernetics and the new economic, sociological and psychological knowledge in the management.

(b) *The idea of planning and programming*

The idea of planning and programming social and economic life in the socialist countries is based on a conception of human labour (advanced by Marx) according to which one of labour's characteristic features is its purposive character, i.e. man creates his work first "in his mind" before doing so in reality; in other words, before creating something real he first conceives it in its ideal form — a plan of it.

The term "plan", therefore, consists of several basic components which can be summarized as follows:

(i) Structure of the goal.

(ii) Complex of means and methods either available for the achievement of the set goals, or which can be ensured in future development (either by using the existing technological means or by anticipating research and development results).

(iii) Projected trends of future development, extrapolation of these trends, forecasts.

(iv) Complex of directives, i.e. direct instruction or projects delimiting the duties (and thus also the degree of responsibility) of the various organs, groups and individuals.

In past discussions on the nature of planning stress was laid on the fact that a plan cannot be limited to forecasts and extrapolation of existing empirically estimated trends, but should make clear the dynamic approach of its creator. The efforts devoted recently to deepening and improving the concept of planning have shown that restricting the nature of planning to its purely directive components were regarded as decisive, the results could, and in some instances did, lead to an increase in the subjective and accidental elements in planning.

The idea of the plan must include an active approach and a directive component (an obligation). Optimal planning, however, cannot be realized only through a single channel, i.e. without the network of feed-backs, without checking and careful evaluation of the effects of the individual steps in the decision-making process, and without a possibility of forecasting these effects. In most cases planning concerns subjects in the development of which certain random phenomena occur in various forms, so that we must reckon with certain risks, possible losses etc. These and some other analogous circumstances mean that a one-sided directive planning without a feed-back, an efficient checking system, and a possibility of correction does not always lead to progress; on the contrary, under certain conditions it may cause losses or disproportions that may be more serious and greater than they would be in a situation when there is no planning.

The deepening and improving of the planning and programming concept of socio-economic life, with which the Czechoslovak experts from different theoretical fields and some practical sectors have been concerned during the last few years have not been limited solely to the last two components *(iii, iv)* of the plan mentioned above. Efforts toward improvement are directed still more to the first two components, i.e. structure of goal and complexes of means and methods available to achieve the set goals. The most important problems which arose for study in dealing with the structure of the goal may be summarized as follows:

(i) In how much detail should the structure of the goal be worked out?

(ii) What should be the bases of individual targets and how should the criteria for their evaluation, their priority and their degree of urgency be determined?

(iii) How is the optimum time-lag between the elaboration of the targets and their realization to be determined?

As far as the first question *(i)* is concerned, experience so far has shown that it is not always advantageous to operate with goals predetermined to the very last detail, and that an unduly detailed elaboration with an over-emphasis on the determination of each detail hinders and limits creative initiative. This was the reason why in Czechoslovakia the number of goals has been radically reduced. It has also been shown that in the planning and programming of a very intricate (and sometimes extremely heterogeneous) spectrum of phenomena belonging to the different areas of economics, technology, science, and social, cultural and health environment, it is on the contrary advantageous to allow a sufficiently wide latitude between the two possible extremes. This position has been illustrated by J. D. Bernal in his contrast between the role of the architect who has in mind all the details of his future construction and has to balance his efforts and means and the role of the army leader who knows his enemy only to a certain extent and has to allow for unexpected obstacles.

A sufficiently wide space between the two possible extremes (types) means that certain fields of human activity which we intend to plan and programme are at different distances from either extreme. Planning in the sphere of basic research is closer to the latter type than is planning in the sphere of applied research and development. It is not always possible to programme in detail the system of means and methods, future demands on time, technological, economic and manpower resources and so on. The balancing of the individual projects, their sequence and interrelationships including time, technological, economic and human balances cannot be based on a uniform model that would be equally binding for all the fields. The principle has recently been advanced both in theory and practice that the individual branches have their specific features which must be respected in the selection of certain methods of planning.

The second question *(ii)*, or rather group of questions, concerns the manner of forming the structure of goals. It is evident that in conditions where certain products are lacking, the formation of goal structure is strongly affected by the endeavour to promote the production of these goods. This leads in some degree towards the promotion of mere reproduction and quantitative growth on the basis of available technological and scientific knowledge. Under such circumstances, when planning is concentrated on ensuring a more extensive growth, little demand is made on research and development, and the structure of goals is based on facts already known and investigated. Some elements of such a situation appeared in the Czechoslovak economy in the period of post-war reconstruction and under conditions of post-war shortages when planning methods were being implemented. The deepening and improvement of the planning concept that has recently taken place has led (and no doubt will continue to lead) to further emphasis on the role played by research in improving the process of goal formulation. In brief, planning policy is ceasing to be the programming of an increased production of goods that are not in sufficient supply on the market, and is becoming more and more programming of goods and services that are not available at all.

The third question *(iii)* is closely linked with the previous one. If the planning policy is oriented towards extensive growth, the determination of the optimum time-lag that separates the setting-up of the goal from its final realization may be quite arbitrary. But if science, research and development more and more affect the determination of targets, as well as the selection of the most advantageous methods, the determination of the optimum time-lag is greatly influenced by the real possibilities of making use of discoveries and research results whether achieved or anticipated. It is evident in such a situation that the true function of planning does not appear until long-term programming is undertaken, while operative management and decision-making will cover shorter terms of programming.

(c) Plan and subordination: a pyramidal system of decision-making

The co-ordination of all the components of the social life (the object of the planning) is a prerequisite for a successful planning of economic, industrial and social life, including the planning of science and research. The fulfilment of this prerequisite presumes a relatively full knowledge of the mechanism of the interrelationships and the degree of their interdependence. These interrelationships should be treated with a view to following the principle of plan coherence.

Even though this principle of plan coherence is undoubtedly a pre-condition of successful planning, evidence has shown that individual components of the plan should be co-ordinated rather than subordinated. Reference has already been made to the fact that the methods of planning and programming basic reserach differ markedly from the methods of planning applied to research and development, while all these methods differ in turn from planning production activity. The coherence and complexity of planning do not therefore presume a mere subordination of one goal to another one (e.g. the subordination of goals for health and social security or way of life—urbanism *vis-a-vis* a more "natural" environment—to the goals in the production sphere); a proper co-ordination of all the goals is required, as regards time, space and context. Extensive studies and inter-discipline investigations of the social and human interrelationships of scientific and technological progress, intensively carried out in the past two years by a great number of the institutions of the Czechoslovak Academy of Sciences together with analogous analyses of the directive concept of planned management in the past, have disclosed that problems of complex, multi-criteria decision-making are involved in which the humanistic interests and needs, the interests of an all-round development of individuals in the conditions of a socialist society, and the cultivation of social relations must all play decisive roles.

The principle of plan coherence calls for coordination of the individual components rather than their subordination. The fact that, as a rule, planning concerns complex and differentiated systems undoubtedly justifies a certain pyramid-structure of the different planning and programming levels. In setting up such a structure it proved useful to improve gradually the distribution of the different roles among the various planning and programming levels in such a way that each partial step did not need to be decided centrally. This means that the individual planning and programming, and the development of complex systems, are still at an early stage of theoretical preparation and that it will be necessary to work out a complicated network of feed-backs, mutual checking, a system of objective criteria for decision-making in the network, information channels etc.

Thus the emphasis on a complex approach, the principle of coherence and the necessity of a certain pyramid-like structure in planning and programming the development of complicated systems does not at all exclude a relative autonomy and, occasionally, even a certain parallelism or independence of the individual components constituting the intricate system. Nor must we lose sight of the fact that greatly differentiated and sometimes even contradictory interests and goals of individual social groups, economic groupings, social institutions and organizations (and in fact individuals as well) are reflected in the planning activity. The analysis of the experience of economic, industrial and social development acquired in the 1950s has clearly shown that the idea of a simple harmony in the society's and group's interests and needs is inadequate to the socialist conditions of planning economics, technology, science, culture and other social spheres. These are the reasons why great attention has lately been paid in Czechoslovakia to the study of these phenomena, which are of great significance to the future formation and improvement of the organizational structure of planning. It is becoming evident that the problems of planning and programming such things as the development of science and research, technology and economics, environment and way of life, cannot be isolated from the problems of the whole future development of socialist society and of planning and programming methods used in relating economic growth targets.

If we have emphasized the fact that the unity and complexity of planning do not exclude a relative autonomy or even a certain independence of the partial projects, it is also necessary to stress that this unity and complexity do not exclude a certain spontaneous development in some areas of social life. It would not be rational to hold that planning and programming—as rationally, analytically and scientifically based and justified activities—can cover all areas of social life, including for example artistic creation, and the development of certain cultural, ethical and emotional values. The deeply human and humanistic significance of planning in socialist society lies not only in the fact that the plan not only prepares a programme and directive for the creative development of all human forces—whether in the sphere of science, technology, or production—but also allows ample room for spontaneous evolution to take place in a number of social, cultural, and related activities.

It might seem that the spontaneous evolution of certain values and the implementation of creative forces have nothing to do with the problems and tasks included in planning activity. In fact it is desirable for the two spheres to overlap and complement each other. It would also be most useful if there could always be the maximum freedom for the development of spontaneous initiative and creative activity in the sphere of planning activity itself.

Between the plan itself and the concrete results of the activity, which are the objectives of planning two steps may be distinguished:

(i) Project planning, i.e. planning covering the determination of certain results.

(ii) Projections, i.e. planning delimiting the trends on which the main effort to achieve new results will be concentrated (those by which the most important results of general targets may be realized in various ways).

Here again it is necessary to point out that this is only an idealization since actual projects in the planning activity as a rule include elements of both types, even if in different proportions. It is, for example, obvious that material discoveries cannot be planned in the basic research area; we cannot plan discoveries of something that is still unknown. Thus, in this area elements of type *(ii)* predominate. On the other hand, elements of type *(i)* are predominant in the sphere of applied research and development, and of course in the production sphere as well.

2. SOME PROBLEMS OF PROGRAMMING AND PLANNING BASIC RESEARCH IN RELATION TO INDUSTRIAL GROWTH: SURVEY OF STATE FIVE-YEAR PLAN OF BASIC RESEARCH UP TO 1970

In the not-so-distant past, scientific activity was regarded as an equal of other high-level intellectual activities, such as literature and the arts. In some countries there used to reign various academies of sciences and arts, joint institutions which society supported mainly out of consideration for cultural and moral values. It is quite evident that in such conditions the question whether it was possible or suitable to plan scientific activity had a very different meaning from what it has nowadays. Scientific activity (like the arts) used to be materially supported from the most varied sources, very largely by private foundations. As recently as ten years ago outstanding scientists held discussions and launched polemics—even at international levels—on the effectiveness, suitability and possibility of programming and planning scientific activities.

The present situation is completely different. The significance of science to social development—not only from the viewpoint of culture, but also directly from that of the economy—is fully recognized all over the world. Scientific activity has become a centre of attention not only for the public, but also (and particularly) for those bodies that make decisions on expenditures for financial allocations to science.

The allocations to and ever-growing expenditures on research obviously lead to evaluations being made of the efficiency and the turn-over rate of the allocated funds; among the consequences of this situation there is also interest in the effectiveness of programming and planning research and in the methods as well as experience of programming research activity.

The fundamental importance of science to the revolutionary progress of new technology which has been seen on a world-wide scale during the last three decades, has not only resulted in an extensive allocation of capital and labour to the development of science but has also given rise to a new concept of science as a direct component of all the productive forces. While this has positive effects on the development of all sciences it has also resulted in attempts at evaluating scientific activity on the basis of practically the same economic criteria as are used for other more conventional productive activities.

A rigid evaluation of research, if based on the usual economic criteria, means a serious simplification of a complicated and highly intellectual activity which has specific differences from the activity of other production forces. We believe that the efficiency of scientific work is dependent to a much higher degree than that of other types of work on the creation of a favourable atmosphere; the discovery of such optimal work conditions for scientific workers is a matter for the psychological and sociological investigation of scientific work.

The main goal of programming and planning research is undoubtedly to create the preconditions necessary to an effective utilization of the scientific capacity for the needs of economic, cultural and social growth in the country. In this sense, the goal is identical with that in the programming of other activities, such as applied research and development, production itself, construction of new plants etc. There, however, the similarity virtually ends. It is a superficial and misleading idea that in programming basic research one has merely to take over the methodology that has been successfully applied in the sphere of programming applied research and development or in production.

Nevertheless, such points of view have been put forward in the course of planning and programming scientific activity; they followed from an erroneous generalization of the facts. They maintained that the programme and time-period of basic research projects are a direct component implicit in the work of basic or applied research, development and production. It is obvious that this simplified view of the problem of programming and planning of basic research may be valid for some projects of oriented basic research of a short-period character and for some others that by their nature are on the boundary line between basic and applied research, even though they may be carried on at one of the basic research institutions.

The problem of programming basic research has proved in fact to be quite an intricate matter, a consequence of science itself being diverse, complex and multi-purpose; programming calls for an individual conception and methodology based on the specific differences and requirements of basic research.

The general need for a deeper knowledge of various aspects of how scientific activity is carried out gave rise to new research which can contribute greatly by its fresh findings to a better understanding of the specific requirements of science, and not least, to the development of programming and planning methodology of scientific activity.

(a) *Importance of a country's size for the programming of basic research*

The scope of basic research as measured by the expenditure indicator at present equals 9–13 per cent of the costs of applied research and development: the level is approximately the same in all advanced countries. Judged from the economic angle there is a difference of about one order of magnitude between basic research and applied research development. The importance of basic research however is very much greater than this economic relationship would suggest.

At a given stage in any country's development there exist specific conditions for scientific activity. These conditions depend to a great extent on the established tradition and the development of science in that country, and on the size and organization of the infra-structure of science. The conditions for the development of science and its infra-structure are further closely connected with the entire economic and cultural development of the country, and with supports from government institutions.

In Czechoslovakia, as in the other socialist countries, great attention is devoted to the development of science. In 1952 the independent Czechoslovak Academy of Sciences (CSAV) was established on the basis of the traditions of the Royal Czech Society of Sciences (founded in 1784), the Czech Academy of Sciences and Arts, and the Slovak Academy of Sciences and Arts. At the present time it consists of 144 institutes with about 12,000 workers. The number of these workers has doubled in the last ten years.

The programming of basic research must of course respect and be based on certain specific conditions in the country concerned. The situation in the largest of the industrially highly-developed countries, the United States and USSR, differs from that in other industrially and scientifically advanced countries of medium or small size. The great economic potential of the large countries makes it possible even with more or less the same percentage allocated from the national income or gross national product to science, to have available funds that are sufficiently large for the most extensive scientific programme and for the realization of costly scientific projects.

Countries of medium or small size, i.e. with a smaller economic potential, are forced more or less to modify their scientific programmes according to financial possibilities even though approximately the same proportion of the national income or gross national product is allocated to science. In this connexion it must be remembered that the production mix does not vary proportionately with the size of the country and its total production capacity. Smaller countries generally do not obtain all the necessary raw materials from their own resources and are accordingly dependent to varying degrees on the export of their products to ensure the import of vital raw materials. In order to find a world market their products, particularly those of manufacturing industry, must meet the requirements of a world market. At the present stage of advanced technology the rising international level of quality and price competitiveness can be maintained only through the application of new scientific knowledge; but the smaller industrial and exporting countries can never build up a scientific and research base to an extent and level sufficient to meet all requirements in the entire spectrum of industrial production and they cannot depend either, for various reasons, on taking over or buying the results of science and research carried out elsewhere.

This is only a brief outline of the effects of a country's size and degree of development on the problems of programming and on the scope of science and research in the smaller countries. Similar effects of the size of a country on research programming may be seen in fields other than industry such as those of environment and health care.

The effect of the size factor is to make it relatively much more difficult for socially and industrially developed countries of medium and smaller size to choose and select scientific programmes. The process of scientific integration that West European countries are undergoing provides evidence as to the influence and consequences of this factor. Either international scientific teams are set up to carry out big projects or a close co-operation between two or more countries is established to work out common scientific programmes.

The socialist countries too – in particular the smaller ones – find it necessary to pool their efforts and resources for the realization of some big projects (for instance in the field of atomic physics) and so to develop, step by step, an organized international division of labour in science.

Thus if the smaller countries can ensure to a limited extent a progressive development of their most important industries by their own basic research they must accustom themselves to making use of new knowledge in the world of science for possible application at home. Here it is a matter of scientific prestige for a country highly developed in science to contribute to the world's fund of scientific knowledge by carrying out basic research also in those branches where there may be no necessity of applying the results to the social life and production of the country itself.

In this matter the position of Czechoslovakia is very complicated. It is an industrial country with about 14 million inhabitants, with a limited variety of production as well as of raw material resources, and has developed traditional as well as various new industries. The manufacturing industry produces more than 70 per cent of the world product assortment. Even though the Government and the National Assembly allocate to science from the national income a sum corresponding to the world average ratio, it is evident that the research base itself is far from meeting the needs for the economic and social tasks of the country. Such a situation emphasizes the importance of international collaboration in science, both with the socialist countries within the framework of the Council for Mutual Economic Assistance and with other countries. International collaboration in science is to be understood in its widest sense: it means that Czechoslovakia, which must necessarily make use of new knowledge in world science, will devote the major part of its own scientific capacity to purely basic research, the results of which will be made known to world science. Thus it will contribute to the world treasury of scientific knowledge.

The situation in Czechoslovakia is thus rather unfavourable to the programming of basic research, particularly in relation to the needs of the national economy, where it is hardly possible to bridge the gap between the needs resulting from industrial growth and the capacity of basic research.

We may distinguish the programming of three main types of basic research projects all of which are involved in the natural and engineering sciences.

(i) The programme may be oriented to the prospective needs of the national economy which, however, are not yet fully specified in the economic sphere; but the results of oriented basic research are to create a new theoretical basis for the prospective development of the most important branches of the national economy.

(ii) It may be a programme of pure basic research, oriented in each branch of science to the exploration of natural laws, with the general purpose of obtaining fresh scientific knowledge which will contribute towards the internal development of science itself as well as create the preconditions for significant changes in production and social life.

(iii) Projects of basic research may be oriented to the study of specific actual problems the solutions of which are immediately required by society or industry. Such solutions should contribute to a concrete realization of specific goals. The programme of applied research and development is associated directly with the results of basic research.

The largest part of the basic research programmes *(i)* and *(ii)* is covered by the Plan of Basic Research, which is worked out for a five-year period and covers all the natural, engineering and social sciences. The Czechoslovak Academy of Sciences, as the highest scientific institution, is responsible for the elaboration of this Plan of Basic Research.

One of the duties of the CSAV laid down by legislation is to study the methodological orientation of basic research on a national scale; basic research is carried on mainly at the institutes of the CSAV or of universities, and only to a smaller extent at the research institutions of the branch ministries.

The projects under *(iii)*, also worked out at the institutes of the CSAV or of universities, are programmed in the plan of technological development, prepared by the State Commission for Technology. This Commission is in charge of introducing advanced technology into the national economy. The projects involved here are those having a direct connexion with research and development and the implementation of their results by industry; they are worked out at the CSAV only by direct request. At present such projects take up about 15 per cent of the total research manpower capacity of the CSAV institutes.

(b) Methodology of programming and planning basic research

Since the beginning of planning scientific and research activity in Czechoslovakia the methods of programming and planning basic research have been based on the principle that the programming should be proposed in the first place by the scientists themselves. It is worth mentioning here that the Czechoslovak Academy of Sciences has taken over on its own initiative the programming and planning of scientific activity; thus as early as 1956, thanks to the CSAV, Czechoslovakia was one of the first countries to work out an all-state plan of important research and scientific projects.

The methods of the plan have undergone some changes since then, but the principle still remains valid. The tentative draft of the state plan of basic research is fully in the hands of the scientific workers at the institutes of the CSAV, affiliated university institutes and the CSAV Presidium; this latter, as a managing body of the CSAV, evaluates the proposed plan. The final formulation of the proposed plan is then submitted for discussion and approval to the Czechoslovak Government, to which the CSAV is directly responsible for its activities.

Proposals as to what research projects should be included in the five-year basic research plan are made by scientific teams of the CSAV institutes or scientific and pedagogical-scientific workers at university-level schools. The proposals formulate the target-orientation of the work, justify its significance, and indicate possibilities of further application as well as further data required by the planning methodology.

Before the five-year basic research plan is drafted, studies are prepared delineating the direction and orientation of the main research trends in the different branches of science. These studies are prepared by the scientific Collegia of the CSAV.

These Collegia are the basic scientific organs of the individual branches of science or groups of branches; they consist of members of the CSAV, directors and scientific workers of the CSAV institutes, and scientific and pedagogical workers of universities or other prominent scientific and professional workers. The chairman and members are nominated by the CSAV Presidium, which directs their activities. The scientific Collegia, which direct and supervise the survey of scientific problems made by CSAV institutes under their authority, are also responsible for carrying out other important tasks in programming and planning scientific activity. They are the managing bodies of complex projects in the basic research plan, co-ordinating, supervising and evaluating the fulfilment of the projects; they further work out for the basic research plan studies and proposals concerning long-term trends in the development of Czechoslovak science as well as proposals for complex projects and their goals.[1]

(c) *Content and structure of the basic research plan up to 1970*

The basic research plan covering the fields of engineering, agricultural, medical and natural and social sciences etc., is based on the prospective needs of the country. These needs are met (at least theoretically) by new scientific solutions and by projects resulting from the requirements of further scientific development in the branches which are studied at the CSAV.

The five-year basic research plan includes projects of three types:

(i) Complex projects, which represent very important general scientific or social tasks; they sometimes call for collaboration of several branches of science. Generally the respective scientific collegium of the CSAV is responsible for the management, co-ordination and supervision of the complex projects which are subdivided into main projects.

(ii) Main projects, which are important sections on one theme of the complex projects worked out in collaboration with several research institutions. The leading institution is responsible for their elaboration and co-ordination. Each main project includes several partial projects.

(iii) Partial projects, which are the scientific problems studied at one institution; they are components of a main project. The work on partial projects is divided in such a manner that it can be under continuous supervision; the total period of elaboration should not exceed three years.

The five-year basic research plan, approved by the Government, itemizes only the complex and the main projects, which are set out in ten chapters of the Plan. It further includes what are known as independent main projects, which are those that cannot be incorporated in complex projects.

The operational plan for each year covers all partial projects being programmed within the framework of the five-year basic research plan structure. Changes are made each year in connexion with the accomplishment of individual partial projects or the programming of others. The Presidium of the CSAV discusses and approves this operational plan.

(d) *Method of elaborating a state five-year plan and an operational plan of basic research*

Methodological instruction and printed forms are sent out for the preparation of a state five-year plan. The principle followed in working out these instructions is that of the least formality possible; stress is laid on the discussion about scientific collaboration of the basic research institutions within the framework of the main projects. As we have seen, the collaboration may be necessary

[1] At the present time there are 21 scientific collegia of the CSAV: for mathematics; astronomy; geophysics; geodesy and meteorology; physics, nuclear research; geology and geography; science of materials; technical cybernetics and electrotechnology; mechanics and energetics; chemistry and chemical technology; organic chemistry and biochemistry; general biology and special biology; medical sciences; theoretical basis of agriculture; history; philosophy and sociology; economics; political science and law; arts; linguistics. A special joint commission of the CSAV and the Ministry of Education has been set up for pedagogics and psychology.

between the different institutes of the CSAV, faculties of the universities, and other research institutions.

(i) Five-year basic research plan. The basis of the preparation of a five-year basic research plan is the elaboration of the plan concept, which lays down the direction and orientation of the scientific work within a particular classification corresponding to the general structure of the plan, i.e. within the classification corresponding to the preliminary proposed complex projects. The concept is worked out on the basis of analyses and studies prepared by the scientific Collegia of the CSAV and in collaboration with the CSAV institutes. The concept of the five-year plan is discussed and approved by the Presidium of the CSAV. The scientific institutions which may carry out the elaboration of the main projects indicate the research goal in accordance with the concept of the complex project; they have a preliminary discussion about the necessary collaboration with other scientific institutions and submit the draft of the main projects to the respective scientific Collegia of the CSAV in charge of the complex project.

The scientific Collegia examine the proposed main projects to ensure that they implement the complex project and are in line with its orientation; the collegium works out a tentative draft of the whole complex project and the targets it should reach. On the basis of these drafts, the Institute for Planning Science then draws up a tentative five-year plan, which is first discussed by the Presidium of the CSAV and is finally approved by the Government.

(ii) Operational plan of basic research. After the five-year basic plan has been duly approved, the operational plan for the first year of the five-year period is prepared, consideration being taken of the proposed second and third year programmes. The operational plan includes all the partial projects being worked out within the scope of the main projects of the five-year plan. In the subsequent years only changes and supplements to the planned projects are carried out.

The dominant role in the elaboration of the operational plan is played by the main CSAV institution in charge of the projects concerned. It delineates the scope and direction of the main project and enters into active contract with research institutions being considered for the realization of partial projects. The main institution discusses with them the content and extent of mutual collaboration and evaluates the projects suggested by them. It then selects the partial projects whose elaboration will ensure the fulfilment of the main project goals outlined by the five-year plan, on the principle that all efforts and resources must be concentrated on the main problems; in particular, a mechanical acceptance of partial projects suggested by the collaborating institutions has to be avoided.

On the basis of the conclusions resulting from the discussions on the partial project, the collaborating institution (either within the CSAV or outside it) sends its proposals in duplicate to the main institution for approval. After these proposals are accepted by the main institution they are incorporated in the operational plan of the main project.

(iii) Financial support of the basic research programme. The budgets of the CSAV research institutes are detailed in the budget of the CSAV, which is covered out of the state budget; thus the expenditures on the basic research projects are also covered out of the budget of the individual CSAV institutions. The expenditures on research at the universities are covered out of the state budget as well. Partial projects worked out by research institutions which are not financed by the state budget (those of industrial enterprises) must be paid according to the terms of the contract by the main institution which has ordered the elaboration of the project. The main institution applies to the Presidium of the CSAV for a special allocation to meet the expenditures.

(e) Programme of basic research plan with special reference to perspective industrial development

The basic research plan for the period 1966–1970 covers selected basic research projects resulting from prospective needs of the economic and cultural development of Czechoslovakia and from requirement for the development of the basic branches of science, as well as from the scientific traditions and resources of the country.

The complex programme of the basic research plan is divided into ten sections. These are:

- I Exploration of non-living matter;
- II Exploration of the structure and function of living matter;
- III Exploration of raw material resources;
- IV Exploration of new types of materials;
- V Theoretical bases of machinery and construction engineering;
- VI Exploration of complex automation and automatic control;
- VII Biological bases of agriculture;
- VIII Research in medical sciences and health care;
- IX Research concerned with developing countries; and
- X Research in social sciences.

The first two sections concentrate on the needs of development of the individual branches of science (purely basic research). Sections three to six are oriented chiefly towards research on the theoretical foundations of the prospective needs of the selected outstanding projects affecting the national economy (oriented basic research). The seventh section, the biological bases of agriculture, is of fundamental importance to the increase of the quantity and quality of agricultural products. Section eight covers research in medical sciences on a national scale; the subject-matter of the research projects included in this section is exceptional in that it covers both the projects of the basic research and those of applied research in clinical institutions. A wide range of problems is dealt with in section nine also, for it concerns basic (and particularly, applied) research from the point of view of assistance to the developing countries; it therefore relates both to the natural and to the engineering sciences. The tenth section is dedicated to the problems of social phenomena, the study of which contributes to a deeper understanding of the laws governing the development of society.

The CSAV institutes, the faculties of the universities and the research institutes managed by ministries participate in the elaboration of the programme of the basic research plan (see figure I). In 1967 the participation of the CSAV institutes ("A" in figure I), calculated by the number of

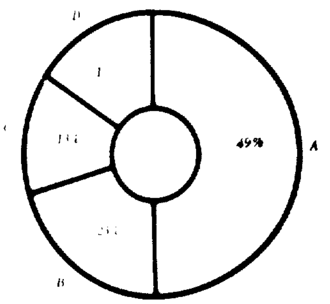

Figure I. Shares in the total research capacity devoted to the basic research plan in 1967

scientific workers engaged in the elaboration of projects of the basic research plan, represented 49 per cent; that of the universities ("B" in the figure) 23 per cent; that of clinical institutions of the Ministry of Health ("C" in the figure) 13 per cent; and that of the research institutions of the other economic branches ("D" in the figure) 15 per cent of the total research capacity so engaged.

The branches of science that are relevant to the development of industries in the basic research plan naturally constitute only some of those studied at the Czechoslovak Academy of Sciences, the main sponsor of the programme. All the engineering sciences are involved, as well as the major part of the physical and chemical sciences, and some of those concerned with the earth; mathematics is also included, as the basis of all the exact sciences. Altogether five sections (I, III, IV, V, VI) are involved in the plan.

The share of these five sections in the entire programme of the operational plan of basic research in 1967, expressed as a percentage of the total research capacity, is 35 per cent. That 35 per cent share is composed of 16 per cent for section I, 6 per cent for section III, 4 per cent for section IV, 6 per cent for section V, and 3 per cent for section VI.

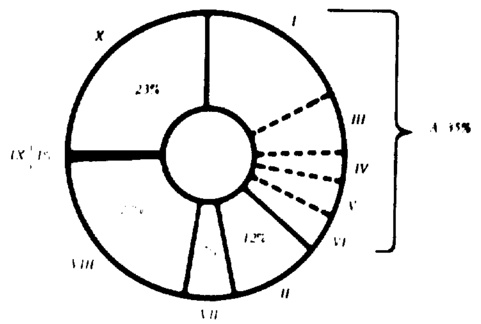

Figure II. Total research capacity by sections of the basic research plan in 1967

In figure II all these sections (which are important for the development of technology and industry) appear as sector A. The shares of the other sections of the basic research plan are 12 per cent for section II, 7 per cent for section VII, 22 per cent for section VIII, 1 per cent for section IX, and 23 per cent for section X.

In 1967, 36 per cent of the total research capacity of the CSAV institutes was dedicated to the programme of the basic research plan; this represents almost half of the total volume of this plan. The CSAV institutes also take part in the elaboration of concrete projects of the research and development plan in which their participation is necessary. The volume of this research, carried out mainly in the sphere of engineering sciences and chiefly by the CSAV Institute of Nuclear Research, represented about 8 per cent of the total capacity of the Czechoslovak Academy of Sciences in 1967. The remaining part of the research capacity of the CSAV institutes is dedicated to institute projects, which are not included into the over-all programme, and which covers such activities as consultations and expert advice, pedagogical activity and study stays abroad.

An analysis of the research capacity employed on the individual projects of the programme of the Basic Research Plan shows that in the part of the programme being worked out at the CSAV institutes (see figure III) approximately one half of the

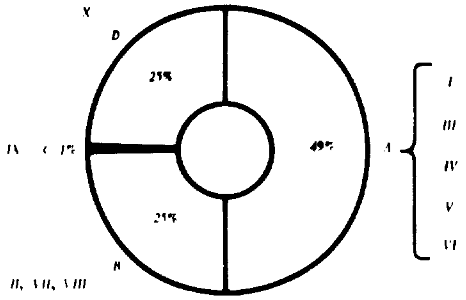

Figure III. Research capacity employed on basic research plan in 1967, by sections of the plan

total capacity of university graduate workers belongs to group A, which covers sections I, III, IV, V and VI of the programme. The participation share of the Czechoslovak Academy of Sciences in this respect is higher than the average, amounting to about 73 per cent.

In the entire group A, section I represents almost one half of the volume of work and 80 per cent of it is carried on at the CSAV institutes. Group B (25 per cent of the whole) consists of sections II, VII and VIII, group C (1 per cent) is section IX, and group D (25 per cent) is section X.

The results of basic research can exert very significant influence on the long-term development of both industrial branches and of the whole national economy. The prospective plans and targets of development in the main industrial branches are among the most important factors in programming scientific research in the branches of science belonging to group A.

The determination of long-term targets and the orientation of economic growth in the various industries not only play an important role in the formation of conditions in the production sphere itself but also to a great extent condition the purposeful orientation and selection of basic research programmes as well as the planning of the development of the scientific base in the country.

The governmental decree on the elaboration of long-term conceptions in all branches of the national economy up to the year 1980 contributes considerably to the preparation and elaboration of the next basic research plan—especially in the sense of a better adaptation of this plan to the needs and targets of social life. In particular it will promote the effective concentration of research and development capacity on the selected and most important problems to be solved by the country's own efforts.

In this regard the CSAV and its scientific Collegia have elaborated eight scientific and technological conceptions; three of them are closely linked to industrial development and are considered below.

The first is the expansion of chemistry and its influence upon the chemical industries and other branches. This conception indicates the prospective rational structure of the chemical industry, the raw material resources of Czechoslovakia being taken into consideration. It also deals with the role of science and research in the fields of chemical products and their application, of chemical technological processes in production, and of the development of machinery and equipment for chemical industry. It also outlines the connexions with all the questions of research and development in the field of chemical engineering that have already been mentioned. In an analysis of the present situation the conception lays down the lines of expansion in research and the development base of the chemical sciences, their prospective structure and the amount of funds that will be necessary.

The second conception is the tendency in the further development of the raw material base of the machine section, in particular of metallurgy. Attention is concentrated in this conception on improvements in the structure of metals (promotion of high-quality steel production and other special steels, of plate production and of economic profiles production etc.) and on evaluating the prospective development of the sector. The two main issues here are the raw material resources of Czechoslovakia and the expected expansion of the chemical industry (e.g. the substitution of steel by chemical materials). The concept likewise specifies certain further demands to be made on science and research and the manner of ensuring their fulfilment.

The third conception is the outlook for nuclear physics in Czechoslovakia. The fuel and energy requirements of Czechoslovakia and the sources from which they are to be met are the subjects of this conception. From this study is derived a statement of the requirements of energy to be produced in nuclear power stations. Various technological conceptions are examined (natural uranium, enriched uranium, classical reactors, breeders etc.) and the line of nuclear power-station construction in Czechoslovakia is determined accordingly. A draft profile of Czechoslovak nuclear research is described, due account being taken of the international division of labour and the conditions prevailing in this line of research.

On the basis of scientific and technological conceptions, the trends, problems and projects to be dealt with in the plans of basic research and of applied research and development are worked out. The relationships between scientific and technological conceptions and planned projects are shown in figure IV.

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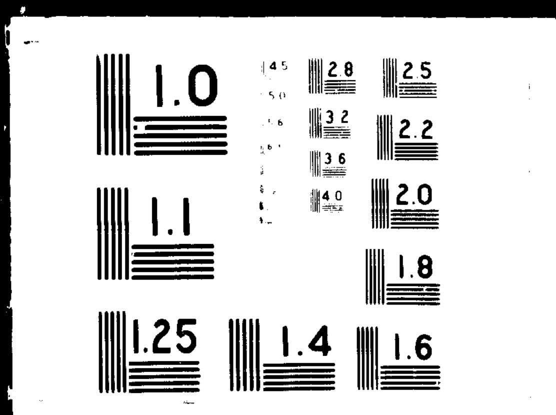
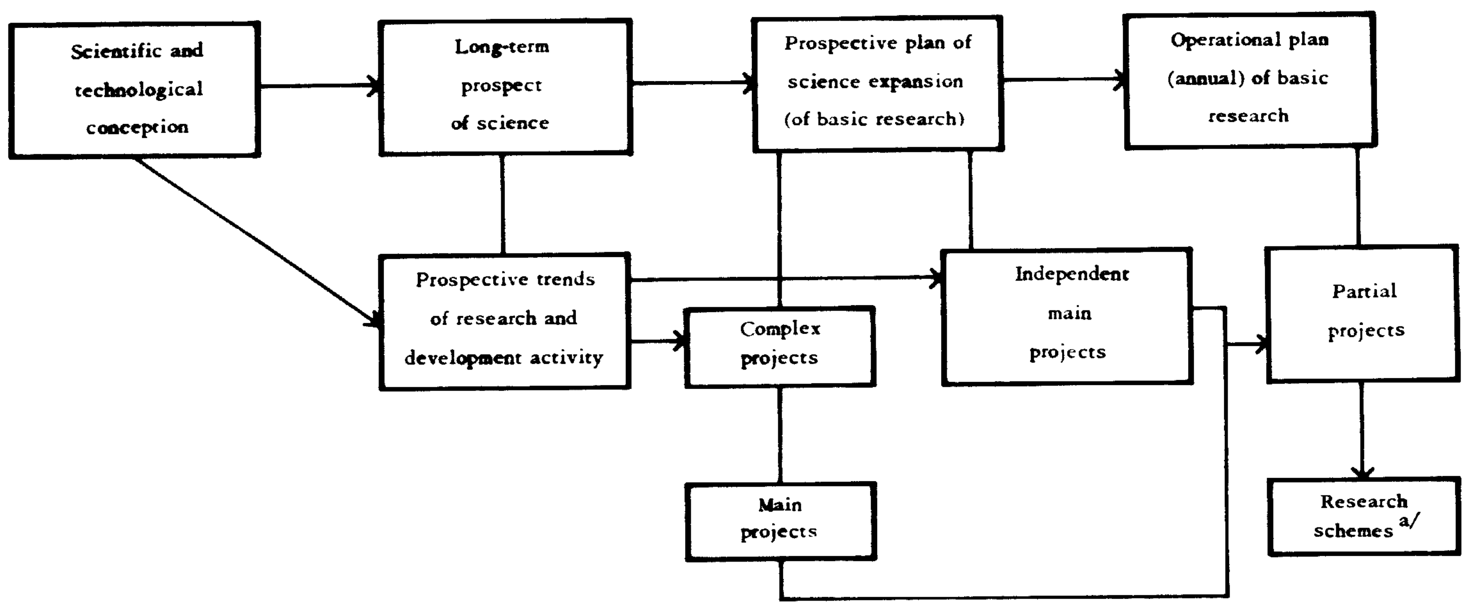




a These are a part of research institute plans

Figure IV. **Relationship between scientific and technological conceptions and plans of scientific and research activities**

Scientific and technological conceptions and plans are elaborated both by the research institutes and by the managing bodies of scientific work (the CSAV Presidium, the scientific Collegia, and the Institute for Planning Science). The fixed trends and projects of research are applied both in the state plans of basic research and in the research plans of single institutes and departments.

3. PROBLEMS OF PROGRAMMING AND PLANNING RESEARCH AND DEVELOPMENT ACTIVITIES IN RELATION TO INDUSTRIAL GROWTH

At the present time, social, cultural and economic progress is more and more dependent on the results of science, research, discoveries and advances in the world of technology. Problems in science and technology, once they have been solved, are realized as a rule in from 5 to 15 years in the development of production forces, and an outstanding scientific discovery frequently affects the life of the society for many decades. It is a fact that the time-lag separating the result of research from its practical application is gradually becoming shorter. Today's state of scientific knowledge will shape the future of society. Scientific and technological development represents together with prospective planning, two organically linked and inseparable facets of social activity.

Thus the analysis of the state and trends in the development of science and technology must be of a long-term character. It is this long-term character which enables society purposefully to give a material form to the basic social and economic changes resulting from contemporary scientific and technical knowledge, and simultaneously to outline a uniform national scientific and technological policy.

The significance of long-term planning therefore rests in the analyses of already-achieved results, of discovered possibilities and the expected results of scientific knowledge; its aim is long-term changes in the life of society, in the development of production forces, and in the methods to secure these most effectively by the development of science. The analysis of scientific knowledge and technical progress generally takes the form of studies and conceptions.

A study represents an analysis and a technological and economic evaluation of all the basic trends of the development of science and technology and finally makes an evaluation of the most promising and efficient trend. It is obvious that this analysis must be based on the results of world science. The scientific and technological base itself in this field has essentially two functions:

(i) It is taken as an integral component of world science and research.

(ii) Its work is to disseminate the achievements of world science.

A conception, on the basis of the analysis carried out in the study, represents an already elaborated complex observation on subsequent development; it gives preference to the most efficient aspects of scientific development, discards others, and creates a uniform, internally well-balanced system of interrelations promoting progress in a certain sphere.

The study is thus predominantly based on the analytical activity, while the dominant aspect of the conception lies in the quantified synthesis to secure the socially most desirable and most efficient progress in one given sphere (sector, branch or group of sectors).

As to the factual character of the conclusions worked out concerning the development of science and technology, they can be further subdivided.

(a) There are the scientific and technological studies and conceptions analysing particularly the tendencies of basic scientific research and the world tendencies in progress in this sphere. They aim at evaluating a possible influence of science on some basic changes in production and, above all, at indicating the most noteworthy trends in the orientation of scientific and research activity. The quantification of such studies and conceptions frequently arising from the internal requirements of the development of science itself is generally difficult from the aspects of both economic effect on the development of production forces and demands made on social resources;

(b) Technological and economic studies and conceptions come next: they cover the evaluation of the basic tendencies in scientific and technological world development, and their influence on the development of production forces, on changes in the structure of the economy itself of the country concerned, and on the prospective orientation of research and development activity. This group is the most important from the point of view of their relationship to the development of the national economy, and their elaboration is vitally conditioned by the quantification of economic effects resulting from the realization of science and technology and by demands made on economic resources (e.g. capital investments) to ensure their further development;

(c) A third group is made up of socio-economic studies and conceptions partially relevant to scientific and technological development, which deal with the basic areas and

spheres of the economic aspects of reproduction processes (e.g. manpower resources and natural wealth) or such basic social questions as changes in living standard etc. In these studies, too, it is essential to make a quantification of the demands on social resources and of the results of putting the studies into practical effect.

These studies as well as others that do not directly concern scientific and technological development, such as studies on the improvement of the system of management and regional development, are being worked out in Czechoslovakia within the framework of the preparation of a long-term plan.

An important question is the length of the time-period for which the studies are drafted. Here the starting point is the duration of the single phase of scientific and technological development concerned: i.e. generally there is a time-lag of from 7 to 15 years between the origin of a scientific idea and its realization[2]. If we take into account the fact that the national economy is affected by the new scientific trends only after technology has massively implemented them, which usually takes several years after the initial realization, we can assume that from 10 to 20 years represents an average period for the realization of a given scientific and technological trend. If the prospective plans and studies are to fulfil the basic requirements—to become the tool of change in the economic structure—they must necessarily be drafted for a period of at least 15 years[3] because of the time-lag in the realization of certain structural changes.

The maximal time-period for which it is effective to work out a long-term forecast is considered, from the point of view of scientific and technological development, to be approximately 25 years. Planning for a longer period is possible, but it is very difficult to express the economic consequences of the expected scientific and technological trends, as their practical application in the majority of cases will require 20 to 25 years. At present their practical application may only be in the stage of basic and pioneer research and is therefore not technically and economically definable. The long-term forecast may thus have only an orientative and uncertain character, pointing to some lines of development rather than providing a realistic evaluation of scientific trends.

[2] The time lag is however much longer in some revolutionary scientific discoveries, such as the problem of thermo-nuclear synthesis; but it is usually shorter in the case of technological developments representing only a "quantitative" improvement of existing technological trends (increase of pressures, temperatures, speed and other performance parameters of engines and devices).

[3] The time of 15 years corresponds approximately to the period between discovery and exploitation of new natural resources, to that of professional manpower training, and in a number of cases to that of the life-time of fixed assets, particularly machinery (although in heavy industries—steel mills, power and chemical plants etc.—the life-time of some aggregates is longer). We cannot exclude the possibility that the time parameters of all these phenomena may change in the future; they might become shorter. Similarly, it cannot be excluded that in the delimitations of the optimum time-period other circumstances will have to be taken into account.

(a) Technological and economic studies and conceptions and the methodology of their elaboration

Studies and conceptions may be divided into four classes.

(i) Studies and conceptions of a sector, section etc. usually analysing the nature of the current state and tendencies of scientific and technological development in one given sector, one section of a branch etc.—subjects such as the development of electronic production and its application, the development of high-quality steel production and the utilization of wood pulp.

(ii) Studies and conceptions of intersectional character, generally analysing the problems of science and technology within the framework of an entire branch; e.g. the development and application of machine engineering technology, fuel mining and its rational exploitation and the rational utilization of water resources.

(iii) Studies and concepts of an interbranch character, analysing the problems of scientific and technological development, usually in a broad national economic context, the utilization of certain products, the technological and technical similarities between certain products etc. An example is the question of extending the application of chemical products and processes in all branches of the national economy; this application includes the development of raw material bases for chemical production, the production of chemical products, their application in the various fields of economic activity, and the production of the machinery necessary to secure such development.

(iv) Studies and conceptions of a cross-sectional character analysing scientific and technological development in a given area through the entire cross-section of the productive and non-productive sphere of the national economy; e.g. problems involving the development and application of automation and data-processing techniques in the various branches and sections of the national economy.

The solution of interbranch and cross-sectional studies and conceptions is of an extraordinary importance. The implementation of the interbranch principle, i.e. the consideration of the interbranch relations and connexions in production and consumption, must be adopted as the basic working method, the application of which is also significant for the evaluation of alternative solutions.

The decisive criterion and final aim in the preparation of long-term technological and economic studies and conceptions must be the endeavour to find the most progressive technological and economic solution of a given problem. The method of finding the optimal scientific solution should be based mainly on the gradual elaboration and comparison of a number of variant solutions and on technological and economic evaluations of the technological and technical provisions (while considering substitutable variants, measures and main trends). In other words, the solution should be based upon an assessment of the possibility of substituting products with the same use-value, particularly substitution of different kinds of raw materials, material and energy, and the corresponding substitution of capital investment projects.

As to the manner of preparing long-term technological and economic studies and concepts, we must consider as the basic building blocks the technological solution of a given part of a technological and economic study which is being investigated in several alternative solutions covering a certain technological area.

These building blocks can be subdivided as follows:

(i) Production capacities with higher parameters (performance, pressures, temperatures, speeds etc.—e.g. complex technological units for brown coal mining, power-plants with blocks of 200, 500 megawatts, new refinery capacities for crude oil processing, completely mechanized forms in agricultural and live-stock production) or equipment based on new production principles (e.g. nuclear power plants).

(ii) Progressive technological production processes (e.g. intensified production of pig iron, steel production in tandem high furnaces or in oxygen converters, progressive technology in machine engineering or in building construction).

(iii) Important trends in the development of automation and data-processing techniques (introduction of automated control systems for technological processes, production, enterprises and plants as a whole, and also the quantification of the main means of automation and data-processing techniques).

(iv) Structural changes in the material base of production (e.g. increasing the share of chemical fibres in the textile industry, utilizing of plastic materials and metals in building construction).

(v) Important one-purpose investment units and projects, e.g. construction of chemical complexes, water-ways and highway networks; and

(vi) Important schemes of renovation, modernization and reconstruction of the productive capacity of industrial branches on a higher technological level, and on a higher level of concentration and specialization of production.

Special attention is given to the technological and economic characteristics of selected products, groups of products and branches.

The bases for the elaboration of the individual long-term technological and economic studies and conceptions are the analyses of the current scientific and technological development in the area investigated by the study. In principle, the inner structure of such studies shows the following analytical stages:

(i) The analysis of the current state of technological and organizational level of the production, and the raw-material bases and the efficiency in the utilization of capital and labour in the industrially advanced countries.

(ii) The assessment of prospective tendencies and trends of scientific progress in the world, and the assumed applicability and prospects of the results achieved in basic and applied research being employed in production.

(iii) The analysis of the current structural development and of the current state of the technological and organizational levels of the production base in the country concerned; an analysis of all the factors determining the basic economic indicators of the production process, and interbranch relations, natural resources, manpower qualifications, relations to foreign trade etc.

(iv) The determination of which decisive trends in scientific development will be applied in the prospective development of the country, on the basis of the analysis of present development of natural resources and world tendencies in scientific development.

(v) The determination, on the basis of analysis of and conclusions drawn from the results achieved in scientific research and development, of which scientific trends will depend on research and development activities inside the country and which on the international division of labour and co-operation with the countries of the socialist system and within the frame of contacts with non-socialist states (in particular through licensing agreements).

As far as the method of technological and economic evaluation is concerned many important relations of the individual studies and the main scientific trends are involved.

From the viewpoint of the national economy these are:

—possible extent of application in view of technological readiness and the optimal volume of the capacity concerned (volume of production, extent of modernization, extent of new construction etc.);

unit and total demand on manpower, expressed in units comparable with those of the production method already used;

—total demand for material, raw material, fuel and energy in the same comparable units;

unit and total investment demand (construction and machinery) in the same comparable units;

—unit and total investment demand being called on in other sectors of the national economy etc.;

effect on foreign trade (imports and exports in the respective material units and the prices in internal and foreign trade); and

development of data on production costs and their relation to a comparable level.

From the viewpoint of research and development activity they are:

—the funds necessary for research and development in the particular country itself; funds for the utilization of scientific findings information and discoveries from abroad;

—construction of new institutes, purchase of special and individual equipment for research and development (i.e. electronic computers, special pilot-plants for experimental productions, laboratories) and other investments to ensure research and development; and

—expected development in the application of the international division of labour and the forms it takes (common institutions, common research teams etc.).

The efficiency analysis should promote mainly an evaluation of the economic prospects of individual research and development trends, the determination of those trends on which attention should be concentrated and—as required—the direct formulation of complex interbranch scientific problems which should be assigned high sectional priority for research and development activity.

The system of technological and economic studies and conceptions forms, by its own inner structure (of different trends, measures and variants), a reserve of scientific and technological solutions at various stages of maturity to be carried out. On this basis (according to the urgency of the needs, economic effect, national resources and degree of theoretical and practical control of each solution) it is possible to make a priority list for the carrying-out of these solutions in a long-term plan.

The elaboration of technological and economic conceptions is based on the analysis already made in the studies, and on the evaluation of current resources of the national economy. The most important of these bases are:

—initial assumptions of national income growth, e.g. for the year 1980;

—the setting up of basic quantified targets or projects of key importance;

—the complex of related projects that will enable results to be compared during the preparation work or that will draw attention to new interbranch relations;

—the elaboration of some cross-sectional technological and economic conceptions, particularly the conception of automation and the use of data-processing techniques.

The complex of indicators applied during the preparation of the technological and economic conceptions, is expected to enable us

—to assess the efficiency of the proposed development trends and measures as well as their variants,

—to assess the applicability and prospects of the proposals, and

—to formulate complex connexions of proposals.

In Czechoslovakia the following data requirements for interbranch technological and economic conceptions were worked out.

Designation of data and indicators	*Sum-total of the entire conception*	*Main trend No. 1*	*Main trend No. 2*
1. *Production (output)**			
(*a*) volume in 1980 corresponding to realization of concept			
(*b*) growth rate in comparison with 1965			
2. *Capital investments**			
(*a*) total volume in period 1965—1980 for realization of conception			
(*b*) for machinery and equipment			

* In 1,000 million Czechoslovak foreign exchange crowns at the official rate.

Designation of data and indicators	*Sum-total of the entire conception*	*Main trend No. 1*	*Main trend No. 2*
3. *Production costs**			
(a) volume in 1980 corresponding to production (output) volume in item 1 (a)			
(b) relative savings in 1980 as compared with 1965			
4. *Manpower*			
(a) total need in 1980 for production (output) volume in item 1 (a)			
(b) relative savings in manpower in 1980 as compared with labour productivity level in 1965			
5. *Influence of selected measures on foreign trade*			
(a) relative decrease in imports in 1980 as against 1965*			
(b) increase in exports in 1980 as against 1965*			
(c) increase in imports of main raw materials in 1980 as against 1965*			
6. *Fuel and energy consumption by type*			
(a) consumption:			
(i) electricity			
(ii) steam			
(iii) coal			
(iv) oil			
(v) other			
(b) relative saving in 1980 as against 1965 (in 1,000 BTU)			
7. *Expenditures on research and development*			
(a) total volume in 1965–1980 period on the realization of planned conception measures*			
(b) investment			

* In 1,000 million Czechoslovak foreign exchange crowns at the official rate.

(b) Elaboration of results of technological-economic studies and conceptions

Interbranch long-term technological and economic studies have been worked out in the last few years in the course of the first preparatory stage of the long-term prospects of national economy development; they include spheres of possible progressive development on the basis of research and development under Czechoslovak conditions (so far without linkage to the economic conditions of realization) in the following economic complexes:

—provision of foodstuffs for the population and its rationalization by intensifying agricultural production and modernizing the food-processing industry;

—promotion of chemical production in all sectors of the economy, and a strengthening of the production base by developing a strong chemical industry;

—influence of scientific development on the effective expansion of the raw material base including the production and application of all types of raw materials;

—influence of science on the development of a fuel-energy base and on economizing fuel and energy consumption;

—speeding up, economizing and increasing the utilization of factory and housing construction processes (orientation of capital investment, industrialization of building construction, and development of a new raw-material base for building construction);

—increase in the efficiency of the transport system and handling of products;

—provision for a new range of consumer goods as well as for an extension of and increase in the quality of services available to the public; and

—provision of an adequate water supply for industry, agriculture and the public through the complex utilization of rivers, lakes etc.

Approximately 40 partial long-term technological and economic studies, which mutually complement and affect each other, have been worked out within the framework of these national economic complexes; they are divided among more than 90 main scientific and technological trends.

The following are among the partial conceptions that have been worked out:

Designation of the technological and economic conception	*Main trends in order of priority*
I Development of agricultural production	1 Application of chemical fertilizers and pesticides 2 Mass-production methods and complex mechanization of crop and livestock production 3 Industrial fodder production
II Development of forestry and exploitation of wood pulp	1 Increase of timber and mechanization of forestry industry 2 Concentration of mechanical wood processing and raising of the level of the woodworking and furniture industry 3 Concentration of the cellulose and paper industry and raising of the technical level of the branch 4 Substitution of timber by other materials
III Development of production base for wide application of chemical products and processes in all branches	1 Development of main products, thus promoting more intensive application of chemical products and processes in agriculture 2 Raising the technological and economic level of processing crude oil, tars, gas and petrochemical raw materials 3 Development of the main products to promote the application of chemical products and processes in the textile industry 4 Development of production of the most important macromolecular substances and their processing 5 Development of the basic chemical intermediate products, thus ensuring the wider application of chemical products and processes in all branches of the national economy
IV Development of the fuel-energy base	1 New methods of black coal mining 2 New methods of quarry mining of brown coal 3 Development of coal dressing 4 Bringing up to date the coking process 5 Intensification and new methods of production and distribution of gas 6 Development of the electrification network 7 Development of the heat-supply system 8 Rationalization of energy and fuel consumption in vital industries, transport, domestic and local administration use
V Development of the metallurgical industry	1 Intensification of pig-iron production to promote a decrease in unit consumption of metallurgical coke 2 Intensification of steel production 3 Increased economy of metal utilization 4 Mechanization and automation of metallurgical processes 5 Expansion of non-ferrous metals and powder metallurgy
VI Development of technology and organization of machine engineering production	1 Development of technological specialization in machine-building engineering 2 Raising the technological level in machining, assembly, surface finish, heat treatment, measuring and control 3 Development of cold shaping 4 Development of welding 5 Development of utilization and processing of plastic and of selected non-metallic materials 6 Improvement of the precision, quality and surface smoothness of metallurgy products 7 Improvement of material handling in enterprises 8 Replacement of component parts
VII Development of industrialization in building construction	1 Changes in the material base structure in building construction 2 Development of the production of thermally-insulating building materials 3 Effective utilization of metals in building construction

Designation of the technological and economic conception	*Main trends in order of priority*
	4 Development and intensification of production of mortar and of ceramic building materials 5 Improvement of prefabricated building panels 6 Improvement of technological processes by introducing progressive building methods with structural changes in transport machinery, assembly, handling and finishing 7 Improvement of material handling 8 Specialization and concentration of production
VIII Development of more extensive use of chemical products and processes in the raw-material base of the textile and leather-working industries	1 More extensive use of chemical products and processes in the raw-material base of the textile industry 2 Technical reconstruction and modernization of that industry 3 More extensive use of chemical products and processes in the raw-material base of the leather-working industry 4 Technical reconstruction and modernization of that industry
IX Development of the glass and fine ceramic industries	1 Intensified use of melting and burning processes in industry 2 Technical reconstruction of the glass and fine ceramic industries 3 Specialization and concentration of glass and fine ceramic production
X Rationalization of the production of foodstuffs and its influence on the industrial structure of the food-processing industry	1 Modernization of the dairy industry 2 Modernization of poultry farming 3 Modernization of the meat-processing industry 4 Modernization of the fat-processing industry 5 Industrialization of bakery production 6 Modernization of sugar refineries 7 Modernization of the beer-brewing and the malt industry 8 Modernization of the canning and beverage-making industry 9 Production of semi-finished and ready-to-serve foods on an industrial basis
XI Development and improvement of the capacity and efficiency of machine and equipment transport	1 Modernization of railway rolling-stock and stationary traction devices 2 Modernization of railway lines, stations and junctions 3 Mechanization of cargo handling in transport 4 Modernization of road transport and improvement of the technical condition of road-truck rolling stock 5 Modernization of municipal transport 6 Modernization of road and highway networks and local road networks 7 New methods and transport systems for public passenger traffic 8 Modernization of inland water transport 9 Improvement of the technical level of airborne traffic
XII Geological survey and research	1 Intensification of geological research in and survey of non-ore raw material deposits 2 Intensification of drilling work on fuel deposits, especially of black coal, crude oil and gas 3 Speeding up of geological research on wolfram, mercury, silver, bismuth, tantalum and fluorite deposits and research of the complex exploitation of the rare earth elements 4 Speeding up of the technical development of geological drilling surveys
XIII Development of water conservation	1 Provision of an adequate water supply 2 Improvement of the water purity of rivers 3 Mechanization and automation of water-processing operations

The analytical economic approach is evident in the fact that technological and economic conceptions and—within their framework—the main scientific trends were evaluated in several technological variants of production and consumption; altogether 600 variant solutions have been worked out and evaluated, and within their framework the best variants have been selected (in addition over 100 complex mechanization schemes have been analysed).

From this preparatory work a synthesis was made with the aid of the uniform system of indicators already mentioned, in such a way that the technological and economic conception was synthesized as a whole and each main scientific and technological trend was treated separately; in many instances the priority was indicated according to prospects and economic effect.

Some special problems also were investigated within the scope of the synthesis. For example, the necessity of reconstructing the manufacturing industry, where more than 20 per cent of all employees in the Czechoslovak economy are engaged, led to the formulation of such questions as the following: which sections of the manufacturing industry are to be modernized in order that they may reach optimal efficiency (engineering industries, textile, leather-working, food-processing or wood-working industries)? is it more advantageous to invest in increased fuel mining and electric power production or to economize consumption by the reconstruction and modernization of fuel-power appliances? Within this framework, the questions were also raised whether to give priority to investments (in the railways) for the reconstruction of the boiler system or for the electrification and motorization of the railway track, and in the glass and fine ceramic industries, whether to intensify the melting process or to modernize the cooking process. A similar question was whether it was better to invest in increasing metal production in the metallurgical works or to economize metal consumption in the engineering industries, building construction and transport etc.[4] (Each possible variant cannot be considered absolutely on its own and therefore comparison may lead to the appearance of further variants.)

Even if all these questions are not absolutely matters of controversy, the limitation of capital investment funds and the differences in the effectiveness of each trend make it necessary, if we want effective economic growth, to indicate the order of priority in the allocation of investment funds to these trends.

The technological and economic studies for the period up to 1970 have shown that at that date we may achieve savings of 10 million tons of unit fuel, 1.8 million tons of raw steel, a substantial rise in labour productivity that may be expressed as a saving of over 1.3 million of workers (the investment costs for each saved worker in material handling amounted to 40,000 Czechoslovak crowns and in the manufacturing industry to 80,000 Czechoslovak crowns). It was shown that by allocating about 160,000 million Czechoslovak crowns to investment we may achieve a yearly saving in production costs of over 40,000 million Czechoslovak crowns.

(c) Economic studies and concepts and their significance

In Czechoslovakia the economic studies and concepts of long-term tendencies in the utilization of resources and the possibilities of economic growth are of great importance to the shaping of future relations in the reproduction process.[5] They deal particularly with the problems of natural wealth resources (especially fuel energy and raw material resources), of population development and structure (mainly manpower and its importance to economic and social growth), of capital investment construction, and of fixed assets; and deal also with the questions of optimal life time and the effectiveness of further utilization of machinery etc. Great attention is paid to a step-by-step examination of long-term tendencies in the field of reproduction of fixed assets; this is being done to enable us to determine reliably the development of production demands for funds and capital investment (taking into account the effects of a number of positive or deteriorating factors); and also to indicate the most effective orientation and methods of a technical reconstruction of the entire production base (with a view to ensuring a maximum growth of social labour productivity as well as the structural changes necessary because of the

[4] The aim was to find the most effective solution through the analysis of substitution possibilities. If society can obtain (say) 1 million tons of a specific fuel either by investing funds and labour in the improvement of mining or by investing in the reconstruction of fuel-energy appliance, a special examination must be made to find out which trend is economically more efficient and investment policy must be oriented accordingly.

[5] Studies are being prepared on subjects such as the degree of utilization of fuel-energy and raw-material resources, optimum life of machinery and equipment, development of capital investment requirements in both the non-production and the production branches, which have been made necessary by changes and development tendencies in the social way of life, by the demands for a skilled labour force etc.

participation of the national economy in the international division of labour).

The thematic content of these studies, even if it chiefly analyses economic growth factors (natural wealth, manpower resources, existing capital funds etc.), is closely connected with scientific development which opens up new resources in these areas; it changes, for instance, the extent of the social utilization of certain raw materials (e.g. germanium, silicon in transistor radios) or the degree of exploitation of others (e.g. new progressive technological methods permit the utilization of inferior ores and so on). These studies and conceptions, which concern themselves with certain natural or economic phenomena and processes, on the bases of a complex concept of their effectiveness, also present analyses of the current resources for economic growth available to the society and indications of the future ones, elaborations of complex sectors of the reproduction process, evaluations of complex and variant forecasts and of the factors limiting economic growth, and an outline of the resulting socio-economic targets of development in the period under investigation (e.g. up to 1980—1985).

(d) *Studies of skill requirements and occupational structures and methods of their elaboration*

The long-term studies on the influence of scientific development on the development of the structure, skill level and total educational level of manpower are of outstanding significance.

These long-term studies take into account the individual trends of scientific development and aim to achieve a harmony on the one hand between the structure and professional training of manpower and the growing requirements of the technological level of the various branches, and the entire national economy; and on the other hand between the training of professional and qualified manpower and the expected economic resources and possibilities of society. Forecasts for the professional training system must also take into account the demands resulting from new or expected tendencies in scientific progress.

The elaboration of studies of this type are mainly the result of decisive changes taking place in the structure and qualification of manpower due to the automation of production and management processes.

In practice this mainly concerns projects based on the utilization of manpower models. These models represent one of the bases for the elaboration of studies on the influence of the expected technological and organizational development of individual industrial branches in the next few years on manpower growth and its skill composition.

Several methods are used in the preparation of these studies. The first method is analytical in nature. The starting point for an elaboration of the manpower model here is the concept of the future structure of the production process, i.e. the perspective model of enterprises, which expresses the highest attainable technological and organizational level in the given year (e.g. 1980); such economic aspects, as the study on the optimum size of production plants and their optimal distribution by branches, must be taken into consideration as well. In Czechoslovakia this method has not yet been fully applied.

The second method is basically synthetic in character and although simpler, is only approximate. It is based on data that are assumed for the entire branch or sector of the national economy.[6] The approximate manpower qualification structure at the various levels of technological development and the main tendencies of its changes (schematically shown in the table 1) do not take into account such influences as different organization and division of labour in the individual production branches (the influence of these differences on the occupational structure is, in fact, less than is usually presumed).

This method has been applied in the forecasts worked out in Czechoslovakia. In each branch of industry the present "level of technological development" (as shown in the above table) has been

[6] The first author in Czechoslovakia to attempt to describe the main tendencies of the changes in the skill structure of manpower brought about by scientific development was Jan AUERHAN (see his "*Technika. Kvalifikace, Vzdelani*" [Technology, Skill, Education], Publishing House SNPL, Prague, 1965).

On the basis of a classification – worked out by the Institute of Economics of the Czechoslovak Academy of Sciences – of the characteristics of the labour function in the production process we can differentiate four basic stages during each production process: execution phase, managing phase, preparatory phase and checking phase. From this classification of the man's functions follows the classification of the degree of technological progress; the latter is based not on the technological properties of the production process but on the functional principle, i.e. on the process by which the individual labour functions are transferred from man to machines. The classification differentiates these degrees of technological progress: hand work and manual tools; machine driven by energy other than human; universal machine; semi-automatic machine; mechanized production line; automatic machine or automized production line; automatic machine or line with computer control of the course, conditions and results of the process; automatic devices equipped with additional automatic recording of characteristic parameters of production process; automatic devices with automatic optimalization and adaptive system; automatic devices controlling the technological and economic parameters of the production process.

TABLE 1. TYPICAL MANPOWER SKILL STRUCTURE AT DIFFERENT LEVELS OF TECHNOLOGICAL DEVELOPMENT

(in percentages)

Levels of technological development / *Categories by skill level*	3	4	5	6	7	8	9	10	11
Unskilled	15	7.0	—	—	—	—	—	—	—
Semi-skilled	20	65.0	57	38.0	11	3	—	—	—
Skilled	60	20.0	33	45.0	60	55	40	21	—
Secondary education completed	4	6.5	8	12.5	21	30	40	50	60
University level education	1	1.5	2	4.0	7	10	17	25	34
Higher scientific degree	—	—	—	0.5	1	2	3	4	6

Source: From Jan AUERHAN, *Technika. Kvalifikace, Vzdelani* (Technology, Skill and Education), Publishing House SNPL, Prague 1965.

found together with the corresponding skill structure. The actual skill structure of the branch under consideration has also been found. On the basis of the techno'ogical and economic studies and conceptions the expected level of technological development has been indicated in each sector and branch and has been approximated for the period 1980 – 1985. From this expected level is derived the corresponding classification (both as to the share of skilled workers and to the educational level, e.g. share of workers with secondary or university-level education). These conclusions have been further corrected with regard to the actual difference between the existing qualifications in the respective branches and the expected ones. Simultaneously the anticipated transfers of manpower from one sector of the national economy to another (particularly between the primary, secondary and tertiary sector) have been determined and consequently, the model of the prospective manpower distribution in the national economy.

The third method (basically the simplest) is based on the comparison of skills over a longer period (both in the country under consideration and in other countries) and on the comparison of skill level in the country under consideration with the skill level in advanced countries.

All the approaches mentioned above enable us to obtain an illustration of the process of gradual change in the position of human labour in production and in its skill requirements. They enable us to determine the typical structure and qualifications of the labour forces at various levels of economic and technological development.

In dealing with changes in structure, skill and total educational level the following have to be clarified:

- the relations between scientific development and growth of demands on education;
- the interrelations between the individual categories of workers in the process of scientific development;
- the relations between the expenditures on the training of specialists and the effectiveness of their contributions to the national economy; and
- the structural changes in the managing and administrative organs caused by the adoption of progressive management methods and the utilization of data-processing devices.

The analysis of these relations will give an indication of the growth (not only in volume, but also in the trends) of the demands on the education level and on the means of securing it as well as on the real trends of structural changes in the key occupations of workers in industrial and non-industrial activity; the analysis should further enable us to evaluate the effectiveness of the different forms of vocational training from the point of view of their social contribution; and finally it should provide a basis for the evaluation of the skill requirements of manpower resulting from the mechanization and automation of management and administration.

The studies worked out in Czechoslovakia on the influence of scientific development on changes in the structure and qualification of manpower in the period ending 1985 focused attention on analysis of the present position as well as on:

- the anticipated influence of the main trends of scientific development up to 1985 on the structure and qualification of manpower;
- changes in the shares of automated, machine and hand work in the various branches;
- changes in the ratio of skilled to unskilled manual workers and in the ratio of the manual worker category to the total number of employed persons;
- changes in the ratio between production and non-production manual workers;
- changes in the ratio of engineering-technical personnel and clerks to the total number of employed persons;

changes in the qualification structure of professional manpower by education; and

qualification changes in the labour content of the individual worker—the influence of scientific development on the existence and number of manual-work occupations and on the function of technicians and administrative personnel.

A long-term study of the influence of scientific progress on the development of the structure, qualifications and general education of the labour force, which is based on the analysis of the current state of the structure and qualifications of manpower as well as their past development, of the scientific knowledge of changes in the labour functions of man at various stages of technological progress, and of the long-term prospective tendencies in the development of science and technology, must lead to the formulation of:

anticipated long-term tendencies and distribution of manpower in the main branches of the national economy (development of the volume of manpower by branches and ministries);

anticipated long-term changes in the structure of manpower, by function performed and qualification level (development of the structure of the work force by degree of required and attainable education and development of the structure of specialized manpower by group of study subjects);

long-term demands of investment funds and professional manpower for the development of universities and secondary schools up to 1980.

Only by new methods will it be possible to answer satisfactorily the vital questions of today and tomorrow which depend on discovering the future influence of the present scientific and technological revolution on the structure of the labour force and its qualificational and educational levels, likely changes in the skill-education ratio, adjustment to new demands for education, and the general advancement of man and his scientific thinking.

(e) Relations of technological and economic studies and conceptions to the complex of plans of scientific and technological development

The complex of plans and projects of scientific and technological development represents an objectively conceived scientific and technological policy and must be based on technological and economic studies and concepts; namely those that are partial (sector or branch ones), those that are synthetic (interbranch and intersector such as the wide application of chemical-products processes in all branches of the national economy) or those that are cross-sectional (e.g. development and application of automation and computer technique).

(i) Long-term prospects of scientific and technological development. A long-term prospect must express the general strategy of scientific policy; as a rule, therefore, it cannot yet deal with concrete individual projects of science and technology. A long-term prospect of the development of science and technology prepared both in the state plan and in the enterprise plan should at least include:

The determination of the most decisive sectors and areas (groups of products, important products, technological methods etc.) on which the major part of research and development capacity will be concentrated; provision will be made to ensure their scientific development, which will enable Czechoslovakia to fulfil its commitments in the Council of Mutual Economic Aid at a high technological level and which will ensure a high efficiency of foreign trade;

an analysis of manpower, material and capital investment requirements to secure an adequate capacity to the research and development base, and an analysis of the convertible currency necessary to purchase licences and know-how for the development of the branches not developed by our own means;

an analysis of the changes in the structure and qualification of manpower in the research and development base.

The long-term prospect provides directives for the elaboration of the five-year plan of scientific and technological development and creates the basis for the management and organization of research and development activities.

(ii) State five-year plan of applied research and development activities. If the long-term prospects are noted for the formulation of the concepts, trends and lines of activity, then in accord with these lines the elaboration of the five-year plan must be based on the statement of important scientific and technological problems and a more precise delimitation of the method for their solution — it must, therefore, describe in detail the projects flowing out of strategic aims of the scientific policy. The five-year plan of development of science and technology (research and development activity) covers the most important scientific projects which promote the main trends of industrial and socio-economic development, e.g. solutions of problems of fuel-energy resources, wider application of chemical products and processes, reconstruction of the

manufacturing industry, efficient exploitation of the non-ore raw material base, introduction and development of data-processing techniques.

The decisive trends and projects in the plan to prepare new technology are generally based on complex requirements and planned in the form of complex interbranch projects,[7] the execution of which is secured by basic and applied research, by developing and testing the prototypes, or by pilot-production and realization. These trends are planned in all their interbranch connexions, taking into account the participation of the respective research and development institutions of the individual branches and of scientific institutions, international scientific and technical collaboration with the socialist countries, and the agreements with the non-socialist countries. Research projects planned and managed in this manner include the construction of atomic power plants, the development of new spinning technologies etc.

In addition to the complex projects the state plan includes some important projects concerning usually only one or a few branches—the independent main projects. Such supporting projects may concern such things as hydromechanized coal mining, underground gasification of coal, development of low-carbon steels, new technology of viscose fibre production, new reversible turbines, development of separators for metallurgical works, development of universal series of diesel engines, development of measuring and regulating devices, or development of new types of glass-furnaces.

Finally, the state plan also covers technological economic studies and research projects, the goal of which is the complex evaluation of new trends in science and technology so as to study the preconditions for the preparation of new machines and technological processes.

The pre-condition for a rise in the level of planning science and technology is a systematic evaluation of new trends in science and technology. That is why technological and economic studies, as well as research projects, have been included in the state plan with the same rank as those with a purely technological orientation. Backed by financial subventions, these plans enable the central organs to regulate the formation of technological and economic conceptions in sectors and branches. An example of such a study might be the concept of atomic power-plant construction schemes.

These projects of scientific and technological development are included in both the state plan and enterprise plans. All the other important projects of scientific and technological development are incorporated only into the science and technology development plans of the respective sector (or branch) in keeping with the principle of the full responsibility falling on the respective enterprise and sector management for the prospective development of that sector. This is the case particularly of those projects that are related to changes in production programme of sector enterprises, and to the growth of their technical and economic production level.

The significance of long-term technological, economic, and other studies and conceptions of the above mentioned types is seen not only in the fact that they will become the means of effective structural change resulting from the realization of scientific and technological progress, but also in the fact that—on the basis of evaluation of science and technology—they will simultaneously become the ground for elaboration of long-term prospects of science and technology development and an organizational tool for the management, planning and co-ordinating of research and development work until they are completed.

The evaluation not only of possible effects but also of demands on social resources is particularly important because the realization of conclusions resulting from long-term technological and economic studies cannot logically neglect the fundamental factors of economic growth. It cannot be placed outside space and time and be solved without a complex assessment of the main socio-economic factors; to the contrary, all the factors and conditions must be taken fully into account and, after a complex evaluation, the realization of the studies and concepts must be begun and its rate set.

All these facts show the necessity for an organic linkage of scientific development with the prospective development of productive forces, for unity in the exploration of scientific and economic development and the mutual interconnexions. The structure of the national economy is influenced

[7] Basically the following criteria are decisive for the determination of important complex projects incorporated into the state plan:

A complex project must, as a rule, have a definite goal which is directly associated with an important capital investment action (introduction of a highly efficient new product or progressive production methods etc.) with the delimitation of the time-period in which the project is to be completed and with the place of its realization.

The completion of a complex project must represent the achievement of significant economic effects (in projects aiming at more economical production the yearly savings of production costs should amount to approximately 100 million Czechoslovak crowns at least).

The achievement of the project aim is conditioned by the fulfilment of a number of other projects preparing new machinery and technology. All these projects are factually and chronologically linked up, and their co-ordination must be accurately secured between the branches as well as the scientific spheres concerned.

by tendencies in science and technology, and incentives for development of science and technology flow out of requirements of economic growth in the country.

4. BASIC DATA ON STRUCTURE AND GROWTH OF RESEARCH AND DEVELOPMENT ACTIVITY, IN FINANCIAL AND MANPOWER TERMS[8]

Science has come into the limelight of industrial and social interest, not only as each discovery, invention or technical improvement is realized, but also in its entirety as a specific sphere of human activity. In economic and social life the continuous process of change resulting from an enormous growth of new scientific information takes place fairly spontaneously; this does not hold true of the effects of science as a decisive factor in structural changes. For science to fulfil this highly important mission, it is necessary for the managing economic, industrial and scientific organs to concentrate part of their creative activity on the consideration of prospective social needs and on such research problems as should open up new paths for the development of technology, and the spread of knowledge. The needs of further advancement in education and culture are also closely connected with the necessity for the over-all management and planning of science. If the respective organs are to carry on this activity successfully, they also need in addition to deep professional knowledge, economic information on the labour, material and financial resources at their disposal. Such information may be supplied chiefly by the statistics of science (statistics of research and development activity). While quantification in science, particularly in determining efficiency of research and development activity, has its limits, and while creative activity generally may be characterized only by means of indirect methods, nevertheless, a more exact definition of the quantitative base is very desirable for the estimation of research and development efficiency. This is especially important in the evaluation of research and development efficiency for industrial targets.

[8] The following sources were used in the preparation of this part of the paper:
NEKOLA and ŽELINKA, *Problems of science statistics*, Prague, April 1967, (Study for UNESCO); GABESAM and NEKOLA, *Zpráva of kvalifikační struktuře pracovníku resortního a podnikového výzkumu v ČSSR* (Report on qualification structure of workers in centrally administered and enterprise administered research in CSSR), UPV, Praha, listopad 1966; RICHTER and DOLEŽEL, *Výzkumná a vývojová základna v ČSSR* (Research and development base in the CSSR), Praha, UTEIN, 1966; and data published by the Czechoslovak Academy of Sciences, the Ministry of Finance, and the State Commission for Technology.

In Czechoslovakia the research and development base has been decreed by a law which does not however infringe the principle of subordination of the individual institutions to the central organs or particular enterprises. The scope of the research and development base is defined as being formed of organizations and organizational units chiefly concerned with tasks of a creative character following from the plan of the development of science and technology, or with tasks contributing toward the development of science and technology;

The research and development base hence consists of:

- the Czechoslovak Academy of Science (CSAV) and the Slovak Academy of Science (SAV);
- institutes of university-level schools or their faculties, to the extent laid down by the Ministry of Education and Culture;
- research and development institutes and organizations under the control of ministries, other central organs of the State administration and the National Committee;
- research and development institutions and organizations under the control or trust of industrial enterprises;
- research and development units controlled by organizations which themselves are under industrial enterprises or form part of them, as well as other units predominantly performing tasks incorporated in the plan of the development of science and technology;
- pilot plants, if included in the research and development base by the State Commission for Technology;
- testing and checking institutes under the control of the ministries and other central organs of the State administration;
- institutes of scientific, technical and economic information controlled by the ministries and other central organs of the State administration; and
- other organizations or units which fulfil the tasks of scientific and technological progress and which the State Commission for Technology has included in the research and development base.

Industry is the branch of major importance; it is probably the only branch in which classification should be carried into the individual sections, since in some progressive industrial sections the number of workers engaged in research and development is greater than in many other branches of the economy. In Czechoslovakia, for instance, over 60 per cent of all workers in research and development are engaged in the industrial sector (see table 2).

Table 2. Distribution of workers in research and development 1962 and 1965
(by branch)

Branch	1962 Number of workers	1962 Percentage of total	1965 Number of workers	1965 Percentage of total	Difference in percentage
Research and development base total	108,900	100	128,300	100	—
of which					
Czechoslovak Academy of Sciences	10,600	9.7	13,200	10.3	+0.6
Industry	72,400	66.5	83,400	65.0	− 1.5
Building construction	3,700	3.4	4,500	3.5	+ 0.1
Agriculture and forestry, including water conservancy	11,400	10.5	13,800	10.8	+0.3
Transport and telecommunications	1,500	1.4	2,400	1.9	+0.5
Health service	5,600	5.1	6,100	4.7	−0.4
Other	3,700	3.4	4,900	3.8	+0.4

Statistical data on the scope and structure of research are only an instrument for the application of science in the development of the economy and for planning and programming its substantial component parts– industrial research and development. In Czechoslovakia, as in the other socialist countries, we use in principle two kinds of indicators to show the position in research and development activities the financial indicator and the manpower indicator.

(a) *Financial indicators*

As far as the financial indicators are concerned, the situation in the Czechoslovak Socialist Republic may be summed up by the fact that in the period 1960—1965 current expenditures on research and development activities were doubled. This is shown in table 3.

The drop from 61.6 per cent in 1960 to 55.5 per cent in 1965 in the share of financial funds for research and development flowing out of the state budget is quite interesting. The enterprise funds allocated for research and development activities about compensated for this drop. The growth of current expenditures and the relative shares of the state budget funds and of enterprise funds may be followed in table 4.

Table 3. Research and development current expenditures in Czechoslovakia, by source 1960 to 1965
(in millions of Czechoslovak crowns)

	1960	1961	1962	1963	1964	1965
Total expenditure	3,263.5	3,699.2	4,160.4	4,603.7	5,714.8	6,246.9
Percentage from:						
state budget	61.6	59.7	59.9	58.8	56.7	55.5
enterprise funds	38.4	40.3	40.1	41.2	43.3	44.5

Table 4. Growth of research and development current expenditures in Czechoslovakia 1960 to 1965
(by source, percentage, 1960 100)

	1961	1962	1963	1964	1965
Total expenditures	113.3	127.5	141.1	175.1	191.4
State budget expenditures	109.9	124.0	134.8	161.2	172.4
Enterprise expenditures	118.8	133.1	151.1	197.4	221.6

More detailed data indicate that the volume of funds allocated to industrial research grew by about 190 per cent in the period 1960–1965. It represented nearly two thirds of all current expenditures for activities, i.e. about 4 billion Czechoslovak crowns.

The survey shows that more than half of the expenditures for research and development in industry was spent on machinery: in Czechoslovakia this includes machines for electronic production, electrotechnical branches, data-processing devices and the vehicle industry. The second largest branch in this respect was chemistry whose share, however, covered only about 13 per cent of the total current expenditures for industrial research and development.

Current expenditures for research and development activities per employed person in all branches grew from about 500 crowns in 1960 to 1,000 in 1965. They were growing more slowly than the total expenditures for research and development activities. The increase in employment—a factor of extensive economic growth—compensated for the rate of growth in the research and development costs per employed person in the Czechoslovak economy. The total of the employed population grew from 6,063,000 in 1960 to 6,477,000 in 1965 and expenditures for research and development activities from 3,263,000 crowns to 6,246,000 in the same time. The most evident employment growth rate was in industries—the index of 100 in 1960 had risen to 113 in 1965; the total of the employed population grew more slowly—index 106.

The share of research and development expenditures in the total investment in the Czechoslovak economy in the years 1960–1965 also doubled. The percentage shares of current expenditure on research and development in the total capital investment in the Czechoslovak economy for the six years 1960 to 1965 were: in 1960, 7.69; in 1961, 8.13; in 1962, 9.39; in 1963, 11.68; in 1964, 14.37; and in 1965, 14.59.

(b) Manpower indicators by number and structure

Between 1951 and 1955 the number of workers in the research and development base grew from 14,000 to 57,000, i.e. an index figure of 410, between 1956 and 1960, from 64,000 to 92,000, i.e. about 144 per cent and between 1961 and 1965, from 100,600 to 128,300 i.e. an index figure of 121. The expected increase between 1966 and 1970 is 160,000—in comparison with 1966 the growth index will reach 119. The slackened rate of growth in manpower after 1955, and particularly in the years 1960 to 1965, and the less dynamic trend of growth until 1970 may be due to several things. First of all, the very fast growth in the period 1951–1955 would naturally be followed by a period of a certain consolidation (of great importance for creative activities). It is a fact that extensive development of the scope—particularly in research and development activities—is not so effective. After reaching a certain scope the rise in the qualification level becomes decisive. The limited number of workers with the highest qualifications then turns out to be the determining factor. The next fact which has to be taken into account in the growth of science will be the increase in the costs associated with more expensive research programmes. This fact has on the whole influenced the growth rate of costs more than the manpower growth (the number of workers in research and development in period 1960–1965 grew by about half while the expenditures doubled).

The total number of workers in the research and development base in the years 1960–1966 were as follows: in 1960—92,000; in 1961—100,600; in 1962—108,900; in 1963—115,800; in 1964—122,300; in 1965—128,300; and in 1966 it was estimated at 134,000.

Table 5, set out by branches of the economy, shows that industry absorbs more than two thirds of the total number of workers in research and development. It also shows the location of research and development manpower by types of research institutions inside those branches.

Qualification structure is an important indicator of the capacity of the research and development base. This is shown in table 6.

Of the total number of workers in the research and development base 22.4 per cent possessed university education, only 3.5 per cent of these had a higher scientific degree of "candidate" or doctor of science (Ph.D. and D.Sc.); these are called scientific workers. It is necessary to point out that in Czechoslovakia the category of scientific workers is defined in a more narrow sense than in other socialist countries.

The highest qualification structure is to be found in the institutes of the Czechoslovak Academy of Sciences dealing with basic research; here the share of workers with university degrees amounts to 38.6 per cent and that of scientific workers with a higher scientific degree to 18.6 per cent. In other words the proportion of university graduates in the institutes of the Czechoslovak Academy of Sciences is two times higher than the average and that of scientific workers is five times higher

TABLE 5. MANPOWER IN RESEARCH AND DEVELOPMENT 1965
(by branch and type of organization)

Branch	Total	Centrally administered		Enterprise administered	
				Research and development	
		Budget institutes	Enterprise institutes	institutes	departments
Industry	83,650	7,834	1,416	26,191	48,209
Czechoslovak Academy of Sciences	11,415	11,415	—	—	—
Building construction	4,502	—	2,200	108	2,194
Agriculture	13,064	13,064	—	—	—
Transportation	2,395	766	1,218	—	411
Trade	222	222	—	—	—
Education[a]	596	501	—	—	95
Health care	5,602	3,987	—	894	721
Other research	5,016	4,087	219	—	710
Total	126,462	41,876	5,053	27,193	52,340

[a] Pedagogical research institutes of the Ministry of Education.

TABLE 6. MANPOWER IN RESEARCH AND DEVELOPMENT 1965
(by branch and qualification)

Branch	With university education		With specialized secondary education	Others	Total manpower
	Total graduates	With higher scientific degree			
Industry	15,918	995	27,884	39,848	83,650
Czechoslovak Academy of Sciences	4,408	2,120	2,180	4,827	11,415
Building construction	1,183	48	1,500	1,819	4,502
Agriculture	2,710	366	2,596	7,758	13,064
Transportation	704	29	648	1,043	2,395
Trade	109	6	75	38	222
Education[a]	266	33	142	188	596
Health care	1,373	485	1,658	2,571	5,602
Other research	1,610	354	1,278	2,128	5,016
Total	28,281	4,436	37,961	60,220	126,462

[a] Pedagogical research institutes of the Ministry of Education.

The total of 126,462 shown in tables 5 and 6 does not include 1,700 workers of the research and development base fully employed in research and development activity at university-level schools. Of these, 930 are university graduates, of whom 390 are in possession of a higher scientific degree*.

From the point of view of the prospective development of the economy and society a survey of the research and development base by main spheres of economy (as suggested by Fourastier) is of interest (see table 7).

The figure for research and development activities in the economic activities of goods production and circulation and basic research of the Czechoslovak Academy of Sciences represent more than 93 per cent of all research and development. The qualification structure in basic research here seems more favourable; it covers 9 per cent of all research and development manpower, the number of university graduates amounts to 15.6 per cent of all graduates, and the total number of workers with a higher scientific degree reaches 47.7 per cent.

General information about the orientation of research activities is given by research plans, the structure of which has already been described above. A more detailed illustration is provided by the capacity allocated to the solution of one of the research plans being drafted in Czechoslovakia, which is shown by time to be spent by specialized manpower on the solution of main projects (spe-

* The pedagogical staff of universities, amounting to 15,400 professors and assistants working part-time in research and development is not included in this survey at all. The full-time equivalent of this research and development might be about 3,000 to 5,000 workers.

TABLE 7. MANPOWER OF THE RESEARCH AND DEVELOPMENT BASE
(by qualification and sphere of economic activity, by number and percentage, 1965[a])

Economic activity	*With university education*				*With secondary specialized education*		*Other*		*Total manpower*	
	Total graduates		*With higher scientific degree*							
	(No.)	*Percentage*	*(No.)*	*Percentage*	*(No.)*	*Percentage*	*(No.)*	*Percentage*	*(No.)*	*Percentage*
Industrial production and building construction	17,600	62.3	1,170	26.4	29,800	78.6	42,500	70.5	89,900	71.1
Agriculture, forestry and water conservancy	2,900	10.1	420	9.4	2,800	7.3	7,900	13.1	13,600	10.8
Transport, communications, trade and other services	900	3.1	30	0.8	800	2.1	1,100	1.8	2,800	2.2
Goods production and circulation	21,400	75.5	1,620	36.6	33,400	88.0	51,500	85.4	106,300	84.1
Social consumption	2,000	7.2	600	13.5	2,100	5.7	3,400	5.6	7,500	5.9
State administration	500	1.7	100	2.2	200	0.6	600	1.0	1,300	1.0
Czechoslovak Academy of Sciences	4,400	15.6	2,120	47.7	2,200	5.7	4,800	8.0	11,400	9.0
Total	28,300	100.0	4,440	100.0	37,900	100.0	60,300	100.0	126,500	100.0

[a] The item "other research" in tables 5 and 6 has been included in individual spheres of economic activity.

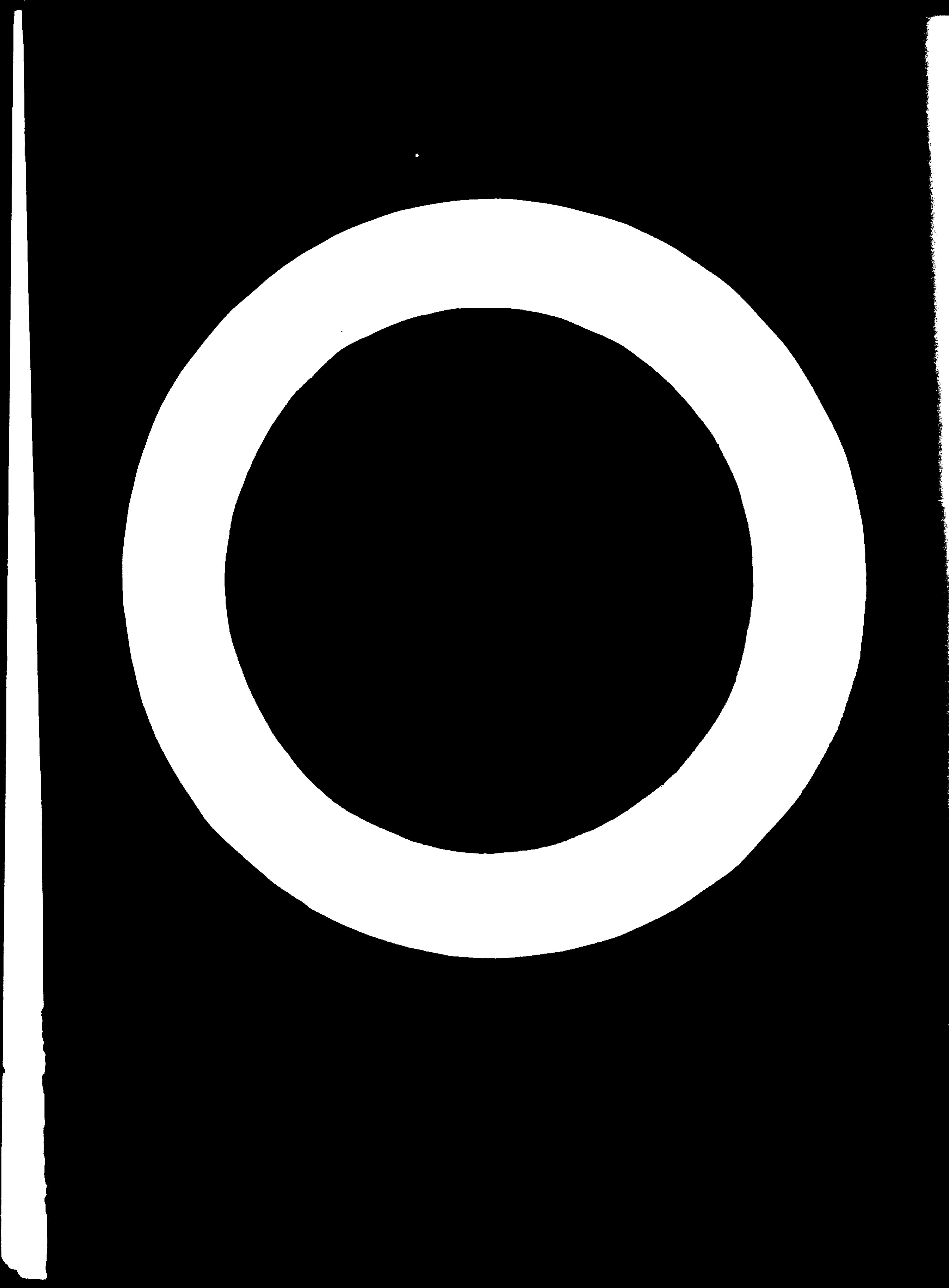
cialized manpower covers scientific workers with university graduation and workers with secondary specialized education). This analysis for the year 1967 has been worked out for the state plan of basic research only (see table 8).

In this plan the first two chapters are focused particularly upon the needs of all scientific branches. From the third to the sixth special attention is given to research on the theoretical bases of the prospective needs of the Czechoslovak economy. The seventh chapter deals with the growth of agricultural production and improvement of its quality, and the eighth also covers research activity in clinics and hospitals. The ninth chapter comprises basic and applied research in natural, engineering and medical sciences, and is focused on the needs of the developing countries. The tenth deals with all problems of social phenomena.

The number of tasks in the structure of the main chapters of the basic research plan provide an approximate indicator only; the number of hours of specialized manpower, surveyed by branches, gives a better account of the participation in the plan.

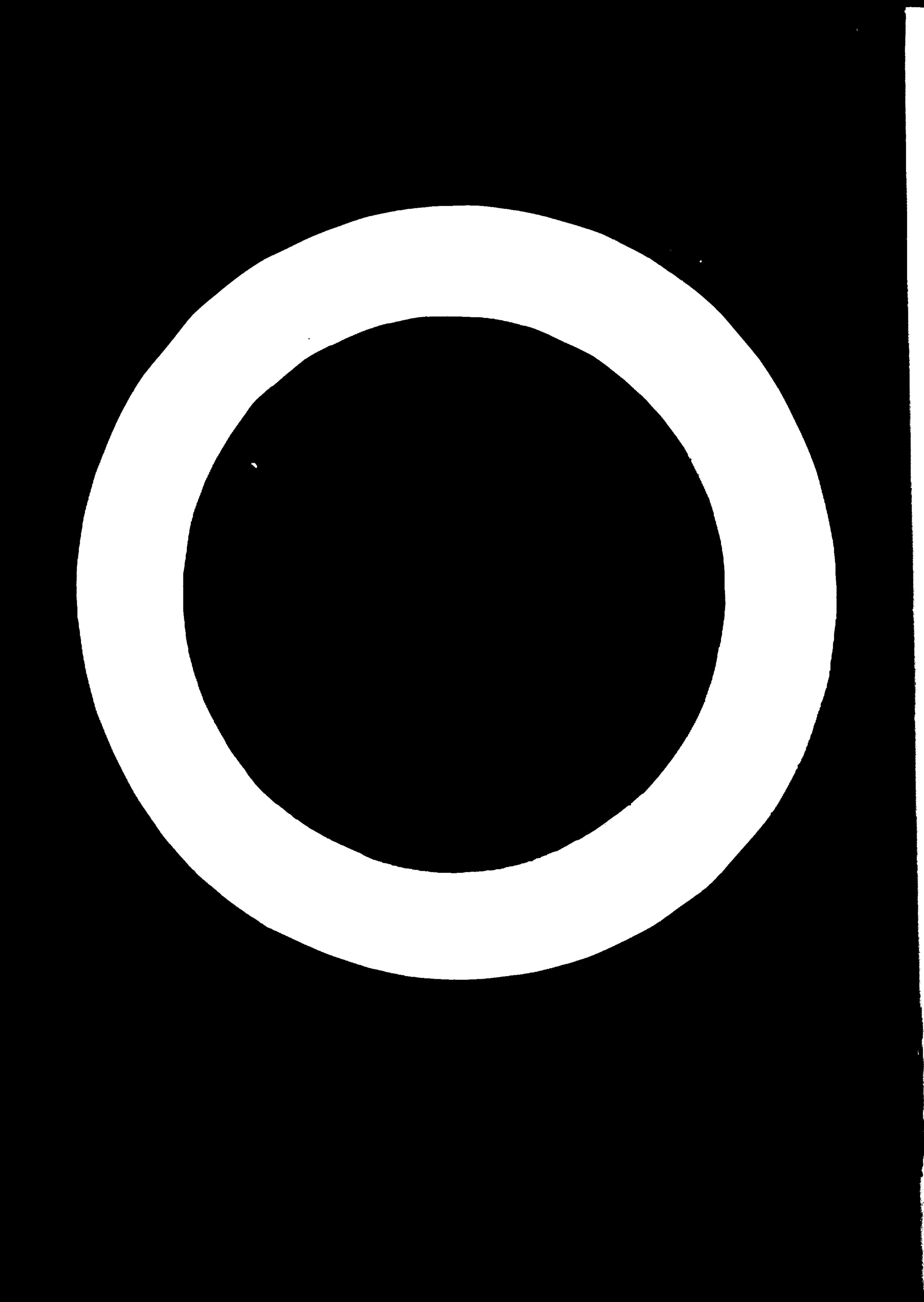
TABLE 8. STATE PLAN OF BASIC RESEARCH, 1967

Chapters of plan	*Number of partial tasks*	*Capacity of university graduates and technicians in thousands of hours*				
		Total	*Czechoslovak Academy of Sciences*	*Universities*	*Health care*	*Other*
I. Exploration of non-living matter	304	3,250	2,578	547	15	110
II. Exploration of structure and function of living matter	370	2,374	1,693	539	83	59
III. Exploration of raw material resources	185	1,174	616	239	—	319
IV. Exploration of new types of materials	88	740	512	94	—	134
V. Theoretical bases of machinery and construction engineering	148	1,194	782	169	—	243
VI. Exploration of complex automation and automatic control	56	622	547	52	—	23
VII. Biological bases of agriculture	359	1,374	423	652	—	299
VIII. Research in medical sciences and health care	1,033	4,517	832	1,164	2,468	53
IX. Research concerned with developing countries	121	239	49	64	31	95
X. Research in social sciences	1,037	4,750	1,867	1,180	20	1,683
Total	3,701	20,234	9,899	4,700	2,617	3,018
Percentage		100	49	23	13	15



Part Four

POLICIES FOR THE ADOPTION OF ADVANCED TECHNOLOGIES



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LOCAL INDUSTRY AND CHOICE OF TECHNIQUES IN PLANNING OF INDUSTRIAL DEVELOPMENT IN MAINLAND CHINA

Carl Riskin, Department of Economics and East Asian Institute, Columbia University, New York, United States of America

THE MAINLAND CHINESE have for some time been providing the world with experiments relevant to a wide selection of topics favoured in surveys of economic development theory: e.g., the presence and exploitability of disguised unemployment, the optimum choice of technology, the "factor proportions" problem, the theory of the "big push", the question of balanced versus unbalanced growth etc. Foreign scholarly evaluations of these experiments are still at a very low level of development for a variety of reasons, including the language problem, the inaccessibility of data, and the emotionalism and bias which attaches to much work in the area. As more information becomes available, however, it will present valuable opportunities for re-examination of many of the problems persistently facing developing nations.

The choice of techniques of production is one of the more interesting questions on which a consideration of Chinese experience may throw some light. Chinese planners have experimented widely and in many industries with various alternative methods of producing identical or close substitute products and have used different techniques in different sectors. Contrary to a widespread belief that such experimentation ceased with the end of the Great Leap Forward (1958--1960) there is considerable evidence that it has continued in a modified form up to the present.

A fundamental characteristic of these experiments is their deliberate recourse to technological dualism (or, more accurately, pluralism); that is, their stress on the simultaneous development of techniques of varying degrees of mechanization and varying combinations of factors of production. In much of the theoretical literature devoted to the problem of the choice of techniques the degree of abstraction in which the analysis is carried out has led to an "either-or" result—i.e. techniques of either a relatively capital-intensive or a relatively labour-intensive nature within any given industry are endorsed. This is true, for example, of the contributions of Polak,[1] Kahn,[2] Galenson and Leibenstein,[3] Bohr,[4] Eckaus,[5] and Dobb[6]. An exception is to be found in the work of A. K. Sen.[7] In these models a recourse to a mixture of different techniques to produce the same products[8] could be explained only in terms of violations of one or more assumptions of the model. Differing ratios of factor costs in different regions of the country due to regional factor immobility, discontinuous substitutability of factors, and non-rational behaviour of planners or entrepreneurs are among such possible violations.

However, when the degree of abstraction itself is lessened to the extent of allowing that products may be made by an indefinite number of "factors" (which may now include specific commodities, imports, raw materials-skills etc.) whose respective costs increase at different rates as the scale of production is increased, then a more general case can be made for resorting to a dualistic (or pluralistic) strategy. This case is rational (in terms of its assumptions), has a certain claim to describe realistically the conditions of some developing countries (China in particular), and thus deserves consideration.

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[1] J. J. POLAK, "Balance of Payments Problems of Countries Reconstructing with the Help of Foreign Loans", *Quarterly Journal of Economics*, Feb. 1943. Reprinted in *Readings in the Theory of International Trade* (A.E.A., 1949).

[2] A. E. KAHN, "Investment Criteria in Development Programmes", *Quarterly Journal of Economics*, Feb. 1951.

[3] W. GALENSON and H. LEIBENSTEIN, "Investment Criteria, Productivity and Economic Development", *Quarterly Journal of Economics*, Aug. 1955.

[4] K. A. BOHR, "Investment Criteria for Manufacturing Industries in Underdeveloped Countries", *Review of Economics and Statistics*, May 1954.

[5] R. S. ECKAUS, "The Factor-Proportions Problem in Underdeveloped Areas", *American Economic Review*, Sept. 1955.

[6] M. DOBB, *An Essay on Economic Growth and Planning*, New York, 1960.

[7] A. K. SEN, *Choice of Techniques*, Oxford, 1960.

[8] The phrase "the same product" may be taken to include close substitutes designed to perform the same function.

The first part of this paper, therefore, is devoted to a short discussion of this concept. The model makes no claim to being an exhaustive, or even an adequate, theoretical consideration of the problem. In particular, I ignore the thorny problems of capital theory involved in introducing capital equipment into such a model. It is intended merely for illustrative purposes, to point to some of the relevant factors that seem to have influenced the decisions of Chinese planners.

In the second part of the paper I shall describe the Chinese approach to the choice of techniques problem and attempt to link history with analysis.

I. The concept of technological pluralism

Our point of departure is the surplus maximizing criterion[9] associated with Galenson and Leibenstein, Dobb and Sen.[10] Assuming that there are only two sectors, a capital goods sector and a consumer goods sector; that there is only one, homogeneous consumer good; that the capital goods which produce it are made by labour alone, and last for ever; that total investment (of labour in the capital goods sector) is given by a pre-existing surplus of consumer goods divided by an institutionally-determined wage rate; and that there are constant returns to scale; then the production function for consumer goods can be written as a single-valued, continuous function of the form:

$$P_c = f\,(L_c, L_i)$$

where P_c is total production of consumer goods, L_c is total number of workers in the consumer goods sector, and L_i is total number of workers in the capital goods sector. The function is assumed to rise to a maximum and then fall again as L_c increases. In other words, as a given number of L_i produce an increasing number of machines (of decreasing cost per machine) for an increasing number of L_c, total production of corn at first rises, then reaches a maximum, then falls. The capital-intensity of a technique is measured by the ratio L_i/L_c. It is assumed that there is always one man to one machine.

The point of immediate maximum consumer-good output is of course the maximum point on this function, given by

$$\frac{\partial P_c}{\partial L_c} = 0$$

and the capital intensity of the technique in question is L_i/k, where k is the amount of consumer-good labour producing the maximum output.

However, if surplus maximization is the objective, then the wage, w, must be considered, since it detracts from the surplus available for reinvestment in the next period. Where workers save none of their wages the surplus-maximizing condition is:

$$\frac{\partial\,(P_c - L_c w)}{\partial L_c} = 0 \text{ or } \frac{\partial P_c}{\partial L_c} = w.$$

Where a constant proportion, s, of wages is saved the surplus maximizing condition becomes

$$\frac{\partial P_c}{\partial L_c} = (1-s)\,w.$$

Clearly, if w is positive and $0 < s < 1$, the surplus-maximizing condition is met at a higher capital intensity (smaller number of consumer-good workers for the given number of capital-good workers) than the output-maximizing condition.

This model has many elaborations and complications which we need not discuss in the present context.

To make this model relevant to the multi-technique case, we extend it, as has already been suggested above, by assuming that a third factor of production (in addition to L_i and L_c) is required. This is taken to be a given commodity or skill whose supply is less than perfectly elastic[11], i.e. its cost increases with its use. We also assume, for simplicity, that this scarce factor, F, must be

[9] This preliminary description is based on that of A. K. Bagchi, "The Choice of Optimum Technique", *Economic Journal*, Sept. 1962, pp. 666–668.

[10] Sen's "Time Series Criterion" differs from the present one in explicitly admitting time-preference as a constraint on surplus-maximization. See *Choice of Techniques*, op.cit., pp. 31–33.

[11] See Hollis Chenery, "Comparative Advantage and Development Policy", *American Economic Review*, March 1961, excerpted in Meier, *Leading Issues in Development Economics*, p. 520: "Both the factor-intensity ratios and the partial-productivity measures assume that there is one principal restriction on the system, the scarcity of capital. They do not allow for the fact that in allocating capital according to any one of these rules some other restriction on the system, such as the supply of foreign exchange, of skilled labour, or of a particular commodity, may be exceeded."

And Gautam Mathur, *Planning and Steady Growth*, Oxford, 1965, pp. 9–10: "The limit to the size of a plan comes in this study from the existence of certain bottleneck resources. These may be certain types of goods or skills... When there is vast non-employment, for every proposed size of the plan the onus is on the proposer to prove that... certain bottleneck goods exist which would be fully employed at that size of the plan, that these bottlenecks cannot be removed by further investment in the short run, and that no substitution of non-bottleneck goods for bottleneck goods is possible. The size of the plan is then a function of the set of existing real goods, skills, foreign exchange, productive capacity etc., and of the technology which can reproduce them or convert them into other goods."

Professor Sen has also dealt with this problem briefly in *Choice of Techniques*, op.cit., pp. 54–57. I am particularly indebted to him for helpful discussions relevant to this section of the paper.

used in fixed proportions with L_c and L_i, the particular proportions depending on the technique in question. There are then constant returns to scale for combined inputs of L_c, L_i and F in the proportions dictated by the technique. But as the scale of production increases, the cost of F increases, i.e. more income must go to pay for F. (Attention is now focussed on the production function for a given technique rather than for the spectrum of techniques, as previously.)

The production function for the surplus-maximizing technique A is:

$$P_c = h\ (L_{c_a}),$$

where L_{c_a} is a unit of consumer-good labour understood to be combined with L_i and F in the proportions dictated by technique A. Since these proportions are fixed the composite input may be measured in units of L_c and, for technique A, $L_c/L_i = A$, a constant.

The cost function for technique A is:

$$T_a = (f_a + w)\ L_{c_a};\ T'_a\ (L_{c_a}) > 0;\ T''_a\ (L_{c_a}) > 0,$$

where T_a is total cost, f_a is unit cost of F, and w is the wage rate. In other words, total cost increases more than in proportion to production, because of the increasing unit cost of F.

We began by assuming that technique A is the surplus-maximizing technique when producing at full capacity, i.e. when all available capital-good workers are producing capital goods for technique A. Suppose, however, we remove a consumer-good worker from producing with this technique. Output declines by $P'_c\ (L_{c_a})$. Surplus declines by:

$$P'_c\ (L_{c_a}) - T'_a\ (L_{c_a}) = P'_c\ (L_{c_a}) - w - f'_a\ (L_{c_a}).$$

Now suppose some other technique, technique B, which does not maximize surplus over-all techniques when used alone at full capacity, and does not use the scarce factor F as intensively as technique A does. The decline in production by technique A releases $1/A$ capital-good workers from producing machinery for technique A (since for technique A, $L_c/L_i = A$). These can equip $(1/A)B = B/A$ consumer-good workers to produce by means of technique B. The resulting increase in output is $(B/A)\ [P'_c\ (L_{c_b})]$. The increase in surplus (assuming all wages are consumed) is:

$$(B/A)\ [P'_c\ (L_{c_b}) - w - f'_b\ (L_{c_b})],$$

where $f'_b\ (L_{c_b})$ is the marginal cost of the scarce factor F embodied in the composite input for technique B.[12]

Since technique A uses the increasing cost factor more intensively than technique B does, it is possible that the latter marginal surplus will exceed the former. In this case it will increase total surplus to shift labour from technique A to technique B, and to continue doing so until the two expressions are equal.

This result can be generalized. If there are n possible techniques in the consumer-goods sector, L_j denoting the number of capital-good workers producing equipment for the jth technique and s denoting surplus, then under our assumptions surplus is maximized when m techniques are being used at scales such that:

$$\frac{ds}{dL_1} = \frac{ds}{dL_2} = \ \ldots\ldots = \frac{ds}{dL_m},\ m \leq n.$$

Some techniques, of course, may not be used at all, i.e. those techniques i for which

$$\frac{ds}{dL_i} < \frac{ds}{dL_1}.$$

In other words, the net gain in surplus from expanding any one of the techniques being used at the expense of contracting any other is nil; and the net gain in surplus from bringing any technique not in use into use is zero or negative.

It must be stressed again that this model is not intended to cover comprehensively the theoretical problem of choice of techniques. In particular, the difficulties associated with depreciation of capital goods, and with the use of machinery to make either machinery or consumer goods or both, are ignored. The model's purpose, as has been pointed out, is only to indicate certain key relations to be kept in mind when examining empirical materials. To these latter we will now turn our attention.

2. THE ROLE OF LOCAL INDUSTRY

This discussion stems from a study now in progress of the role of local industry in China's development strategy. As Dwight Perkins has noted, "The main features of the industrial sector in mainland China, which made centralized control anything but a simple task, were the number of firms involved and the diversity of techniques used in the production of any given commodity".[13] I have chosen to focus attention upon local industry because the relatively small-scale, technologically-simple techniques are concentrated in this sector.

[12] If technique B does not make use of F, then of course this term is equal to zero.

[13] D. PERKINS, *Market Control and Planning in Communist China*, Cambridge, 1966, p. 107.

Nevertheless, this correspondence is not perfect. Local industry is defined in terms of the unit of control, not the technique of production:

> "By the central industries and local industries are meant the forms of leadership of industrial enterprises. By local industry is meant the local leadership and management of all the economic activities of enterprises. Like central industry, it is industry owned by all the people. Handicrafts and industrial enterprises operated by the agricultural producers' co-operatives are part of the local industry and the socialist economy, but such industries are owned by collective bodies."[14]

Moreover, various decentralization measures taken after the mid-1950s drastically changed the relationship between technique of production and unit of control. Nevertheless, a rough relation holds, so that if local industry is defined as all industry under the jurisdiction of provincial level government or below and of collective groups such as the agricultural producers' co-operatives (APCs) and communes, then it is generally true that *(a)* local industry is both less mechanized and smaller in scale than central industry; and *(b)*, as one moves downward through the control hierarchy of local industry, from province to special district to *hsien* (county) to *hsiang* (administrative village), and so on, the scale becomes smaller and the technique simpler.[15]

As will become apparent, most of the information considered here pertains to Kwangtung province in southern China, the province for which most material is available. Kwangtung has many special peculiarities with respect to geographical features, resource base, population characteristics, language, history, and cultural and political evolution. There is no intention of regarding it as representative in any general sense of the country as a whole. But some of the specific problems encountered and of the policies applied in the industrialization programme in Kwangtung do have more general application.

With the exception of the city of Canton, Kwangtung was industrially one of the less developed provinces of China before 1949, and what development there had been was almost solely in light industry — especially textiles manufacturing and agricultural goods processing. Furthermore, Kwangtung's natural advantages in the production of food grains, sub-tropical and tropical crops (its island of Hainan and the contiguous Leichou peninsula is China's only tropical crop-producing region) relegated it to the role of agricultural products provider in the first five-year plan (1953–1957).[16] In addition, Kwangtung lagged in its implementation of the land reform programme of the early 50s, not completing its re-examination of agrarian reform results until the middle of 1954, so that prior to that time substantial leadership forces were not available for allocation to the industrial sector.[17]

All of these factors made for a difficult beginning of industrialization in the province. The output of local industries recovered rapidly during the "rehabilitation" period (1949–1952) mainly because of the return to over-all political stability; but because of its preoccupation with rural matters the government did not turn any real attention to

[14] CHEN TA-LUN, "Local Industry Takes a Big Stride Forward", *Chung-kuo Ch'ing-nien*, No. 7, April 1958; translated in *Selections from China Mainland Magazines* (SCMM), No. 134.

[15] Thus, 156 "large-scale factories" were newly built in Kwangtung Province from 1949 to 1957 at the province level or above, while a similar number of "small and medium enterprises" were newly built by the special districts and *hsien*. (*Nanfang Jihpao*, 11 July 1957).

A division of tasks among different levels of industry was suggested in 1958 on the following lines: (1) *hsiang* and co-operative levels should establish factories primarily for self-use, small-scale extractive and processing activities; (2) *hsien* level organs might operate: *(a)* "large-scale factories and mines which process concentrated resources, and which the organs at *hsiang* level or the co-operatives are unable to operate"; *(b)* "manufacturing plants which supply simple equipment to telecommunications, transportation, agriculture and the industries operated by the organs at the *hsiang* level or by the co-operatives"; *(c)* "enterprises which process local agricultural produce and sell on the local market, and which the organs at *hsiang* level or the co-operatives are unable to operate"; *(d)* "other technically complex enterprises"; (3) administrative district organs and above "may establish some industries with a decisive significance to industrialization, such as the above-norm raw-materials industries extracting in a large area of concentrated resources, power industry, machine-building industry able to turn out enough machinery to equip local industry, industry processing agricultural produce but requiring a high degree of technique, and other industries which the organs at *hsien* and *hsiang* levels are unable to operate". (HO CH'U, "Overall Planning, Division of Labour and Co-operation are Required in the Development of Local Industry", Peking *Ta Kung Pao*, 20 August 1958, in: *Survey of the China Mainland Press* [SCMP], 1863).

[16] See LI CHUNG-SHIH, "Kwangtung Province on the Road to Five-Year Plan Construction", *Ching-chi Tao-pao* (Economic Bulletin) No. 43, 7 Nov. 1955, in ECMM No. 19; also WANG CH'UANKUO (Kwangtung Industrial Bureau Director), "The Past Year's Accomplishments in Kwangtung's Construction", in *Yang Kwang Jenmin* (Rangoon People), 30 Dec. 1955; also speeches by T'AO CHU, reported in *Nanfang Jihpao*, 6 June 1953 (SCMP 625); 11 Aug. 1954 (SCMP 970-s); 15 Aug. 1954 (SCMP 932-s); 1 Oct. 1955 (SCMP 1159); 24 Sept. 1955 (SCMP 1237-s); and T'AO CHU, "The Tasks of the Party Organisation in South China During the Nation's Five-Year Construction Plan", *Nanfang Jihpao*, 31 Oct. 1953 (SCMP 703).

[17] See LI SHEN-CHING, Director, Department of Propaganda, South China Sub-Bureau, Central Committee of the Chinese Communist Party, report to the first Kwangtung Provincial Congress of the New Democratic Youth League, 5 June 1953, *Nanfang Jihpao*, 11 June 1953 (SCMP 625).

the development of local industry until the second half of 1953. Policy toward local industry then was geared to the task assigned to Kwangtung by the national five-year plan: to concentrate on the development of agriculture. The major industries to receive attention were almost all in the light industry sector and included sugar refining, paper manufacture, silk weaving, jute textiles, food processing (including canned fruits, distilling of alcoholic beverages, rice milling and oil pressing), small-scale ship building, agricultural implements, small-scale coal and iron mining, non-ferrous metals, salt production, resin production etc. The electric power and machinery industries were considered to possess relatively strong foundations and therefore to require only adjustments permitting full utilization of existing capacity rather than a further expansion.[18]

The existing industrial base at the beginning of the plan was weak and highly scattered. Incomplete statistics for Kwangtung in 1953 counted 568 factories owned either by the State or jointly by State and private interests. Statistics for 512 of these showed a total gross production value of ¥ 148,060,000. In addition, there were in 1953 more than 4,000 private industrial enterprises employing over 10 persons, with total gross production value of over ¥ 590,000,000.[19]

One of the main problems of the pre-plan years and of the beginning of the plan period was "blind expansionism". For example, 216 larger state and local public-private jointly-owned factories claimed to have increased their total production value for the first half of 1953 by 54 per cent as compared with the first half of 1952. Capital construction plans in Kwangtung for 1953 included some 300 units of construction both large and small, 43 per cent of them in the industrial sector.[20]

Rapid expansion of output, combined with lack of governmental leadership and a private market in disarray because of the agrarian upheaval and the anti-corruption "wu fan" movement in the industrial sector, led to a proliferation of problems. Among the most common complaints were the irrational distribution of factories, severe dislocation between materials supply, production and marketing, improper management, high production costs, poor quality, lack of standard specifications, high accident rate, and under-utilization of equipment. The sugar and coal industries were to be major targets of development in Kwangtung, yet throughout the central-south region of the country the rate of equipment utilization in these industries was put at only 50–60 per cent.[21] In Kwangtung, factories producing gunny sacks and egg products shut down for lack of markets, and farm implements produced by many factories piled up in stock because of poor quality, high prices and unsuitability to the needs of their local customers. Ideological problems also ensued, as cadres in their enthusiasm at the prospect of rapid industrialization and modernization found it difficult to accept policies emphasizing agriculture and small, local industries. They adopted a "cool and passive" attitude toward local industries and were reluctant to operate small and old factories, overlooking their importance to agriculture and as adjuncts to larger enterprises.[22]

In the face of this situation, various readjustment measures were decided on in the summer of 1952, in accord with which several hundred factories drew up readjustment plans towards the end of the year; but there the matter rested until a conference on Kwangtung local industry was convened in August 1953. This conference published plans for a comprehensive readjustment of industry over a period to extend until June 1954. Readjustment was to include the establishment of production quantity plans, sound management policies and a series of other reforms prior to transition to the stage of production and construction. Larger plants were to be dealt with first, and cities before rural areas. In particular, factories in the sugar, silk, machinery repair, construction materials, electric power and food-processing industries were to receive priority attention.

Progress was undoubtedly made in bringing some system and order to the local industrial network as a result of these and subsequent rectification drives. Nevertheless, the impression remains that

[18] *Nanfang Jihpao* (report by T'AO CHU), 15 Aug. 1954, (SCMP 932-s).

[19] *Nanfang Jihpao*, 18 Aug. 1953 (SCMP 677-s); WANG CH'UAN-KUO, "Development of China's Local Industry During 1955", *Ta Kong Pao* (Hong Kong), 1 Jan. 1956 (SCMP 1204). *Yuan* are in the New People's Currency adopted 1 March 1955 at the rate of one to 10,000 of the Old People's Currency. Foreign exchange rates fluctuated in the early 1950's and are subject in any case to conceptual difficulties, but recently the nominal yuan-US dollar rate has been 2.46 : 1.

For China as a whole in 1954 the total value of production of local industry constituted about 57 per cent of total industrial production value. Forty per cent of all "means of production" were produced by local industry, 70 per cent of all consumer goods (*NFJP*, 10 Jan. 1956, "Ti i-ko wu-nien chi-hua ch'i-chien ti ti-fang kung yeh" [Local Industry in the First Five-Year Plan Period]).

[20] KU TA-TS'UN, "Report on Work of the Kwangtung Provincial People's Government", *China News Service*, Canton, 29 Oct 1953 (SCMP 681); *NFJP*, 21 Oct. 1953 (SCMP 672).

[21] *NJFP*, 18 Aug. 1953 (SCMP 677-s); *New China News Agency* (NCNA) 21 Nov. 1953 (SCMP 695).

[22] *NCNA*, 21 Nov. 1953 (SCMP 695); *NFJP*, 18 Aug. 1953 (SCMP 677-s).

the pressure to increase production always overshadowed desires for greater efficiency, and that this order of priorities was reversed only in periods of great deterioration in the cohesiveness of the industrial system. Thus, only two months after the 1953 readjustment campaign was announced, T'ao Chu (then an Acting Secretary in the Kwangtung Provincial Party Committee) announced that positive measures were to be taken to increase production in all enterprises which had already readjusted and that those which had not yet done so were to carry out "absolutely necessary" reforms immediately and later formulate plans for the "production increase and economy" drive.[23] Yet the complaints which had given rise to the readjustment movement persisted in the local press through 1957.

Despite the cross pressures of conflicting objectives, a clear and consistent policy position with regard to local industry evolved from the need to bring order and a sense of priorities to the chaotic conditions in which local industrial growth commenced. The guiding principle of this position, which both pre-dated and survived the Great Leap Forward period, was that of complementary relations between central, large-scale, and local, small-scale industry, with prior claim to scarce resources given to the former. It was strictly maintained that competition for such resources between the two sectors should not arise, and that local, indigenous or semi-mechanized techniques were to supplement (rather than substitute for) modern industry. Local industry was to concentrate upon producing "those industrial goods needed locally or throughout the country but which cannot be supplied by the central state-owned industry and existing industry".[24]

Behind this principle was the observation that widely scattered throughout the country were low-quality material resources which were unfit to be exploited on a large scale by mechanized enterprises, and which in any event transportation difficulties made inaccessible to the centre.[25] Added to this was the indisputable fact that modern industry by itself lacked the resources to fulfil the joint needs dictated by a rapid development programme and increasing demand for consumer goods. For example, early in 1957 "leading industrial departments" were criticized for slackening leadership over the production of native paper in the belief this product would be replaced quickly by machine-made paper and thus had no future. It was therefore reiterated that "for a long time to come it will be impossible for machine-made paper to replace the native paper; on the contrary, native paper will make up the shortage of machine-made paper". In reply to the argument that an extension of native paper production would reduce the amount of raw materials available to the modern sector, it was argued that the characteristic feature of indigenous industry was its ability to mobilize local raw materials, thus increasing the total stock available. Furthermore, native enterprises were urged to forego the use of bamboo and hemp, required by the mechanized sector, in favour of miscellaneous straws, wheat stalks, cotton plant skins, and other waste materials.[26]

Even the famous "backyard iron and steel" campaign of the summer and autumn of 1958, which has come to symbolize the local industry policy of the Great Leap Forward, was based on a view of modern and indigenous industry as mutual complements rather than substitutes. It was in fact frankly admitted that

> "small and native iron-smelting and steel refining furnaces are inferior in technique to large and medium-scale modern layouts. . . When we champion the construction of small native enterprises as the mainstay, we are by no means opposed to the simultaneous building of large and medium-scale ones. These are high in efficiency and low in cost and it is, in fact, the objective of our technical revolution to bring the national economy (including the iron and steel industry) to a modern technical channel. . . And the ultimate goal of our technical revolution is modern mass production".

But modern iron and steel plants require complete sets of modern equipment, scarce building materials (mainly steel products), and a core of technical personnel. Hence they can be established only by the central government, the provinces, the municipalities or the autonomous regions. "This, on any extensive scale, is not feasible at the moment. Thus, the time is not yet ripe for the construction of large and medium-scale modern steel and iron plants as the mainstay."[27]

That this view extended during the Great Leap to all local industry (which was then largely

[23] T'ao Chu, op. cit., *NFJP*, 31 Oct. 1953 (SCMP 703).

[24] Wang Ch'uan-kuo, "Development of China's Local Industry During 1955", *Ta Kung Pao* (Hong Kong) 1 Jan. 1956 (SCMP 1204).

[25] For a clear statement of this position, see the editorial in *Jenmin Jihpao*, 9 Aug. 1957.

[26] *Ta Kung Pao* editorial (Peking), 22 Jan. 1957 (SCMP 1467).

[27] Editorial in *Jenmin Jihpao*, 8 Aug. 1958, "Simultaneous Use of Native and Modern Methods is Shortcut to Fully Developed Steel and Iron Industry" (SCMP 1836).

commune industry) can be seen from a rule of thumb used at the time to characterize local industrial policy: "If foreign (modern) is possible then foreign; if foreign is not possible, then native." Of course modern methods were not attainable for the millions of small enterprises which sprang up during this period. In keeping with the principle of complementarity, it was therefore reiterated that commune industry must be self-reliant, and must develop its own materials and raw materials base, without competing with modern industry for scarce resources or reaching out to the State for aid. The principle was defined thus: where excess capacity existed in the state-owned large-scale sector, where raw materials could be transported conveniently over large distances, and where the commodity involved met the needs of a relatively large area, its production should be undertaken to the fullest possible extent by state-owned large-scale industry, but where the opposite conditions obtained, the job should be left to commune industry. Cotton, hemp and leather materials were suggested as examples of what was to be assigned to the first category, thus spinning, weaving and leather manufacturing were not to be undertaken by the communes. The "comprehensive utilization" of straws, and the processing of food grains and edible oils for village consumption were allocated to the second category.[28]

These examples are taken from an article published in 1961. As the modesty of the tasks which they assign to commune industry suggests, it had become clear by that time that the principle of complementarity between modern and indigenous industries had been violated on a large scale. Indeed, the abandonment of the Great Leap was partly due to the major structural imbalances for which this violation was responsible. The scale of industrial activities undertaken by the communes was curtailed according to the principle of "'use steel only for the cutting edge of a knife', which means we must devote our limited financial and material resources and manpower in a planned manner to the areas or projects where they are most needed". New construction was also sharply cut back, and all projects not approved and included in the state plan were forbidden. The proposition that local projects should use only locally available materials and capital and should not compete with the State was specifically dismissed by a Kwangtung editorial as "this queer argument". The editorial included a long analysis listing the numerous ways in which resources for extra-plan projects were obtained illegally or improperly, and concluded: "from this we can see clearly that those people claiming reliance on their own resources actually impair the State's interests and thwart the completion of the planned projects and the smooth progress of production."[29]

To sum up, "indigenous" (*T'u fa*) forms as well as other forms of technologically simple local industries in China were designed to expand under the constraint of refraining from competition with modern industry for scarce resources. They were to supplement the maximum efforts of the modern sector by mobilizing on a local scale those widely scattered and poor-quality materials that were unsuitable for exploitation by technically sophisticated production methods. The mass movement to build local industry during the Great Leap Forward overstepped these bounds and interfered with the flow of resources to the modern sector. However, despite severe restrictions on local industrial expansion of a very small-scale, labour-intensive kind since 1961, China continues to lay emphasis on the development of relatively small mechanized and semi-mechanized plants in several important industries. A significant proportion of the greatly increased chemical fertilizer output of recent years is produced by the more than 300 small and medium fertilizer plants in the country as a whole. Since they require little investment or technological skill they may be left to the administration of local authorities, freeing the central government to concentrate on expanding or building new, large, sophisticated plants, still the backbone of the industry as a whole.[30]

In Kwangtung's important sugar-refining industry last year there were altogether some 90 large, medium and small mechanized refineries and "several thousand" native sugar-pressing shops. In 1965, to remedy inadequate pressing capacity, Kwangtung chose to build seven new medium-scale plants, each with a daily pressing capacity of 500 tons of cane.[31]

3. HINDRANCES TO INDUSTRIAL EXPANSION

It has become clear from the above discussion of the complementary principle that materials

[28] Article by LI CH'ENG-JUI in *Hung Ch'i* (Red Flag), Apr. 1961.

[29] *NFJP*, 15 May 1962 editorial; (SCMP 2757). Of course a major reason why commune industry was cut back in 1960 and 1961 was the agricultural crisis, which resulted partly from disastrous weather, but also from such mistakes as the excessive drain of labour out of agriculture in 1958 and 1959.

[30] Alexandra CLOSE, in *Far Eastern Economic Review*, 8 Dec. 1966.

[31] *Ta Kung Pao* (Hong Kong), 25 Apr. 1966.

and raw materials shortages have constituted a major bottleneck to more rapid expansion of modern industry in China. The tendency of agricultural growth to lag behind that of industry was much commented on after 1955. In order to deal with the resulting scarcity of raw materials, various means of substituting and economizing were urged, among which the promotion of small scale local industry was one of the most important.

In 1955 insufficiency of raw materials was cited as the chief source of difficulties in plan fulfilment among Kwangtung's larger factories.[32] The same reason was given for non fulfilment by some 591 of the province's factories in the first half of 1956. The following year, there were widespread complaints of severe shortages of coal, copper, paper, pig iron, electric power and agricultural raw materials in general. Enterprises were urged to decrease losses associated with transport and storage, to collect old and waste iron and steel and other substitute and waste materials. Early in the year *People's Daily* announced that "increases in the production of raw materials and economy in their use are the main aspects of the programme of production increase and economy for the industrial departments this year".[33] The editorial went on to suggest the establishment of small coal and other mines, steel plants, cement factories etc. to supplement the production of industrial materials. In August, Feng Pai-chü, the Vice-Governor of Kwangtung, delivered an important speech on the industrial situation in the province to the Sixth Session of the Kwangtung First People's Congress. He criticized the previous lack of leadership in planning, organization and technique with respect to expanding small scale, mass-type extraction activities, and recommended the local development of paper production to circumvent the shortage of pulp in the mechanized paper mills, extending the suggestion to the production of porcelain and earthenware, iron and steel, and other industries.[34] National policy at that time was predicated on the conviction that

> "one of the new contradictions which emerge in the course of industrial development in China finds manifestation in the inability of the raw materials industry to catch up with the needs of the processing and manufacturing industries, the building construction industry and the livelihood needs of the people".[35]

The suggested solution was to establish medium and small hand operated mines for coal, iron, non-ferrous metals, non metallic minerals, salt and soda, to be operated by provincial, special district and *hsien* governments or by relevant handicraft producer co operatives, or even by the agricultural producer co operatives as side line enterprises.

Thus one of the principal roots of the Great Leap Forward strategy toward native-type local industry was a chronic shortage of materials and raw materials, which became increasingly severe over the first five-year plan period. The first mass movements of the Great Leap were designed to increase production of coal, iron and other scarce industrial materials by indigenous production, and to boost agricultural output by means of mass water conservancy construction projects and extremely labour-intensive methods of cultivation.

Similar policies continue to be implemented, although in attenuated form. For example, the rapid proliferation of small ammonium bicarbonate plants in China over the past few years has to some extent replaced the previous emphasis on ammonium sulphate. The small plants that produce the former are said to require only pig iron rather than special steels, and to need less sulphuric or nitric acid, both of which are essential materials in defence production.

Other strategic barriers to growth which the development of local industry, if kept within the bounds of complementarity, is intended to circumvent include the bottleneck in transport facilities, and the seasonality of labour supply. "By virtue of the location problem, plants may be operated at levels well below the optimum scale and yet have a competitive advantage over large plants which are located farther from the market"[36] or, it may be added, from raw material sources. The small, decentralized chemical fertilizer factories, for example, are reported to have reduced wastage of their highly volatile products far below the level

[32] "Sixty Principal Factories and Mines in Kwangtung Fulfil Insufficiently Well Their Plans for May", *NFJP*, 16 June 1955.

[33] *Jenmin Jihpao*, 17 Feb. 1957 (SCMP 1481). See also "Kuan-yü chi-chung li-liang cheng-ch'ü wan-ch'eng ho ch'ao-o wan-ch'eng 1957 nien tseng-ch'an chi-hua ti chih-shih" (Directive on Concentrating Forces to Struggle to Fulfil and Over-fulfil the 1957 Plan for Increased Production), issued 20 July 1957 by the Kwangtung Provincial Committee of the CCP and Provincial People's Council, *NFJP*, 29 July 1957.

[34] Feng Pai-chü, "Kuang-tung kung-yeh sheng-ch'an chien-she ti ch'eng chiu yü tsun-tsai wen-t'i" (On Accomplishments and Existing Problems in Kwangtung's Industrial Production and Construction), *NFJP*, 10 Aug. 1957.

[35] "A Contradictory Problem that must be Solved in Industrial Development", *Jenmin Jihpao* editorial, 9 Aug. 1957 (SCMP 1595).

[36] "Plant Size and Economies of Scale", *Industrialisation and Productivity*, Bulletin 8, p. 58 (United Nations Department of Economic and Social Affairs, New York, 1964).

which occurs through the transport and storage required by large, centralized plants.

The seasonal character of agriculture in China imposes constraints on the availability and use of labour in industry. Over the past 18 years the intensification of cultivation, associated with increased irrigation, multiple cropping, afforestation, fertilizer application and land reclamation has probably led to increased agricultural labour requirements proportionate to population growth. The proportion of the year covered by "busy seasons" has, if anything, increased. Consequently, if idle rural labour is to be used in industry, it must remain available for peak-season work in the fields.[37] The sugar refining and agricultural implement making industries, among others, have therefore worked out contract arrangements with agricultural communes and their sub-units to utilize agricultural labour during the slack season and return it to the fields during the heavy season. (Sugar manufacturing is particularly well adapted to this system, since the refining season of November to May dovetails nicely with the busy period in agriculture). But the contract system heavily influences industrial location, which in turn affects plant size and level of technique.

All the above examples—materials and raw materials shortages, transport and storage bottlenecks, seasonal labour requirements in agriculture—as well as others that could be cited, fall into the category of constraints which Chinese planners have associated primarily with resources available to the large-scale, technologically advanced sector of industry. The promotion of local industry of a small-scale, primitive character was regarded as a means of avoiding these constraints, and thus increasing the total amount of resources mobilized and the total output produced. Where this estimate has proved seriously wrong, as pointed out above, the leadership has retreated in its local industry policy; in the minds of the planners the *sine qua non* of success in rapid industrialization has remained the growth of modern industry at a maximum speed. But their continued adherence to a dualistic strategy, although within more realistic bounds, is evidenced by the considerable reliance they continue to place on small and medium scale industry in many sectors.

The foregoing has all related to the use of mixed technologies within given industries. However, there has also been in China a pronounced and consistent correlation of advanced and backward techniques respectively with certain specific sectors. The guiding principle has been that those industries which rank high in the planners' preferences—heavy industry in general, the defence industry in particular, and important exports—should be allowed to co-opt the supply of centrally mobilizable resources and to monopolize the modern technology available to the economy—which perhaps explains why textiles, an increasingly important export item, has not been to the fore among local, native type industries. This has left lower priority sectors—particularly agriculture and consumer goods production—largely dependent upon small-scale local industry and handicrafts.

In this respect also the Great Leap Forward was not so much a reversal as an intensification of past policy, designed to rectify inadequate performance. As early as August 1953 a Kwangtung conference on local industry directed that the policy be upheld of "serving the needs of increased production in agriculture . . ."[38] But this proved difficult to implement where neither a market nor adequate leadership was available to guide local industrial development, and where the glamour associated with modern industry made emphasis on meeting the needs of agriculture a difficult basis on which to rally cadre or mass enthusiasm. Thus, although Governor T'ao Chu observed in September 1955 that "the central authorities instructed us not long ago that all local industries had to serve agricultural production"[39] a year later *Nanfang Jihpao* was complaining that the province produced only 13 types of agricultural tools in 1955 and that their production value was only 1.08 per cent of the total value of provincial local industry.[40] With neither centre nor localities providing adequate amounts of needed agricultural inputs, and with the intensity of cultivation growing, Chinese planners faced

[37] This statement refers not only to "disguised unemployment" but to open unemployment as well. Throughout the 1950's China had to combat "blind" migration of peasants to the cities and towns, where they hoped to find industrial employment at incomes higher than those they received on the farm. Because the pace of industrial development was insufficient to permit the employment of all migrants, a pool of unemployment continued to exist, and periodic campaigns were undertaken to return the unemployed to the countryside. Not only were there problems of providing for them in the cities and towns, but their labour was said to be required during the heavy seasons in agriculture. Thus the problem was not that they produced nothing on the farms but that the price of their production and the income they earned did not reflect the relative scarcity of agricultural output. See, e.g. *Kuangchou Jihpao* (Canton Daily), 6 Dec. 1956 (SCMP 1454). This article cites a spokesman for the Canton People's Council who complained about the large flow of labour into Canton from the surrounding countryside, which had "already caused a shortage of labour in rural areas. . . slowing down agricultural production in these areas and adversely affecting the consolidation of the agricultural producers' co-operatives".

[38] *NFJP*, 18 Aug. 1953.

[39] *NFJP*, 24 Sept. 1955 (SCMP 1237).

[40] *NFJP*, 16 Aug. 1956.

the choice of either implementing the intended role of local industry or tapping the modern sector to produce capital goods for agriculture. From this point of view, the Great Leap represented an attempt to free the modern sector from this responsibility by investing greater energy and in drawing attention to the same policy of relying on local industry: "the heavy task of agricultural mechanization and modernization will principally fall on the shoulders of local industry . . . The principal objective of the development of local industry is the quicker development of agriculture."[41] Only after the Great Leap and in the throes of an agricultural crisis was the modern sector tapped on a significant scale to produce agricultural inputs. Yet this is being accomplished partly by building networks of small, local fertilizer plants, agricultural machinery factories etc. If and when this system is deemed extensive enough, there may be a return to the previous strategy. But the local industries now being constructed are larger and of a higher degree of technical sophistication than those of the Great Leap period and before.

4. Summary

The simple model with which this paper began explained the recourse to the simultaneous use of more than one technique of production in terms of the multiplicity of specific inputs required for the production of any given commodity; the uneven rate at which these inputs become scarce as the scale of production expands; and the different proportions in which the inputs are required by different techniques. It may be concluded that this explanation is applicable to the Chinese experience of the past 18 years, and in particular that the emphasis on technological dualism which has characterized Chinese industrial policy has stemmed from these considerations.

Despite the preoccupation of this paper with the problems encountered in the course of development and the policies undertaken to solve them, it should be remembered that the Chinese economy has grown very rapidly over most of the period since 1949. For the decade of the 50s the average growth rate of national income was probably around 10 per cent *per annum*; for the first five-year plan period (1953 – 1957), from 7 to 8 per cent. The growth rate for industrial output during the first plan was 14 to 16 per cent, and for the whole decade, 21 per cent *per annum* – the world's highest.[42]

It is especially in a situation of extended rapid growth that bottlenecks are apt to be encountered in raw materials, the transportation network, capital goods imports, specific skills etc. Hence the arguments for a multi-technique strategy might seem to be stronger in a context of continuous rapid growth, weaker in one of slow growth or stagnation.

[41] *NFJP*, 14 May 1958.

[42] The magnitude of the latter rate is due in part of course to the war-torn, depressed state of the economy in 1950 and the above-trend level of industrial production during the Great Leap Forward at the end of the decade. It should therefore not be taken to represent the long-term growth potential of Chinese industry.

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BUSINESS ORGANIZATION AND TRANSFER OF TECHNOLOGY: EXPERIENCE OF THE UNION OF SOVIET SOCIALIST REPUBLICS

Alexander Woroniak, Catholic University of America, Washington, D.C., United States of America

IN THE TWO DECADES following the Second World War, a major change occurred in the evolution of economic thought. Dynamic and controversial problems of economic growth were thrust upon the new generation of economists, as suddenly every nation was painfully pressed to reconstruct, to broaden, and to diversify its economy in order to meet the needs of an increasing population. With the help of two post-war prodigies, applied mathematics and the computer, economists forged powerful analytical tools and instruments of economic policy. The concept of economic planning and a new set of institutions involved in developing a national economic policy became the subject of vigorous research. It seems that economic science to some degree abandoned its dogmatic positions in favour of empirical approach, scientific analysis of facts, and concrete policy recommendations. Possibly the fact of the rapid recovery of many countries, despite their devastated industrial plants, focused attention on the importance of technological knowledge and the role of its diffusion and transfer in the growth of output. Undoubtedly, however, Jacob Schmookler is correct in saying that "it was our renewed interest in economic growth that led to the rediscovery of the importance of technological progress".[1]

Out of many aspects of technological progress, the transfer of technology—its forms, channels, and finally development of national and international policy with the role and the attitude of government clearly delineated—is not only new to the economists but is also controversial, challenging, and poses serious problems of identification, quantification and analysis. I stress the role of government, because in both Soviet-type and Western-type economies the central government supports the bulk of the scientific and technological activity; the way in which it does this will have a large impact on the process of technology transfer. The director of the Institute of Economics, USSR Academy of Sciences, L. Gatovskii,[2] classified the planning of scientific and technical progress as the most lagging link in the whole complex of national economic planning, whereas it should have been the leading link. Another Soviet economist[3] in a recently published book bemoans the fact that there does not exist at present in the Soviet Union one institution engaged in the scientific study of the total complexity of problems of managerial economics of production. Of course numerous organizations devote their effort to specific problems, but not one attacks the problem holistically with the aid of modern analytical tools and data collected by specific research. The same author concludes that technical revolution of administrative and managerial work is the only possible solution to the crucial problem posed by the contemporary production process—control and analysis of operations.

1. FACTORS AFFECTING THE TRANSFER OF TECHNOLOGY

The purpose of this paper is to discuss some significant factors that seem to affect favourably or adversely the pace and the direction of technological progress in the Soviet Union, and to indicate obstacles that institutional *milieux* might cause to the rapid progress of technology. The paper is not planned to present a full picture of technological transfer and innovative process in the USSR. Neither will an attempt be made to evaluate the efficiency capabilities (the merit) of the Soviet economy relative to Western economies in making effective use of opportunity for technological change, and consequently efficiency growth.

First, however, a few concepts and terms will be briefly identified. The concept of technology,

[1] Jacob SCHMOOKLER, "Technological Change and Economic Theory", *American Economic Review*, Vol. 55, May 1965, p. 336.

[2] *Ekonomicheskaya Gazeta*, Vol. 48, 1965, p. 5.

[3] S. A. LENSKAIA, *Krugooborot i Oborot Obshchestvennykh Fondov v SSSR*, (Moscow) *Izd. Mysl*, 1967, pp. 184–217.

of course, includes not only machines and physical tools, but also the organization and systematization of ways of doing things. In this broader sense, principles of management by exception, when embodied in an organization, are just as much technology as a turret lathe. Transfer of technology, as distinct from diffusion, incorporates an additional, specific element: action of a planned and purposive type. "The purposiveness manifests itself by conscious, predetermined effort and commitment of resources to transplant technology from one country to another, or from one use to another."[4] Two types of technology transfer are usually distinguished which Harvey Brooks has labelled vertical and horizontal.[5] The first refers to a transfer "along the line from the more general to the more specific"—the progression of technology from science to final product. This is a process by which new scientific knowledge or "state of art" becomes embodied in a technological system, and by which the confluence of several different and apparently unrelated techniques leads to a new technology. Horizontal transfer occurs through the adaptation of a technique from one application to another, e.g. military or space to civilian, or from one country or locale to another through technical assistance to less-developed nations.

The prominent role of investments in physical and human capital as major determinants of the capacity of a society to absorb or transfer technology and to stimulate development of new technology is hardly disputed, although the controversy as to which factor is more important causes many heated disputes. A preliminary study of Japanese experience and data,[6] points out that the absorptive capacity, at least in the case of Japanese introducing technology from abroad, would seem to depend mainly on the complex of variables representing the educational and technological levels, totality of effort in science and research, foreign contacts, and action of government (such as stimulating technological borrowing by well-planned depreciation policies). If the data on technical and educational levels and on capital expenditures to raise the technological level in various countries are compared with those on the speed of technological progress or transfer and with the rates of economic growth, it would seem that other factors, in addition to capital and manpower, affect indirectly the rate of growth and directly the innovative and absorptive capacity. Possibly the most important among these other factors is business organization and management. It seems to affect critically the process of technological assimilation—the blending of imported and indigenous (or new and old) technology—that breeds a new technological mix suitable to the institutional set-up, market structure, and factor endowment of a particular economy. In my opinion the Soviet experience supports the hypothesis that business organization and management are of importance in shaping the peculiarities of technological transfer and in creating certain bottlenecks and problem areas.

Vnedrenie novoi tekhniki—the introduction of new technology, regardless of whether indigenous or foreign, whether in the form of an invention of a new technique or of the transfer of an existing one—is a standard slogan in the Soviet Union today. Technological progress is practically singled out as the moving force that will eventually bring society to the threshold or realization of the idea of distribution according to needs. Consequently, as Gregory Grossman aptly observed, a new social technique has been developed: the routinization of innovation and the routinization of economic growth. "Virtually everything connected with the process of economic growth—the accumulation of society's saving, capital formation, education and training, invention, research and development, dissemination of technological information and the massive take-over of technology from abroad—has been centrally organized and planned and subjected to standardized, repetitive, routine methods and procedures."[7]

An illustration of such routinization, in the particular case of the information flow, is presented in figure I.

A very complex, uniform system of documentation, classification, and rendering information on foreign and domestic technical and scientific data has been created,[8] that is in its way unique in the world's experience. The financing of the introduction of new technology and of the expansion of the physical capacity is another example of routinization. Capital investments, which recently

[4] See Daniel L. SPENCER and Alexander WORONIAK (eds.), *Transfer of Technology to Developing Nations*, New York, Praeger, 1967, p. 186.

[5] Harvey BROOKS, "National Science Policy and Technology Transfer", paper read before the Conference on Technology Transfer, Washington, D.C., 16 May 1966, pp. 2—3.

[6] Daniel L. SPENCER and Alexander WORONIAK, "The Feasibility of Developing Transfer of Technology Functions", *Kyklos*, Vol. 20, fasc. 2, 1967.

[7] Gregory GROSSMAN, "Innovation and Information in the Soviet Economy", *American Economic Review*, Vol. 56, May 1966, p. 118.

[8] At the beginning of 1967 the Council of Ministers, USSR, accepted a resolution "On the All-Union System of Scientific-Technical Information", see: *Ekonomicheskaya Gazeta*, Vol. 34, No. 13, Mar. 1967, p. 13.

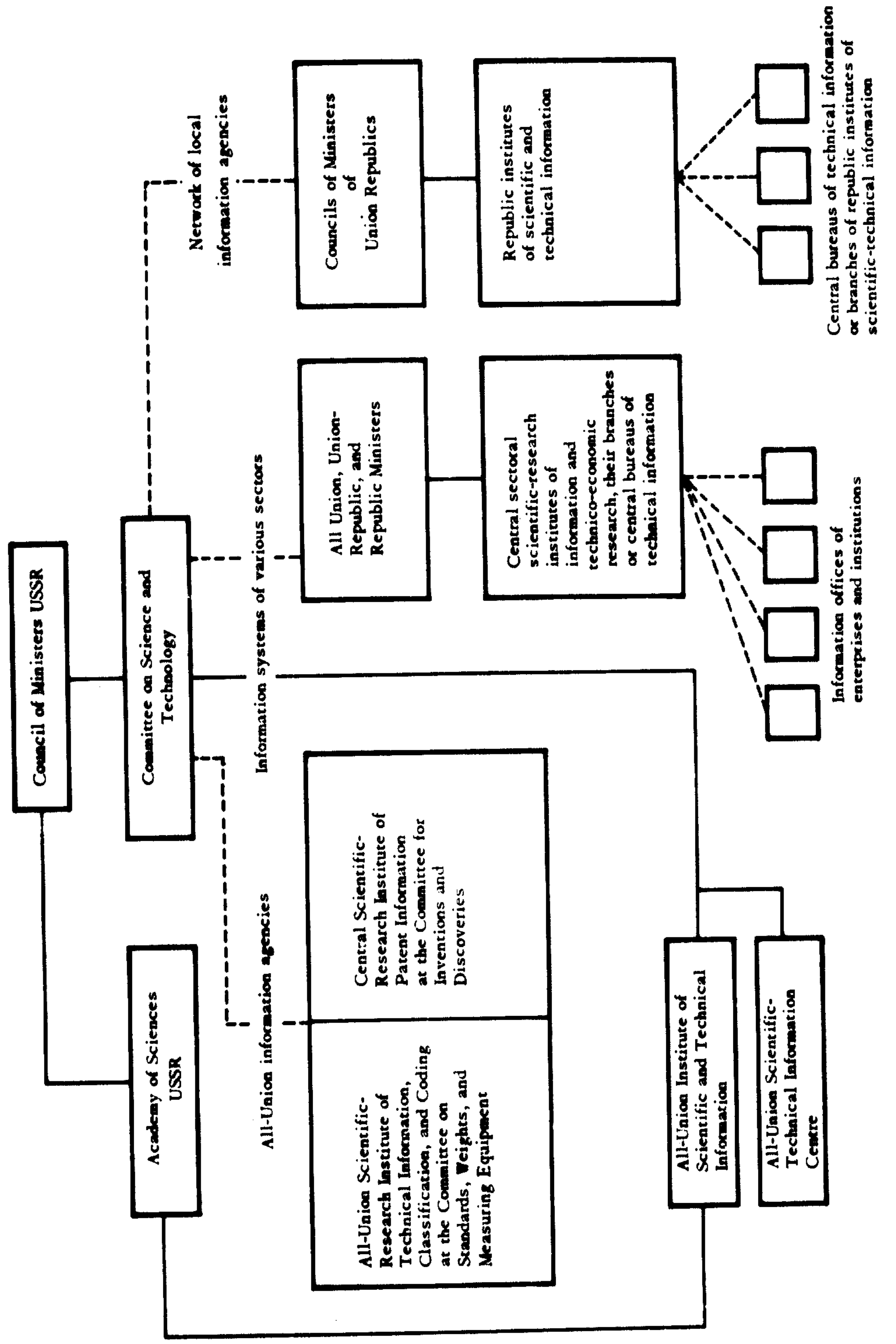

Figure I. Information flow in the USSR

——— *subordination.* - - - - *co-ordination. Source: Ekonomicheskaya Gazeta*, Vol. 34, No. 13, Mar. 1967, p. 13

accounted for about one third of the gross national product, are centrally planned and distributed, with the exception of a small part of profit left at the disposal of enterprises. Investment is considered not only as a propellant of rapid growth but as the conveyor of technology into the economy. A general view among Soviet economists is that capital intensity is directly related to labour productivity,[9] and that technical progress is identical with electrification, mechanization, automation, modernization of equipment, and "chemicalization".

2. ORGANIZATION AND MANAGEMENT OF PRODUCTION

Although Soviet technological progress is undoubted and its technological achievement praised,[10] certain paradoxes, bottlenecks, contrasts, and inconsistencies require explanation and proper corrective action. One can hardly look for explanation on economic grounds, however, because of the high commitment of resources to technological advancement, an adequate technical and scientific base, and a well-educated labour force. Peter Wiles stresses "one specifically Communist investment policy which is a definite advantage: they try to use all educated people, and to educate only for use".[11] Thus the explanation must be sought in institutional set-up, particularly in business organization and management of production process. In fact, since 1957 the Soviet managerial apparatus has been continually and intensively in search of effective organizational forms, of a better balance between centralization and decentralization, between territorial and branch organizational structure and control.

Published Soviet data indicate the declining efficiency of capital investment during the current seven-year plan. This is shown in tables 1, 2 and 3.

[9] M. RAKOVSKII estimates that new technology embodied in automated and modernized equipment accounts for 60 per cent of the increase in labour productivity. The remainder is equally divided between organizational innovations and improvement in the quality of labour through both education and learning-by-doing. See: "Nazrevshie Zadachi Mekhanizatsii i Avtomatizatsii Proisvodstva", *Kommunist*, No. 2, 1962, p. 33.

[10] For a critical view see Michael BORETSKY, "Comparative Progress in Technology, Productivity, and Economic Efficiency: U.S.S.R. versus U.S.A.", in United States Congress, Joint Economic Committee, *New Directions in the Soviet Economy: Studies Prepared for the Subcommittee on Foreign Economic Policy*, Part II-A-Economic Performance, 89th Cong., 2nd Sess., 1966, pp. 155–185.

[11] P. J. D. WILES, *The Political Economy of Communism*, Harvard University Press, Cambridge, Mass., 1962, p. 328.

TABLE 1. GROWTH OF CAPITAL ASSETS AND OF NATIONAL INCOME, 1958–1965

	Growth (1950 = 100) 1958	1960	1963	1964	1965
National capital assets (including cattle)	210	254	337	367	405
National income	229	265	311	340	361
Ratio of growth of national income to growth of national capital assets	1.10	1.03	0.92	0.92	0.89

Source: S. GUREVICH, "Statistical Study of the Economic Effectiveness of Production", *Vestnik Statistiki*, No. 8, 1966, pp. 3–16.

TABLE 2. CAPITAL INTENSITY OF NATIONAL INCOME, 1959–1965

	1959	1960	1961	1962	1963	1964	1965
Increase of national income, in comparable prices — thousand millions of roubles	9.6	10.6	10.0	9.0	6.8[a]	16.1	11.6[a]
Capital investments, in comparable prices — thousand millions of roubles	20.8	22.6	23.9	25.5	27.4	31.0	33.4
Capital intensity	2.2	2.1	2.4	2.7	4.0	2.0	2.9

[a] Probably due to bad harvests.

TABLE 3. EFFECTIVENESS OF PRODUCTION
(in percentages)

	1951–55	1956–60	1961–65	Average Annual Growth 1961–65	Average Annual Growth 1966
Gross national output	168	154.5	137	6.5	8.0
Capital assets of all sectors	163	157.5	159	9.7	8.0
Gross industrial output	185	164	151	8.6	8.6
Capital assets of industry	178	169	169	11.1	—
Increase in output per 1 per cent growth of capital assets (annual rates):					
Total economy	1.07	0.96	0.67	0.67	1.0
Industry	1.07	0.94	0.77	0.77	—
Labour productivity:					
Industry	149	137	125	4.6	5.0
Agriculture:					
Collective farms	137	136	118	3.4	12.0
State farms	135	127	105	1.0	
Average annual growth:					
Capital assets per worker	7.3	6.8	7.1		
Electro-energy per worker	7.8	5.7	7.1		
Labour productivity	8.3	6.5	4.6		

Source: S. KEINMAN, "Nauchno-Tekhnicheskii Progress – Vashnieishee Uslovie Povysheniia Effektivnosti Proizvodstva", *Voprosy Ekonomiki*, No. 4, Apr. 1967, pp. 88 – 89.

According to Professor Notkin[12] and other Soviet economists the return on capital assets has declined in recent years: for the whole economy by 9 per cent; in industry by 4 per cent; in agriculture by 21 per cent; and in construction by 11 per cent. The problem is serious, as about 55 per cent of total investments in the production sector fall under the category of capital assets. Particularly in the agricultural sector the only effect of capital investment was some saving of labour resources; the increase of output was negligible. In 1962 the equipment of agricultural labour with energy increased by 11 per cent, labour productivity rose by 3.5 per cent, and real output by 1.1 per cent. However, a British journal commented that "there is some correlation between the slowdown in Soviet economic growth and the improvement in the quality of economic thinking".[13]

The problems have already been in existence for some time, but at present they have been made worse by the increasing complexity of the Soviet socio-economic system, by the diminishing ability of the system to mobilize resources by political means rather than by economic incentives and persuasion, and to some extent by the high level of sophistication of Soviet technology, which limits borrowing innovations from abroad. It is not surprising that leading points of the new five-year plan are: acceleration of technological progress, increasing the effectiveness of investments and of labour input, and closing the gap between industrial and agricultural rates of growth. At the end of 1965 the economic reform[14] was announced, and by the third quarter of 1966 the management and control of approximately 700 enterprises have been converted to the new system, which presumably stresses economic rationality and economic principles of management.[15]

The concept of business and industrial management organization is complex, and only major aspects that are particularly noticeable and significant in the Soviet Union are listed below:

(1) Financing (source) and management of resources committed to the advancement of technological progress (research and development expenditures):

(i) Centralized versus decentralized financing.

(ii) Whether the chief carriers of the research and development activities are separate and independent research institutes, universities, or plant laboratories, and the closeness of staff and research to the production line.

[12] *Planovoe Khoziaistvo*, June 1964.

[13] *Economist*, 30 May 1964.

[14] For discussion and a preliminary evaluation of the economic reform see the series of ten pamphlets by leading Soviet economists, *Ekonomisty o Novoi Khoziaistvennoi Reforme v SSSR*, Moscow, Izd. Ekonomika, 1966.

[15] *Ekonomicheskaya Gazeta*, Vol. 34, No. 1, Jan. 1967.

(iii) Government guidance and control.

(iv) Risk-bearing and incentives to innovative activities and to the introduction of new products.

(2) Organizational set-up affecting the decision as whether or not to introduce (transfer) the new technology:

(i) Considerations of economic, engineering, political, and other nature.

(ii) Determination of economic effectiveness, computation of costs and returns of new technology.

(iii) Gestation period factors affecting the lag between an innovation and its application and spread.

(iv) Existence of a market, or ability to develop one, for the product of new technology.

(3) Pricing of new products:

(i) Considerations affecting pricing policies (producer goods versus consumer goods, foreign trade considerations etc.).

(ii) Pricing of new equipment and the productivity problem.

(4) Quality control:

(i) Standardization of production.

(ii) Decentralization of technological service.

(iii) Spread and effectiveness of quality control measures.

(iv) Role of the foreman.

The limited scope of this paper does not permit comment on all of these aspects.

3. Research and development and the introduction of new technology

In 1965 over 2.6 million workers in the Soviet Union were engaged in research and development; including post-graduate students (aspirants) and engineers at plants working as designers or researchers; the total in 1967 reached 3.3 million. The total expenditure on science and research, including the cost of construction of new facilities, reached almost nine thousand million roubles, which amounts to 4 per cent of the national income or one fifth of the total capital investment in the USSR.[16] At a recent meeting of the USSR Academy of Sciences, L. Gatovskii stressed that whereas in 1960 about 57 per cent of research personnel in the United States worked for industrial corporations, in the Soviet Union less than 2 per cent were employed by enterprises. Practically all Soviet research manpower works for the research institutes and has little if any contact with the concrete problems of production and profitability. Remoteness from the production line, poor organization, and the bureaucratic nature of the planning and control of the activities and operations of research institutes result in low productivity of research and parallelism, and explain why technical rather than economic considerations are guiding the selection of projects and design of equipment.[17] Lack of technical help and proliferation of meetings are said to be among the reasons why scientific personnel spend less than half of their time on actual research. Determination of the effectiveness of research work and of the productivity of scientific personnel raises complex problems, which until very recently have not even been discussed in Soviet literature. Oddly enough, on the average, the salary of an engineer switching from production to research would be cut by almost 20 per cent, and many leave research jobs for teaching positions where pay is much better. Inadequate rewards for successful research and an almost complete lack of risk-sharing by the institutes or workers result in the misdirection of an enormous reservoir of well-trained and talented manpower.

The complex relationships between research institute, producer of new equipment, and user of machinery are complicated by rather limited channels of direct communication between producer and user. From the point of view of the user, expenditures for new machinery equal zero under the existing system of economic accounting (this presumably will be changed with the introduction of payment for the capital assets allocated by the State to the enterprise). On the other hand, the producer is forced to aim at the highest possible price for new equipment so as to cover higher production costs and to maintain the level of profitability.

Since September 1965 the index of profitability has become the basis for allocations of profit to the enterprise fund and will consequently affect bonuses, awards and other incentives. A number of enterprises that switched to the new economic system in 1966 reported difficulties in the adoption of new technology caused by the disorder due to the pricing of new equipment out of line with the productivity increases.[18]

[16] V. Sominskii, *Ekonomicheskaya Gazeta*, Vol. 34, No. 10, Mar. 1967, pp. 7–8.

[17] P. D. Shoshmin and V. A. Shcherbakov, *Planirovanie v Nauchno-Issledovatel'skikh Institutakh i Konstruktorskikh Biuro*, Moscow, Izd. Mashinostroenie, 1964.

[18] A. Rakhleev and R. Tikidzhiev, "Opyt Ispol'zovaniia Proizvodstvennykh Fondov v Novykh Usloviiakh Khoziaistvovaniia", *Voprosy Ekonomiki*, No. 11, 1966.

TABLE 4. ORGANISATIONS ENGAGED IN PROJECTING AND PLANNING CAPITAL CONSTRUCTION, 1960 AND 1965

(at beginning of year)

Type of organization	1960	1965
Total	1,092	1,343
Organisations subordinated to the Council of Ministers of Union Republics	712	529
under Councils of national economy (Sovnarkhozy)	211	41
under ministries	357	390
under local authorities	144	98
Organizations subordinated to the ministries of the USSR	380	814

Source: Vestnik Statistiki, No. 8, 1965, p. 84.

TABLE 5. INNOVATIONS, RATIONALIZATION AND TECHNICAL PROGRESS IN THE SOVIET NATIONAL ECONOMY, 1940–1964

	1940	1945	1964
Innovations and rationalization in national economy			
Number of proposals received	591,000	387,000	4,053,000
Number of innovations and rationalization proposals applied to production	202,000	165,000	2,761,000
Total annual savings resulting from application of proposals *(million roubles)*	90	125	1,774
Mechanization of labour-intensive and heavy work (in percentages)			
In coal mining industry:			
coal cutting	0.1	0.1	64.3
coal loading	—	—	79.9
In timber industry:			
timber cutting	—	—	98.9
delivery of wood to storage area	5.6	2.1	95.5
removal of wood	32.8	26.9	98.8
In construction industry:			
earthwork	60.0	54.0	97.0
plaster work	7.0	9.0	59.0
paint work	25.0	39.0	67.0

Source: Vestnik Statistiki, No. 4, 1965, p. 74.

Many cases of a recent rise in production costs as a result of the introduction of new equipment, particularly fully automated production lines, were caused not only by deficiences in the design and production of new equipment but also by different wage-levels of producer and user.[19] In the construction of new facilities, under the present system of economic accounting neither the planning and designing agency nor the management of the plant being constructed is stimulated to apply the most effective and economically justified technique. All problems are simply reduced to the size of the limits of an approved estimate of the construction costs.

The proliferation of agencies involved in innovation and technological transfer is illustrated by table 4. At the beginning of 1965, in one sector only, that of capital construction, over 1,300 agencies were in operation.

Tables 5 and 6 show Soviet data on technological transfer and innovation.

It would seem from table 6 that the bulk of innovational activity is in the form of modernization of equipment. The modernization of machinery is considered in the Soviet Union to be effective if productivity increases by 20–30 per cent. An analysis of 6,800 pieces of equipment in 140 plants showed that only in 52 per cent were there any increases in productivity. Of that 52 per cent 16 per cent showed an increase of 5 per cent or less; 18 per cent showed an increase of from 6 to 10 per cent; 13 per cent showed an increase of from 11 to 20 per cent; and 5 per cent showed an increase of over 20 per cent.

A similar study of the expenditures of machine-building plants on modernization disclosed that

[19] A. MATLIN, *Tekhnicheskii Progress i Tseny Mashin*, Moscow, Izd. Ekonomika, 1966.

between 1961 and 1963 outlays increased by 78 per cent, but the overall productivity of the machinery declined from 14 to 10 per cent.[20]

Heavy expenditures on modernization are indicative of the age of some Soviet machinery and equipment. Table 7 shows, for instance, the age of metal-cutting and forging-pressing equipment.

Soviet economists estimate that in 1963, 2 million workers were employed, 800,000 machine tools used, and 2.5 million machine-hours spent for repairs and modernization. This effective use of resources is paralleled by the replacement and amortization policies, as well as by the existence of numerous unspecialized shops, using antiquated hardware, which are permitted to operate next to very efficient and modern facilities. Table 8 shows that 55 per cent of iron-producing enterprises produce less than 1,000 tons of iron castings. Out of 100 machine-building plants, 99 produce their own cog wheels, 71 their iron castings, 57 their non-ferrous castings, and 84 their die castings. The level of specialized production of instruments in the Soviet Union does not exceed 25–30 per cent of

[20] A. CHERNYI, "O Planirovanii i Uchete Modernizatsii Oborudovaniia", *Vestnik Statistiki*, No. 11, 1966, pp. 73–74.

TABLE 6. INTRODUCTION OF NEW TECHNOLOGY IN INDUSTRY, 1958–1960

	1958	*1959*	*1960*
Development of new types of machinery and equipment	2,051	2,265	2,500[a]
Installation of automatic, semi-automatic and mechanized conveyer production lines	1,545	1,764	2,800[b]
Modernization of equipment in machine building plants	42,000	54,000	70,000[a]

Source: Vestnik Statistiki, No. 2, 1961, pp. 34–35.
[a] Approximate figure.
[b] Minimum figure.

TABLE 7. AGE OF METAL-CUTTING AND FORGING-PRESSING EQUIPMENT
(percentages)

Type of equipment and year	*Age of equipment* Less than 10 years	10–20 years	Over 20 years
Metal-cutting machine tools			
1940	71	13	16
1955	40	42	18
1958	49	30	21
1962	57	20	23
Forging-pressing equipment			
1940	67	15	18
1955	43	38	19
1958	53	27	20
1962	62	19	19

Source: G. A. PRUDENSKII, *Vremia i Trud*, p. 188.

TABLE 8. GROUPING OF IRON-PRODUCING INDUSTRIAL ENTERPRISES BY VOLUME OF ANNUAL OUTPUT OF IRON CASTINGS, 1961

Volume of annual output (thousands of tons)	*Number of enterprises (as percentage of total)*	*Percentage share of output produced by various types of moulding* hand	machine	*Output per square metre of shop area*	*Average output per worker*	*Cost of production per ton*
				percentage of group producing over 50,000 tons of castings		
Less than 1	54.6	95	5	24	26	238
1–3	25.6	82	18			205
3–5	6.9	63	37	37	35	205
5–10	5.9	53	47			190
10–25	4.2	44	56	50	51	152
25–50	1.5	35	65	60	59	131
over 50	1.3			100	100	100

Source: Vestnik Statistiki, No. 1, 1965, p. 13.

total output, whereas in the United States over 70 per cent is produced in specialized plants.[21]

Soviet studies emphasize the long period of gestation of new technology. The development and adoption of such simple machinery as cultivators or ploughs that do not require specially trained labour usually take from five to seven years; in the case of complicated machinery the period extends to ten years. In the meantime the parameters underlying the rationale for the adoption of the new machinery become obsolete.[22] The Soviet organizational structure evidently permits long lags between the beginning of the construction of new facilities and the time when they reach their full operational efficiency. At the end of 1964 the uncompleted construction projects reached 27,000 million roubles—one seventh of the national income. A study of 600 projects in Siberia disclosed that the average lag is between five and seven years. However, longer periods are common; the case of Cherepovetz metallurgical plant gained well-deserved notoriety, for there was a lag of eighteen years between the start in 1949 and the completion in 1967.[23]

A study conducted by the Moldavian Institute for Planning and Projecting of Construction disclosed that in numerous cases the introduction and transfer of new technology did not bring expected results. The main causes are: unusually long gestation period, deficiences in design, failure of new technology to blend with the conditions of production, absence of demand for the new output, and inadequate or faulty preliminary analysis of the economic effectiveness of the innovations. The Institute found that many of the enterprises do not calculate the effectiveness and many do it incorrectly. Often the volume of output is left out, necessary additional investments are not included, the reduction in semi-variable costs due to the change in volume is classified as a benefit from the new technology, and some variable costs are omitted.[24]

[21] I. V. MAEVSKII, *Tekhnicheskii Progress i Rost Proizvoditel'nosti Truda*, Moscow, Izd. Ekonomicheskoi Literatury, 1963.

[22] M. I. GORIACHKIN, "Ekonomicheskie Printsipy Osnovnykh Napravlenii i Tekhnicheskogo Progressa Sel'sko-Khoziaistvennoi Tekhniki", in Vsesoiuznyi Nauchno-Issledovatel'skii Institut Ekonomiki Sel'skogo Khoziaistva, *Doklady i Soobshcheniia*, No. 29, Moscow, 1965, pp. 3—12.

[23] V. D. KAMAEV, *Moshohnyi Uskoritel': O Nauchno-Tekhnicheskom Progresse v Promyshlennosti S.S.S.R.*, Moscow, Izd. Znanie, 1966.

[24] M. ZAKHARKIN and Ia. GRADSHTEIN, "Opyt Ucheta Effektivnosti Novoi Tekhniki", *Vestnik Statistiki*, No. 11, 1966, pp. 11—18.

There is no agreement either in official pronouncements or in professional literature as to the proper methodology and technique of determining the effectiveness of new technology. In some respects official pronouncements lack theoretical and practical foundation; various problems, particularly the impact of the time factor, are treated incompletely. What is important for practical results is the fact that both the index of effectiveness and the pay-back (or recoupment) period are determined by the relationship between capital investments and cost reduction. In the reality of business transactions and economic accounting, capital investments are *de facto* separated from cost reduction. The full-scale introduction of payments to the State for capital assets assigned to enterprises might bring a considerable change here.

Another characteristic of Soviet business organization is the low level of mechanization of the auxiliary services, in which about 9 million workers are employed, including 3.2 million engaged in maintenance and repairs. The causes are: the great quantity of antiquated equipment, the low quality of new equipment, and the lack of centralized and specialized repair services. In the Altai tractor plant 171 auxiliary workers provide services for 100 production workers. Between 1959 and 1962 the total number of workers in the Soviet Union increased by 15 per cent; but the number of storekeepers and packers went up by 25 per cent, and of transport workers and riggers by 40 per cent.[25] Table 9 suggests that only a fraction of machine-time is actually used for the machine-work during one shift. The utilization of machinery rarely exceeds 40 per cent of the shift time and deteriorates with subsequent shifts.[26] On the average, time used for the auxiliary operations and for idle runs—particularly in the case of machinery with non-automatic work cycle—exceeds the processing time.

4. CONCLUDING REMARKS

A powerful factor that could, if properly used, significantly affect the pace of technological transfer and the effective use of resources is the system of incentives. To use Marshall's phrase, it would harness man's strongest though not necessarily highest motives. Unfortunately this versatile instrument of business management is applied in-

[25] LENSKAIA, op.cit., p. 199 *(see table 9, Source)*.

[26] Study of 172,000 metal-cutting and 24,000 forging-pressing machines in 1962. *Vestnik Statistiki*, No. 1, 1964, pp. 87—88.

TABLE 9. STRUCTURE OF WORK-TIME OF UNIVERSAL METAL-CUTTING TOOLS DURING ONE SHIFT UNDER UNIFORM, SERIAL PRODUCTION

Machines	Percentage of time used for types of work				
	Machine	*Auxiliary*	*Technical services*	*Pre-paratory and closing*	*Lost (org.-technical causes)*
Lathes	26	24	5	16	29
Turret lathes	35	23	7	13	22
Circular grinding	37	25	13	6	19
Horizontal spindle boring	18	26	10	7	39
Vertical boring	45	23	9	6	17
Side boring	32	17	10	17	24

Source: Data of the Experimental Institute for the Scientific Research and Study of Metal-Cutting Machine Tools, quoted in S. A. LENSKAIA, *Krugooborot i Oborot Obshchestvennykh Fondov v SSSR*, Moscow; 1967, p. 182.

effectively, and in limited scope. The level of wages is but weakly related to the profitability achieved. Whereas total industrial profit increased by 84 per cent for the period 1959—1963 the increase per worker was only 44 per cent. Payments of bonuses from the enterprise fund (which is based on the wage fund) increased only by 2 per cent. Managerial personnel, particularly engineering staff and administrative employees, receive special bonuses for over-fulfilment of plan in respect to the reduction of costs or, occasionally, for quality improvements. However, the wage fund remains the basic source of stimulation, but is not related to the level of production costs or to economies resulting from cost reduction. In this respect the implementation of pronouncements of the September 1965 plenum of the Central Committee of the Communist Party of the Soviet Union might result in significant improvements.

It seems the Soviet business organization and managerial policy is at the crossroads, and the direction of its next course will vitally affect technological progress, information efficiency, and every aspect of decision-making within the system. At present, central planning organizations are concerned with some 18,000 different types of production. The documentation alone involved in such operation wastes an enormous quantity of useful manpower, and the simple solution would be to establish direct relations between producer and user of goods. A study by the Scientific-Research Institute for Trade and Food Distribution conducted in 1962 in Moscow, Gorki, Cheliabinsk and Kalinin established that 72 per cent of the customers left the store without a purchase because of the poor quality of the merchandise.[17] Evidently the existing system of management of the Soviet enterprise does not include the special managerial function of full control of the material flow in the enterprise, from the moment of the receipt of materials and supplies to the release of the finished product. Time will show how the new economic reform will solve this problem.

[17] LENSKAIA, op.cit., p. 263 *(see table 9, Source)*.

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REQUIREMENTS AND TRAINING OF HIGHLY SKILLED MANPOWER FOR LATIN AMERICAN INDUSTRIAL DEVELOPMENT

Zygmunt Slawinski, Economic Commission for Latin America, Santiago, Chile

1. General trends and problems of Latin American industrial development

Discussion on the subject of this paper should start with a broad picture of industrialization problems in Latin America, and the presentation of the main trends of the region's industrial development. Within this framework it becomes easier to discuss the related problems of requirements and training of skilled manpower for industrial development, with special reference to highly skilled personnel. The magnitude and the general development trends of the industrial sector in Latin America can best be appreciated through the figures for employment and gross product in this sector. In this connexion it will be useful to discuss the present 30-year period of industrial development in Latin America beginning in 1950, and including a forecast up to 1980. By now it is possible to make a broad analysis of the first half of this period, 1950—1965; and some projections could be prepared for the second half, 1965—1980, in which we in 1967 are already involved. This projection period has the advantage of being covered in many countries of Latin America (and the world) by short-term national development plans in which industrial development is often considered as the driving power of over-all economic development.

The relative importance of industry and its development during the period 1950—1965 may best be appreciated through the employment figures for the whole region presented in table 1.[1]

It will be seen that over-all manufacturing employment accounts for an almost constant proportion (around 14 per cent) of the total economically active population. While this is largely due to the percentage decline of employment in handicrafts and homecrafts (which have undergone an

[1] See Economic Commission for Latin America, *Economic Survey of Latin America*, 1966, chap. II, section 10, "Economic Growth and Employment Structure", tables 1—13 and 1—14.

Table 1. Latin America[a]: estimates of employment by economic sector, 1950—1965
(thousands of persons)

Sector	Absolute figures 1950	Absolute figures 1960	Absolute figures 1965	Percentage of the total 1950	Percentage of the total 1960	Percentage of the total 1965
Total	*51,971*	*67,113*	*76,416*	*100.0*	*100.0*	*100.0*
A. *Agriculture*	28,100	32,596	35,221	54.1	48.6	46.1
B. *Non-agricultural sectors*	*22,673*	*32,496*	*38,023*	*43.6*	*48.4*	*49.8*
(including unspecified activities)	(23,871)	(34,517)	(41,195)	(45.9)	(51.4)	(53.9)
1. *Goods and basic services*	*12,005*	*16,216*	*18,259*	*23.1*	*24.2*	*23.9*
(*a*) Mining	557	681	753	1.0	1.0	1.0
(*b*) Manufacturing	7,357	9,497	10,546	14.2	14.1	13.8
(*i*) Factory industry	(3,526)	(5,041)	(5,734)	(6.8)	(7.5)	(7.5)
(*ii*) Handicrafts and homecrafts	(3,831)	(4,456)	(4,812)	(7.4)	(6.6)	(6.3)
(*c*) Construction	1,940	2,662	2,969	3.7	4.0	3.9
(*d*) Basic services	2,151	3,376	3,991	4.1	5.0	5.2
2. *Services*	*10,668*	*16,280*	*19,764*	*20.5*	*24.3*	*25.9*
(including unspecified activities)	(11,866)	(18,301)	(22,936)	(22.8)	(27.3)	(30.0)
(*a*) Trade and finance	4,007	5,996	7,220	7.7	9.0	9.5
(*b*) Other services	6,661	10,284	12,544	12.8	15.3	16.4
C. *Unspecified activities*[b]	*1,198*	*2,021*	*3,172*	*2.3*	*3.0*	*4.1*

Source: Economic Commission for Latin America, *Economic Survey of Latin America 1966*, (E/CN.12/767) Part One, table 1—13.
[a] Excluding Cuba.
[b] Mainly overt and disguised unemployment in the form of marginal services.

estimated relative drop from 7.4 to 6.3 per cent of the total labour force), some anxiety may be caused by the rather inadequate growth of employment in factory industry (covering by definition establishments with five or more persons employed) which, as a proportion of the total active population, grew over the whole period 1950–1965 from only 6.8 to 7.5 per cent and during the last few years has probably remained unchanged.

Consequently, the absorption capacity of factory industry in relation to the total net increase of the economically active population remained at a very unsatisfactory level. While the development of factory industry provided in the period 1950–1960 jobs for 10 per cent of the net total employment increase, it is estimated that during the period 1960–1965 it absorbed only 7.5 per cent of this total (see table 2).

TABLE 2. LATIN AMERICA[a]: ESTIMATED ABSORPTION OF THE NET INCREASE IN THE LABOUR FORCE, 1950–1965
(thousands of persons)

Sector	Absolute figures 1950–1960	Absolute figures 1960–1965	Percentage of total 1950–1960	Percentage of total 1960–1965	Annual rate 1950–1960	Annual rate 1960–1965
Total	*15,142*	*9,303*	*100.0*	*100.0*	*2.6*	*2.6*
A. *Agriculture*	4,496	2,625	29.7	28.2	1.5	1.6
B. *Non-agricultural sectors*	*9,823*	*5,527*	*64.9*	*58.4*	*3.7*	*3.2*
(including unspecified activities)	10,646	6,678	70.3	(71.8)	(3.8)	(3.6)
1. *Goods and basic services*	*4,211*	*2,043*	*27.8*	*21.0*	*3.0*	*2.4*
(*a*) Mining	124	72	0.8	0.8	2.0	2.0
(*b*) Manufacturing	2,140	1,049	14.1	11.3	2.6	2.1
(*i*) Factory industry	(1,515)	(693)	(10.0)	(7.5)	(3.6)	(2.6)
(*ii*) Handicrafts and homecrafts	(625)	(356)	(4.1)	(3.8)	(1.5)	(1.5)
(*c*) Construction	722	307	4.8	3.3	3.2	2.2
(*d*) Basic services	1,225	615	8.1	6.6	4.6	3.4
2. *Services*	*5,612*	*3,484*	*37.1*	*37.5*	*4.3*	*4.0*
(including unspecified activities)	(6,435)	(4,635)	(42.5)	(49.9)	(4.4)	(4.6)
(*a*) Trade and finance	1,989	1,224	13.1	13.2	4.1	3.8
(*b*) Other services	3,623	2,260	23.9	24.3	4.4	4.0
C. *Unspecified activities*[b]	*823*	*1,151*	*5.4*	*12.4*	*5.4*	*9.4*

Sources: ECONOMIC COMMISSION FOR LATIN AMERICA, *Economic Survey of Latin America, 1966*, op. cit., tables 1–13 and 1–14.
[a] Excluding Cuba.
[b] Mainly overt and disguised unemployment in the form of marginal services.

TABLE 3. LATIN AMERICA[a]: ESTIMATES OF THE GROSS PRODUCT BY ECONOMIC SECTOR, 1950–1965
(millions of US dollars, at 1960 prices)

Sector	Absolute figures 1950	Absolute figures 1960	Absolute figures 1965	Percentage of the total 1950	Percentage of the total 1960	Percentage of the total 1965
Total	*44,741.5*	*70,925.1*	*88,055.6*	*100.0*	*100.0*	*100.0*
Total (excluding housing)	42,813.4	67,878.1	84,454.9			
A. *Agriculture*	11,060.2	15,479.7	18,916.6	24.7	21.8	21.5
B. *Non-agricultural sectors*	*31,753.2*	*52,398.4*	*65,593.3*	*71.0*	*73.9*	*74.4*
(including non-specified activities)	(31,753.2)	52,398.4	65,538.3	71.0	73.9	74.4
1. *Goods and basic services*	*14,926.5*	*26,662.2*	*33,931.0*	*33.4*	*37.6*	*38.5*
(*a*) Mining	1,857.8	3,587.6	4,408.1	4.2	5.1	5.0
(*b*) Manufacturing	8,265.0	15,110.5	19,620.1	18.4	21.3	22.3
(*i*) Factory industry	(7,259.3)	(13,802.3)	(18,136.8)	(16.2)	(19.5)	(20.6)
(*ii*) Handicrafts and homecrafts	(1,005.7)	(1,308.2)	(1,484.3)	(2.2)	(1.8)	(1.7)
(*c*) Construction	1,510.5	2,346.6	2,660.8	3.4	3.3	3.0
(*d*) Basic services	3,293.2	5,617.5	7,242.0	7.4	7.9	8.2
2. *Services*	*16,826.7*	*25,736.2*	*31,607.3*	*37.6*	*36.3*	*35.9*
(including unspecified activities)	16,826.7	25,736.2	31,607.3	37.6	36.3	35.9
(*a*) Trade and finance	7,882.4	12,921.8	16,170.9	17.6	18.2	18.4
(*b*) Other services	8,944.3	12,814.4	15,436.4	20.0	18.1	17.5
C. *Unspecified activities*[b]	—	—	—	—	—	—

Source: ECONOMIC COMMISSION FOR LATIN AMERICA, *Economic Survey of Latin America, 1966*, op. cit., tables 1–15.
[a] Excluding Cuba.
[b] Mainly overt and disguised unemployment in the form of marginal services.

The contribution of manufacturing industry to the gross product, as compared with that of the other sectors, is shown in table 3, while table 5 shows the product per person. The development rate of the industrial product and of the product per person (see table 4), though perhaps unimpressive when compared with other areas of the world, clearly demonstrates the dynamic role of manufacturing and especially of factory industry in the process of economic development in Latin America.

The low proportion of manpower absorbed by factory industry in Latin America as a whole, and in nearly all the countries of the region taken separately, seems incompatible with the assump-

TABLE 4. LATIN AMERICA[a]: ESTIMATED RATE OF INCREASE OF THE GROSS PRODUCT AND THE PRODUCT PER EMPLOYED PERSON BY ECONOMIC SECTOR, 1950–1965
(percentages)

Sector	Gross product			Product per person		
	1950–1960	1960–1965	1950–1965	1950–1960	1960–1965	1950–1965
Total	*4.7*	*4.4*	*4.6*	*2.1*	*1.7*	*1.9*
Total (excluding housing)	4.7	4.5	4.6	2.1	1.8	2.0
A. *Agriculture*	3.4	4.1	3.6	1.9	2.5	2.1
B. *Non-agricultural sectors*	*5.1*	*4.6*	*4.9*	*1.4*	*1.3*	*1.4*
(including unspecified activities)	5.1	4.6	4.9	1.3	0.9	1.2
1. Goods and basic services	6.0	4.9	5.6	2.8	2.5	2.7
(*a*) Mining	6.8	4.2	5.9	4.7	2.2	3.8
(*b*) Manufacturing	6.2	5.4	5.9	3.5	3.2	3.4
(*i*) Factory industry	(6.6)	(5.6)	(6.3)	(2.9)	(2.4)	(2.7)
(*ii*) Handicrafts and homecrafts	(2.7)	(2.6)	(2.6)	(1.1)	(0.9)	(1.1)
(*c*) Construction	4.5	2.5	3.8	1.2	0.3	0.9
(*d*) Basic services	5.5	5.2	5.4	0.9	1.8	1.1
2. *Services*	*4.3*	*4.2*	*4.3*	*0.0*	*0.2*	*0.1*
(including unspecified activities)	4.3	4.2	4.3	0.0	−0.4	−0.2
(*a*) Trade and finance	5.1	4.6	4.9	1.0	0.8	0.9
(*b*) Other services	3.7	3.8	3.7	−0.9	−0.3	0.6
C. *Unspecified activities*[b]	—	—	—	—	—	—

Source: ECONOMIC COMMISSION FOR LATIN AMERICA, *Economic Survey for Latin America, 1966*, op. cit.
[a] Excluding Cuba.
[b] Mainly overt and disguised unemployment in the form of marginal services.

TABLE 5. LATIN AMERICA[a]: ESTIMATES OF THE GROSS PRODUCT PER EMPLOYED PERSON BY ECONOMIC SECTOR, 1950–1965
(US dollars at 1960 prices)

Sector	Absolute figures			Percentage of the total		
	1950	1960	1965	1950	1960	1965
Total	*861*	*1,057*	*1,152*	*100.0*	*100.0*	*100.0*
Total (excluding housing)	824	1,011	1,105	95.7	95.6	95.9
A. *Agriculture*	394	475	537	45.8	44.9	46.6
B. *Non-agricultural sectors*	*1,400*	*1,612*	*1,723*	*162.6*	*152.5*	*149.6*
(including unspecified activities)	1,330	1,518	1,591	154.5	143.6	138.1
1. *Goods and basic services*	*1,243*	*1,644*	*1,858*	*144.4*	*155.5*	*161.3*
(*a*) Mining	3,335	5,268	5,854	387.3	498.4	508.2
(*b*) Manufacturing	1,123	1,591	1,860	130.4	150.5	161.5
(*i*) Factory industry	(2,060)	(2,738)	(3,085)	239.2	259.0	267.8
(*ii*) Handicrafts and homecrafts	(263)	(294)	(308)	30.5	27.8	26.7
(*c*) Construction	779	882	896	90.5	83.4	77.8
(*d*) Basic services	1,531	1,664	1,815	177.8	157.4	157.6
2. *Services*	*1,577*	*1,581*	*1,599*	*183.2*	*149.6*	*138.8*
(including unspecified activities)	1,418	1,406	1,378	164.7	133.0	119.6
(*a*) Trade and finance	1,967	2,155	2,240	228.4	203.9	194.4
(*b*) Other services	1,343	1,246	1,231	156.0	117.9	106.9
C. *Unspecified activities*[b]	—	—	—	—	—	—

Source: ECONOMIC COMMISSION FOR LATIN AMERICA, *Economic Survey of Latin America, 1966*, op. cit.
[a] Excluding Cuba.
[b] Mainly overt and disguised unemployment in the form of marginal services.

tion that Latin America is engaged in an intensive industrialization process, although certain major industries, especially in the field of intermediate products and transport equipment, have obviously made tremendous headway towards covering the bulk of the needs for such commodities in the Latin American region.

The general employment figures, even when supplemented by gross product data and average productivity figures derived from them, cannot convey the qualitative aspects of Latin American industrial development and structural changes. A simple interpretation of the structural transformation of the manufacturing industries in Latin America could be presented in the following way. In nearly all developing countries, as well as in advanced industrialized countries, industrial development may be divided into five basic stages, as outlined below.[2]

(i) The first, or pre-factory, stage is characterized by the intensive pursuit of cottage and artisan industries which supply most of the demand for simple manufactured goods, including textiles, clothing and domestic equipment. The early factory industries are mostly related to the primary processing of national raw materials for export. The following are some typical examples: slaughterhouses (packing plants); sugar refineries; cocoa, coffee and fruit drying plants; plants for the extraction of vegetable oils; saw-mills; plants for concentration of metal ores; and other similar establishments. Nearly all the Latin American countries had reached this stage at the beginning of the century, and the industrial development of the more remote regions and of extensive rural areas of the continent is still at this stage. Almost all factory-made consumer goods were imported at that time, not to mention capital equipment which was entirely foreign in origin.

(ii) The second stage, that of the development of traditional consumer goods industries, is characterized by the development of factory industry for the production of simple consumer goods: construction materials and the simpler tools. This phase marks the creation of the following factory industries: textiles and leather; food and beverages; the simpler chemical preparations; basic pottery, china and glass-ware; and wood processing. Moreover, it constitutes the first stage of the nationally conscious process of import substitution.

(iii) The third stage, that of the development of basic industries and of the production of simple equipment, witnesses the emergence and development of the steel industry. This is supplemented by the processing of metal products and the construction of simple equipment; by the large-scale development of the cement industry; by petroleum refining and the development of the basic chemical industry; and by the manufacture of simple basic chemical products.

This stage marks the development of the important rubber industry, coupled with the production of tyres and of plastic goods from imported raw materials. As regards equipment, at this stage there is a development of the mass production of simple electrical items in common use, simple tools, and household and industrial equipment, the more complex parts of which are imported. Under the head of basic transport equipment, railcars—mainly goods wagons—are produced; but in so far as motor vehicles are concerned there are only plants for the local assembly of imported parts. During this phase the range of industrial items expands considerably, though low and medium-grade industries still prevail. Higher-grade manufactures are limited by the level of technological development, the shortage of all types of skilled personnel and the small size of the domestic markets.

This phase is the second in the general process of import substitution, and the first step towards making investments partially independent of foreign technical contributions.

(iv) The fourth stage is defined as that of the upsurge of high-grade industry, involving the development of more complex forms of the processing of intermediate products and the production of complex equipment. Some notable features are: the production of special steels; the creation of the petrochemical industries and the production of synthetic chemicals; the precision metal and electrical transforming industry, on the one hand, and the heavy equipment industry on the other; and, in general, the production of high-grade machines and equipment of complex design, manufactured or assembled in complicated processes. The high technological level required by this stage entails the intensive use of skilled manpower.

This phase corresponds to the third stage of the import-substitution process, and is the second step towards making investment partially independent of foreign technical contribution.

(v) The fifth stage marks the upsurge of the full range of highly advanced or high-grade industries, and represents the peak of industrial

[2] See Z. SLAWINSKI, "Structural Changes in Employment Within the Context of Latin American Economic Development", ***Economic Bulletin for Latin America***, Oct. 1965. For further details see also ECLA, ***The Process of Industrial Development in Latin America***, (E/CN.12/716/Rev.1), New York, 1965, chap. I.

development within the present limits of science and technology. The following are its most characteristic achievements: development of the highest forms of chemical synthetics; highly advanced processes for the manufacture of special steels, highly purified elements, and other high-quality materials; the atomic energy industry and general atomic research for peaceful uses; the production of highly complex electronic equipment; the large-scale aircraft industry; and the production of equipment for space research and manned flights.

A clear picture of the place occupied by Latin America's past, present and future industrial development according to this scheme will make it easier to interpret the figures for industrial employment and assess the intensity with which the factory sector absorbs the increase in the labour force. It will also make it easier to give an opinion regarding the demand for, and the use of, skilled manpower at different industrial levels in the various countries of the region.

In broad terms Latin America might be said to have accomplished the first stage of industrial development during the first two decades of the present century and to have been in the middle of the second stage by 1925. About 1940 it entered the third stage, which predominates at present. From 1955 onwards, however, the fourth stage of industrial development was initiated—although in a very piecemeal fashion—mainly with the development of higher grade steel products, the creation of motor vehicle industries, the start of production of some complex machinery and certain branches of the electrical industry, the erection of petrochemical plants, and the emergence of special pharmaceutical products.

The process varies from country to country. While most of the smaller countries are still at a fairly backward stage, some remaining at the second stage of industrial development, the three with the biggest populations are well advanced towards the completion of the third stage or are making a significant advance into the fourth stage. Some medium-size countries also are beginning to enter the fourth stage, though very fragmentarily.

The industrial development process in each country is in fact more complicated than the above outline of the basic phases of industrialization. In practice, the various stages tend to overlap, so that before the branches of industry characterizing a given stage are fully developed, with their goods saturating the market, industries characteristic of the succeeding stage are already making their appearance. This overlapping (which would be considered perfectly normal in any part of the world) has taken on special characteristics in Latin America, particularly in the last few years, which have witnessed the accentuation of huge disparities between the income distribution of the various socio-economic groups, and between the levels of economic development in metropolitan areas and in the remote rural areas of nearly every country.

The excessive concentration of purchasing power in the high-income sectors of the community, who reside in the principal cities, has given rise in some urban areas to the establishment of luxury-goods industries to supply the growing and increasingly varied consumer and investment needs. By contrast, since the purchasing power of the broad masses has remained at a low level, the traditional industries in the Latin American countries are developing more slowly than they would in other circumstances, and their production capacity is often underutilized.

Another distinguishing feature is the virtual stagnation of industrial activities in the more remote areas. Thus, geographically speaking, the major part of the region is still in the first stage of industrialization, although the development of industries manufacturing simple consumer goods for the population of those areas would be a very important source of employment and income.

In the light of this structural analysis, it is easy to see why the manufacturing sector absorbed manpower on a relatively intensive scale during the years 1925—1950, while from 1950 onwards manufacturing industry, including factor industry, has played a far less important role as a source of employment.

The period of transition between the first and the second stages of industrial development is characterized by the rapid replacement of cottage industry by factory industry, which means the accelerated growth of factory employment in the development of the types of industries which are typically labour-intensive. This process was in full swing by 1925. In 1950, although the third phase of industrialization had begun several years earlier in the immediate post-war years, the expansion of industries corresponding to the second stage of industrialization was still going ahead rapidly in most countries, to the point at which during recent years the markets of Argentina, Brazil, Chile and Uruguay have become practically saturated with traditional consumer goods. This has given rise to idle capacity without any practical possibility of starting large-scale exportation of these goods.

The transition period between the second and third phases implies a far slower rate of manpower absorption, since many of the basic industries characteristic of the third phase are highly capital-intensive and have a low labour intensity. Although other industries typical of this phase—such as metal products and chemical preparations—are more labour-intensive their development is limited by the shortage of skilled manpower and the restricted purchasing power of the bulk of the consumers. The latter factor curbs the rate of growth of industries in the second stage, which are nearly all highly labour intensive. This was the position during the last few years in all the Latin American countries (except the smaller ones) that had completed the second stage of industrial development.

In Argentina, Brazil and Mexico—which have already entered the fourth stage of industrialization this process, though promising from the standpoint of the future expansion of the labour market, is as yet relatively unimportant compared with the main industrial development process, which is still dominated by the growth of industries characteristic of the third phase. However, in both Brazil and Mexico—which contain half the population of Latin America—the extremely low income level of most of the population does not yet allow industries in the second stage to expand freely. The same might be said about the remote areas farthest from the principal cities in nearly all the Latin American countries, whose inhabitants have very little opportunity to become full-scale users of the fruits of the industrial progress of their own countries.

The above-mentioned problems might be regarded as main indicators for the purpose of evaluating industrial employment changes and trends, with special reference to skilled manpower problems. Shortage of skilled manpower considerably influences the rate of transition from the lower to the higher industrialization levels. This transition process has indeed, despite major efforts and a substantial capital contribution, proceeded relatively slowly and painfully. The Latin American nations are paying dearly for their industrialization through chronic neglect of agriculture, creeping inflation, high and unstable prices, and the relatively poor quality of their industrial goods, which are highly protected against external competition. Undoubtedly among the main reasons for these typical infant-industry ailments are the adverse economies of scale caused by the smallness of national markets, and the skill shortages at all levels of the industrial structure.

The level of industrialization achieved in Latin America during the period under discussion, despite the acute shortage of skilled manpower, is indeed unexpected. Various factors have contributed to this phenomenon. A very important role has undoubtedly been played by the surprising adaptability of the workers, technicians and managers to the new tasks, and their capacity to absorb new production techniques or to improvise industrial processes. It should not be forgotten, however, that up to the completion of the second stage of industrialization and well into the third stage, the industries undergoing major development were those utilizing relatively simple production methods and not requiring a large proportion of highly skilled manpower. When national skilled personnel was in short supply, immigrants from outside the region could fill the gaps, and the contracting of small numbers of highly skilled foreign specialists did not give rise to any difficulty or create financial problems.

As more headway is made in the third stage of industrialization, and especially with the entry into the fourth stage, the persistent shortage of skills begins to be a major obstacle in the way of industrialization. In a few cases the lack of specialists has already created bottlenecks, postponing the development of prepared and well-financed industrial projects. This situation has induced most of the countries of Latin America—although unfortunately only during the last four years—to start programming human resources development policies, mainly for general economic development, but with special attention to the requirements of industrialization. A little earlier, and almost simultaneously in various countries of the region, action had been initiated to establish large-scale training schemes for the preparation of skilled manpower for industrial development. These schemes, enjoying substantial assistance from various agencies of the United Nations family as well as from other international bodies, have proved highly successful, though the generally low educational level of the working masses seriously hampers their efforts. Moreover, all these schemes are more or less limited to the workers and the intermediate levels of unskilled manpower, therefore tending to leave the high-level professionals outside the scope of their work. Consequently there is still an acute shortage of highly skilled technicians, scientists, administrators and managers, while properly designed plans to solve these shortages are only beginning to be developed and to become operative.

This continuous shortage of skilled industrial personnel at all levels is probably one of the principal reasons for the unsatisfactory manufacturing productivity and low average quality of industrial goods in most of the countries of the region, which hampers their capacity to compete on international markets. With the emergence of new industries in the high-grade category the industrialization process will become more and more difficult, unless it can reckon with a much larger number of highly trained professionals. In the near future this problem may represent one of the main bottlenecks in the rapid and well balanced process of industrialization.

The above analysis needs to be complemented by a general statement on the degree of modernity and consequent productivity of manufacturing establishments in the region. These may roughly be divided into three quite different types, corresponding to the modern, the underdeveloped or intermediate, and the altogether primitive type of activities.[3] The last of these three may correspond only to handicrafts and homecrafts, thus leaving factory industry clearly divided into two main levels. These are determined by technologies and type of organization, usually but not always closely related to the scale of industrial operations. The striking discrepancy between the productivity of these two industrial sectors is the result of these factors.

With reference to specific branches of industry whose emergence corresponds to the previously outlined basic stages of industrial development, it is a fairly general rule that the new higher-grade industries belong to the "modern" sector as regards their structure, type of equipment and production methods, while the traditional old-established staple industries are more often within the "not-so-modern", or "under-developed" or "intermediate" industry sector. Some industrial establishments producing traditional consumer goods however may become exceedingly "modern" and achieve high rates of productivity—indeed this is fairly common.

This dualistic nature of factory industry, which has been pointed out by some authors as one of the peculiar characteristics of the Japanese economy,[4] is equally characteristic of Latin America and, indeed, of all developing countries, and has fundamental implications for the present and future use of highly skilled manpower throughout the industrial sector. Fundamentally, the employment of highly skilled industrial manpower is, by definition, very intense in the modern high-grade industries. But this is true not only of the strictly modern industrial branches. There is also a great demand for highly skilled personnel in establishments utilizing up-to-date technologies and organized on modern lines, although belonging to the traditional branches of an industry.

Forecasts of the future trends of industrial development, and the possibility of preparing reasonable projections for 1980, will be discussed below in section 3. Total industrial growth in the period 1965—1980 may reach 195 per cent in terms of the gross product (i.e. 7.5 per cent yearly) and 90 per cent in terms of employment (i.e. 4.4 per cent yearly). Thus the industrial product per person employed would increase by 56 per cent, i.e. 3 per cent yearly. While in 1965 the average industrial product per employed person was about US $ 1,860 at 1960 prices in 1980 it would be about US $ 2,900. This modest average productivity increase shows that contemporary Latin American industrial policies will not be in a position to abolish the pluralistic industrial structure, which for many years to come will have to contend—apart from the creation and expansion of modern-type industries—with the development of far more primitively equipped industrial and artisan enterprises. With relatively little capital these enterprises could provide a great number of jobs and at the same time furnish a great quantity of cheap consumer goods to the rapidly growing population, even in the most remote areas of the Latin American countries.

In the light of the over-all figures of industrial development some forecast can be made of the structural and technological characteristics of the Latin American industrialization process in the forthcoming decade. These forecasts are of special interest to the modern industry sector, which is precisely the one in which advanced skills and technologies are of paramount importance. It is a good guess that this development will proceed simultaneously in two main directions. One will be the diversification of the industrial structure through the creation of new manufacturing branches, and the introduction of new production lines in existing industries. The other will be the modernization of the existing industrial system; this will cover the traditional and the so-called modern industries alike, but in many respects will show serious deficiencies.

It is probably safe to assume that by 1980 Latin America as a whole will have practically completed its third industrialization stage and be well on into the fourth stage, pushing ahead energetically with steel making, metal transforming, the mechanical and electrical industries, the petroleum industry and a broad range of industrial, intermediate and consumer chemicals. A fair beginning in electronics is also to be expected, if optimism prevails over scepticism. The probabilities are that there will be general industrial pro-

[3] For more details see: Z. SLAWINSKI, *The Modern, the Underdeveloped, and the Primitive Sectors in the Latin American Economies in the Last Years and Their Role in Providing Employment to Available Manpower*, Conference room paper presented to the Seminar on Community Development, Santiago, Mar. 1964.

[4] See, for instance, SABURO OKITO, *Causes and Problems of Rapid Growth in Post-war Japan and Their Implications for Newly Developing Economies*. Japan Economic Research Center, 1967, Center Paper No. 6, pp. 15—19.

gress of that type not only in the three big countries—Argentina, Brazil and Mexico—but also in the smaller ones, whose prospects for advanced industrial development may improve very substantially through integration arrangements at a regional or sub-regional level.[5] Naturally, some doubts may be raised with regard to the possibilities of the smaller countries of the region, if they remain somewhat isolated, developing very intricate types of industry demanding large-scale operation. These countries should first of all complete their third stage of industrialization before embarking on a more difficult type of industrial pursuit. In any case it would seem a sound guess that Latin America as a whole will tend to achieve a more equalized level of industrialization.

Many key conditions will have to be fulfilled to allow an entirely satisfactory completion of Latin American industrialization programmes. Their completion will signify not only an increase in the gross value of industrial production but also a desirable degree of industrial diversification. A broad product range is an important indicator of increasing industrial maturity. Almost as important are the achievements of: *(i)* a level of quality in industrial production that is close to the high quality standards set by the advanced countries, *(ii)* the power to compete in international markets, and *(iii)* an adequate increase in productivity permitting the reduction of industrial prices simultaneously with the payment of high industrial wages and salaries. These conditions put an additional emphasis on the absolute necessity of securing during the next few years an adequate (that is, a very large) supply of highly skilled manpower, starting with well-trained entrepreneurial, managerial and top technical and scientific industrial research staff, capable of adopting up-to-date technologies whenever economically justifiable and of introducing the most rational type of management and organization throughout the industrial sector.

Before we go into these problems in more detail it is necessary to get a bird's-eye view of the whole problem of the present and future professional and educational structure of the Latin American labour force, in order to establish the proper framework for discussing the role of the advanced technologies and highly trained manpower in industrial development in this region. At the same time it should not be forgotten that the skilled labour supply is the end-result of a flow of continuous changes through time, starting from primary and secondary school preparation, passing through all sorts of more advanced training, and ending with given numbers of persons belonging to various categories of professional training and practical skills, whose distribution would be according to the laws of supply and demand in all sectors of the economic system, and who would have full liberty to change their branch of activity to one inside or outside the manufacturing sector.

[5] A stimulating example of a step in this direction is the sub-regional agreement of the five Andean-Pacific coastal countries Chile, Peru, Ecuador, Colombia and Venezuela (52 million inhabitants in 1965) to establish a common plan for the development of selected large-scale manufactures.

2. PROFESSIONAL AND EDUCATIONAL STRUCTURE OF THE LATIN AMERICAN LABOUR FORCE

In order to provide for the region as a whole a general framework for an analysis of the problem of skilled manpower by main sectors including manufacturing, a broad picture was drawn of the professional-functional and the educational structure of the economically active population.[6]

Although national statistics have provided deficient sources for these estimates because of their recognized limitations, and although the highly aggregative sectoral classification of the figures presented naturally limits their exactitude and usefulness for analytical and planning purposes, they afford nevertheless an illustration of the general situation of the educational level and professional structure of the manufacturing labour force, and a basis for comparison with other sectors.

(a) The professional structure of the labour force

Estimates of the professional structure of the labour force for Latin America in 1965 are given in table 6, and the resulting coefficients in tables 7 and 8.

In general, these figures confirm the qualitative evaluation, on which there seems to be general agreement, as to the relatively low levels of qualifi-

[6] These estimates were prepared by the secretariat of the Economic Commission for Latin America (ECLA), with the co-operation of the Latin American Institute for Economic and Social Planning, for the Conference of Ministers of Education and Ministers responsible for Economic Planning in Latin America and the Caribbean, held at Buenos Aires 20—30 June 1966, and published in the ECLA document *Human Resources Training in the Economic and Social Development of Latin America* (UNESCO/MINEDACAL/9). The original figures were revised in April 1967 to be consistent with the new estimates of the employment structure in Latin America in 1965, as presented in the *Economic Survey of Latin America, 1966*. (The revision was very superficial and it did not change the significance of the figures presented, which were originally calculated from very broad estimates.)

TABLE 6. LATIN AMERICA: ESTIMATED OCCUPATIONAL STRUCTURE OF THE LABOUR FORCE, 1965
(thousands of persons)

Sector of activity	Total	Professional and technical personnel			Administrative and managerial staff	Employees and salesmen	Operatives and artisan workers				Services personnel
		Total	Professional	Technical			Total	Skilled	Semi-skilled	Unskilled	
Total	*76,416*	*2,792*	*604*	*2,188*	*2,319*	*9,319*	*51,514*	*4,330*	*13,033*	*34,151*	*10,472*
Agriculture and fishing	35,221	44	18	26	63	132	34,610	1,730	5,191	27,689	372
Mining and quarrying	753	30	18	12	12	53	634	63	137	434	24
Manufacturing	10,546	194	49	145	309	825	9,102	1,820	4,551	2,731	116
Construction	2,969	90	27	63	57	56	2,735	274	1,367	1,094	31
Basic services	3,991	126	32	94	105	598	3,002	300	1,501	1,201	160
Other services (including unspecified activities)	22,936	2,308	460	1,848	1,773	7,655	1,431	143	286	1,002	9,769

Source: ECONOMIC COMMISSION FOR LATIN AMERICA. *Human Resource Training in the Economic and Social Development of Latin America* (UNESCO/MINEDECAL/9), table 4. Paper presented at the Conference of Ministers of Education and Ministers responsible for Economic Planning, Buenos Aires, 20 – 30 June 1966.

TABLE 7. LATIN AMERICA: ESTIMATED OCCUPATIONAL STRUCTURE OF THE LABOUR FORCE, 1965
(percentage composition by sector of activity)

Sector of activity	Total	Professional and technical personnel			Administrative and managerial staff	Employees and salesmen	Operatives and artisan workers				Services personnel
		Total	Professional	Technical			Total	Skilled	Semi-skilled	Unskilled	
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Agriculture and fishing	46.1	1.6	3.0	1.2	2.7	1.4	67.2	40.0	39.8	81.1	3.6
Mining and quarrying	1.0	1.1	3.0	0.5	0.5	0.6	1.2	1.5	1.1	1.3	0.2
Manufacturing	13.8	6.9	8.1	6.6	13.3	8.9	17.7	42.0	34.9	8.0	1.1
Construction	3.9	3.2	4.5	2.9	2.5	0.6	5.3	6.3	10.5	3.2	0.3
Basic services	5.2	4.5	5.3	4.3	4.5	6.4	5.8	6.9	11.5	3.5	1.5
Other services (including unspecified activities)	30.0	82.7	76.1	84.5	76.5	82.1	2.8	3.3	2.2	2.9	93.3

Source: Human Resource Training in the Economic and Social Development of Latin America, op.cit., table 5.

TABLE 8. LATIN AMERICA: ESTIMATED OCCUPATIONAL STRUCTURE OF THE LABOUR FORCE, 1965
(percentage composition by vocational categories)

Sector of activity	Total	Professional and technical personnel			Administrative and managerial staff	Employees and salesmen	Operatives and artisan workers				Services personnel
		Total	Professional	Technical			Total	Skilled	Semi-skilled	Unskilled	
Total	*100.0*	*3.7*	*0.8*	*2.9*	*3.0*	*12.2*	*67.4*	*5.7*	*17.0*	*44.7*	*13.7*
Agriculture and fishing	100.0	0.1	0.05	0.07	0.2	0.4	98.2	4.9	14.7	78.6	1.1
Mining and quarrying	100.0	4.0	2.4	1.6	1.6	7.0	84.2	8.4	18.2	57.6	3.2
Manufacturing	100.0	1.9	0.5	1.4	2.9	7.8	86.3	17.3	43.1	25.9	1.1
Construction	100.0	3.0	0.9	2.1	1.9	1.9	92.1	9.2	46.0	36.9	1.1
Basic services	100.0	3.2	0.8	2.4	2.6	15.0	75.2	7.5	37.6	30.1	4.0
Other services (including unspecified activities)	100.0	10.1	2.0	8.1	7.7	33.4	6.2	0.6	1.2	4.4	42.6

Source: Human Resource Training in the Economic and Social Development of Latin America, op.cit., table 5.

cation of the labour force in Latin America; they also permit this evaluation to be supplemented by a numerical illustration of the staggering magnitude of the problem.

It is striking that, of the total of about 600,000 persons described as university level "professionals" who represent less than 1 per cent of the over-all labour force, three-quarters are employed in the "other services" sector. Agriculture employs less than 3 per cent of this functional group, although it absorbs 46 per cent of the total labour force, and the professionals engaged in agriculture account for only 0.1 per cent of the agricultural labour force (in absolute figures only 20,000). The ratio is much the same in the extractive industries, whose share in total employment is much smaller. Because of the relatively high technical level of the mining sector in Latin America, the proportion of professionals employed is 2.4 per cent of the total. This is the highest percentage in any of the economic sectors and reflects the fact that the extractive industries employ twenty times more professionals per thousand of the sectoral labour force than agriculture. The manufacturing sector is in the middle of the scale, and because of the weight carried by the figures for the artisan sub-sector, where university-level professionals are practically non-existent, the coefficients for manufacturing as a whole are much closer to those for agriculture, since it absorbs slightly over 8 per cent of all professionals, who account for only 0.4 per cent of the total manufacturing labour force. Naturally, in factory industry taken separately, this percentage would increase to about 0.7 per cent of total employment. This last figure is very similar to those of construction (0.9 per cent) and basic services (0.8 per cent). The figure is much higher for "other services" (2.0 per cent), which includes professionals such as architects, physicians, lawyers, secondary school teachers and public service university graduate staff, as well as other groups.

Of the 2.2 million included under the heading of intermediate level professionals—who, for the sake of simplicity, will be described here as "technicians"—at least one third are primary school teachers, and another third or so are book-keepers and accounting assistants. Hence the ratio between professionals and technicians, which is particularly significant for the purpose of evaluating the effectiveness of education and training at the higher and intermediate levels, appears highly distorted if one looks only at the over-all figures. However, if the two above-named groups are excluded, and a stricter definition of "technicians" is adopted, it seems likely that the figure for the group in the manufacturing sector would not be much higher than that for the university level professionals group. It might perhaps even be less in some sectors, notably in agriculture.

These estimates reveal another interesting situation regarding the levels of skill of those included in the broad category of "operatives and artisan workers", which represents about 70 per cent of the total labour force. Of the 52 million workers in this group, 34 million have no skill of any kind, while 13 million are regarded as semi-skilled, and only 4.3 million (less than 10 per cent) as artisans and skilled operatives. Once again the lowest proportion of skilled members of the labour force is in agriculture (5 per cent), but the proportions are not much higher in the other sectors (under 10 per cent in the extractive industries, construction and basic services, and under 20 per cent in manufacturing).

(b) *The educational profile of the labour force*

Despite the marked shortcomings of the above analysis of the professional-functional structure, these estimates seem to show that about 7 per cent of the labour force consists of persons carrying out administrative and professional or technical functions; this seems to indicate a relatively satisfactory professional structure, at least in this respect. However, this conclusion is subject to reservations as to the real level of training of these groups, especially of the administrative and managerial staff; which means that more information is needed as to the educational profile of the labour force in relation to the main professional-functional categories.

On this point the lack of organized data on actual conditions in Latin America is very striking, for these data ought to constitute the main basis for effective educational planning. In view of this lack of basic data, it is once again useful to turn for illustrative purposes to a quantitative picture that furnishes at least some orders of magnitude that appear reasonable in the light of the incomplete and scanty statistics available. For this purpose, table 9 gives the results obtained on the basis of a hypothesis as to the educational profile of the labour force in 1965, and in tables 10 and 11 these figures are translated into the percentage composition by professional categories and levels of training.

An approximate indication of the probable degree of validity of this hypothesis can be obtained by a comparison with estimates worked out independently, relating to the distribution by level of education of the total population aged 15 and over, both active and inactive. These estimates, based on the 1950 censuses for 16 countries of the region and on the 1960 census for six countries,[7] give the number of grades of schooling certified. In brief, these calculations show that persons with over 12 years of schooling represented only 0.9 per cent of the total in 1950, and 1.6 per cent in 1960 (although these figures are not strictly comparable, since they do not refer to all the same countries); those with 7 to 12 years of schooling certified constituted 6 per cent of the total in 1950 and 9.3 per cent in 1960 (in this year a further subdivision was made, showing that those with 7 to 9 years of schooling represented 5.9 per cent of the total and those with 10 to 12 years represented 3.4 per

[7] The 16 countries are Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, the Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Mexico, Nicaragua, Panama and Paraguay; and the six countries are Chile, Ecuador, Honduras, Mexico, Nicaragua and Panama.

TABLE 9. LATIN AMERICA: A HYPOTHESIS ON THE EDUCATIONAL PROFILE OF THE LABOUR FORCE, 1965
(thousands of persons)

	Total	*Professional and technical personnel*	*Administrative and managerial staff*	*Employees and salesmen*	*Operatives and artisan workers*	*Services personnel*
Total	*76,416*	*2,787*	*2,312*	*8,543*	*53,484*	*9,290*
University training (complete and incomplete)	1,060	660	230	170	—	—
Secondary education	8,730	1,500	1,050	3,010	2,700	470
General secondary	*6,240*	*640*	*930*	*2,580*	*1,620*	*470*
Complete	1,490	280	350	860	—	—
Incomplete	4,750	360	580	1,720	1,620	470
Technical	*1,770*	*140*	*120*	*430*	*1,080*	—
Teacher training	*720*	*720*	—	—	—	—
Primary education	66,626	627	1,032	5,363	50,784	8,820
More than three years	29,492	367	576	2,979	21,389	4,181
Less than three years or none	37,134	260	456	2,384	29,395	4,639

Source: Human Resource Training in the Economic and Social Development of Latin America, op.cit., table 7.

TABLE 10. LATIN AMERICA: A HYPOTHESIS ON THE EDUCATIONAL PROFILE OF THE LABOUR FORCE, 1965
(percentage composition by vocational categories)

	Total	*Professional and technical personnel*	*Administrative and managerial staff*	*Employees and salesmen*	*Operatives and artisan workers*	*Services personnel*
Total	*100.0*	*3.6*	*3.0*	*11.2*	*70.0*	*12.2*
University training (complete and incomplete)	100.0	62.3	21.7	16.0	—	—
Secondary education	100.0	17.2	12.0	34.5	30.9	5.4
General secondary	100.0	10.3	14.9	41.3	26.0	7.5
Complete	100.0	18.8	23.5	57.7	—	—
Incomplete	100.0	7.6	12.2	36.2	34.1	9.9
Technical	100.0	7.9	6.8	24.3	61.0	—
Teacher training	100.0	100.0	—	—	—	—
Primary education	100.0	0.9	1.6	8.1	76.2	13.2
More than three years	100.0	1.2	2.0	10.1	72.5	14.2
Less than three years or none	100.0	0.7	1.2	6.4	79.2	12.5

Source: Human Resource Training in the Economic and Social Development of Latin America, op.cit., table 8.

TABLE 11. LATIN AMERICA: HYPOTHESIS ON THE EDUCATIONAL PROFILE OF THE LABOUR FORCE, 1965
(percentage composition by level of education)

	Total	*Professional and technical personnel*	*Administrative and managerial staff*	*Employees and salesmen*	*Operatives and artisan workers*	*Services personnel*
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
University training (complete and incomplete)	1.4	23.7	10.0	2.0	—	—
Secondary education	11.4	53.8	45.4	35.2	5.0	5.1
General secondary	*8.2*	*23.0*	*40.2*	*30.2*	*3.0*	*5.1*
Complete	2.0	10.1	15.1	10.1	—	—
Incomplete	6.2	12.9	25.1	20.1	3.0	5.1
Technical	2.3	5.0	5.2	5.0	2.0	—
Teacher training	0.9	25.8	—	—	—	—
Primary education	87.2	22.5	44.6	62.8	95.0	94.9
More than three years	38.6	13.2	24.9	34.9	40.0	45.0
Less than three years or none	48.6	9.3	19.7	27.9	55.0	49.9

Source: Human Resource Training in the Economic and Social Development of Latin America, op.cit., table 9.

cent); those with between 1 and 6 years of schooling represented 43.8 per cent of the total in 1950 and 52.5 per cent in 1960 (the subdivision in 1960 into those with 1 to 3 years and those with 4 to 6 years showed the two groups to be practically equal); lastly, those who had less than a year of certified schooling represented 49.3 per cent of the total in 1950 and 36.6 per cent in 1960.

In short, the hypothesis presented is to some extent confirmed by these other estimates, which (incidentally) once again show the large element of guess-work in the quantitative data available, and the urgent need to provide an organized flow of data of this type.

Even with such provisos, this hypothesis indicates a series of conclusions that underline the defects in the vocational structure of the labour force from the standpoint of the effective training that has been received by the members of the various categories. A striking example is the paradox of the high proportion of managers and administrators (about 15 per cent of the total) who have had no formal professional training, and the even higher proportion (about 45 per cent) who have not completed their secondary education. Of the group performing strictly professional functions it appears that about 23 per cent have had nothing more than a primary education, and nearly 10 per cent no more than three years of formal schooling.

However far-fetched these findings appear, they unquestionably point to the need for a critical analysis of the professional structure that appears to exist in Latin America, to judge from the piecemeal data available, and also for a standardization of concepts and definitions that would permit more accurate assessment. The existing situation undoubtedly includes the results of all types of efforts to overcome the inadequacy of the formal education systems, by means of experience gained on-the-job, complemented by all sorts of extramural and informal systems of training. In other words, the educational profile of the labour force from the standpoint of actual skills is not as unsatisfactory as the school-completion figures appear to indicate; the figures cn the professional structure revealed by the occupational statistics no more accurately reflect the real situation.

It is useful to supplement this general impression of the educational profile by main professional categories by a more detailed study of the situation as it appears in terms of skilled staff with a complete or partial university training, and of skilled staff with an intermediate professional training. In 1965 these two categories together comprised about 2.5 million, slightly over 3 per cent of the total labour force—a percentage that would be only 2.3 if primary school teachers were excluded.

Additional calculations based on piecemeal data for Argentina, Chile, Colombia, Uruguay and the Central American countries indicate that, out of the slightly over one million estimated as the number of professionals at the university level available in 1965, about 700,000 had received some type of degree, whereas the remaining third either did not graduate or took only short university courses. Of the graduates it is likely that 180,000, which is about a quarter, were scientists and engineers; a slightly lower proportion, about 170,000, belonged to the medical and allied professions; about 90,000 were social science professionals; about 120,000 were lawyers; 130,000 had taken courses in the humanities or teacher training; and 20,000 had taken fine arts and other miscellaneous courses. This structure is being modified by recent trends. In conjunction with a substantial rise in the number of university graduates between 1957 and 1964 there has been a proportionally much slower increase in the number of professionals in law. There was an accelerated increase in the number of graduations in industrial engineering, in agronomy and related subjects, in architecture, natural sciences, social sciences and education, while the percentages to total graduates of those graduating from the faculties of civil engineering and medicine have remained about the same.

The consideration of these trends and the analysis of the available stock of professionals are unquestionably essential for educational planning, and at the same time they are very useful in evaluating the direction of the changes that certain significant ratios indicate as necessary. For example, the present total supply of engineers and scientists represents a ratio of only 750 university professionals per million of the population (0.75 per mil), whereas in some countries the same proportion applies to the number graduating every year, and in the United States and the Soviet Union the annual graduation figure represents twice this number per million of the population.

Furthermore, of the 180,000 included in the group of university engineers and scientists, it is likely that engineers proper amount to only some 90,000, of which perhaps half are engaged in the construction sector. This latter group, together with the architects (slightly over 20,000) add up to a number which gives a better ratio of university professionals with technical training to other workers in this sector than in manufacturing, not to mention agriculture. Out of 40,000 to 50,000 engineers with an industrial type of training a large proportion are employed in mining, basic services, trade, public administration and teaching; this leaves an absolutely inadequate number of persons (perhaps 20,000) available for work in manufacturing enterprises.

In agriculture the situation is even more adverse. The total of about 24,000 agricultural engineers available in 1965 gives a ratio of 0.7 professionals at this level for every thousand employed in the sector, offering the possibility of employing only 1 agricultural engineer for every 4,000 hectares under cultivation or every 19,000 hectares generally used for agriculture; and this does not take into account that a high proportion, probably the big majority, of agricultural engineers do not in fact work on the land.

The 40,000–50,000 estimated professionals with training in the natural sciences give a ratio of 0.19 per thousand of the population. An appreciable proportion of these are employed in the teaching of science in secondary schools and universities.

The structure of the group of professionals at the intermediate level is harder to estimate than that of professionals with university training. Probably about 20 per cent (about 600,000) are technicians in agricultural, industrial, construction and other specific production processes, energy supply, transportation and communication. Not more than 1 to 2 per cent (some 30,000 persons) are paramedical technicians and graduate nurses; over 40 per cent (about 900,000 persons) are commercial technicians and office workers; 35 per cent (700,000 persons) are teachers graduated from teacher-training schools; and 20,000 are technicians in various other specialties. Needless to say, this classification depends on how strictly the level of training is defined; the above figures would be considerably higher if they included persons with a lower standard of professional training, or practitioners attending courses at specific professional schools but who, in actual fact, were below the intermediate level.

Without losing sight of these provisos it is interesting to examine the ratios deduced from the above comparisons between professionals at the university and the intermediate levels. They are particularly significant in the technological and scientific professions, although from information available the figures appear to fluctuate widely according to what criteria are adopted in defining the intermediate level and the method of estimating the number of professionals in that category. For example, on the basis of alternative definitions—a very broad one that would include incomplete training, and a narrow one restricted to technicians with advanced secondary training—the ratios between engineers and scientists on the one hand, and technicians with intermediate training on the other, would be 1:2 in the first case and 3.5:1 in the second. In science alone, where the number of laboratory personnel graduating from technical school is small, the ratios range from 5:1 to 10:1.

However wide those margins may be it seems reasonable to conclude from the above ratios that there is an even more acute shortage of intermediate technical personnel than of professionals with university training. Besides the direct effects of this situation upon the rational profile of the labour force, the inevitable result is the wrong utilization of highly trained personnel (although they are in such short supply) through the underutilization of their professional capacity, since they are required to perform functions that could be taken care of by more junior technicians. The same observation is applicable to the medical and allied professions.

There are, of course, a great many more technicians—both in absolute terms and in proportion to the number of professionals with university training—in the administrative, economic and social science fields who, at these intermediate levels, can employ various types of economic techniques applicable to trade, office work, accounting and financial services. This is partly due to the extensive system of business schools and specialized courses. It is estimated that by 1965 business schools and vocational training courses at the appropriate level in Latin America had helped to train about 1.5 million accountants, secretaries and typists, librarians, and registry clerks. Probably not more than 60 per cent of this number continue to form part of the economically active population, because of the premature withdrawal of a high proportion of female workers. Thus the ratio between university-trained professionals and intermediate-level technicians probably ranges from 1:5 to 1:10, according to the stringency of the criteria for classifying the latter.

(c) *Present supply of formal educational and extra-mural training systems*[8]

The hypothetical characteristics of the educational background of the economically active population as outlined above are the results of the lines along which the educational system has evolved through the years. One of the purposes in formulating these estimates is to anticipate the requirements in terms of skilled personnel that are likely to arise in the course of the 15 years beginning with 1965. It would be useful to supplement them by the systematization of some background

[8] This sub-section may be considered as an appendix to section 2.

data concerning the present capacity of the system, in an endeavour to demonstrate the scale on which it would have to be expanded in respect of the various sectors and levels. For that purpose the two basic educational and training systems should be considered separately: the formal school system and the extramural training services. Some illustrative data is given below.

The formal school system

Primary education in Latin America has shown a marked rate of increase in recent years. An estimated total of about 2 million persons passed out of Latin American primary schools in 1965. As a result of a relatively rapid increase in school enrolment (about 5 per cent per year) and of an appreciable rise in the primary system retention rate (although this is still very low for the region as a whole) there has been a cumulative annual increase (about 8 per cent) in the last few years of persons finishing their primary education. None the less, as against 2 million persons who completed their primary education the total enrolment in all primary education courses numbers some 33 million.

Secondary education includes general secondary education, professional training (technical), and teacher-training. The lack of reliable information on the number of persons who complete their education is fresh evidence of the considerable delay in systematizing a regular flow of statistics in respect of these questions.

It is a rough estimate that in 1965 nearly 370,000 persons completed their education in general secondary schools in Latin America as a whole and that a total of some 3.3 million were enrolled in the various secondary grades. About 50 per cent of the school-finishers will probably enter university (though a large proportion will leave university before completing their studies), while the other 50 per cent will be incorporated in the labour force or will join the economically inactive population not covered by the school system. From another standpoint it should be noted that the number of persons completing general secondary education doubled between 1957 and 1965, a fact which represents a considerable annual rate of growth.

Total enrolment in professional training schools is probably in the neighbourhood of 1.3 million persons, and the number graduating annually is about 140,000. Approximately 100,000 of these have attended business courses, some 36,000 have received training in engineering and industrial techniques, and barely 4,000 have studied agricultural techniques.

As regards teacher-training schools it is estimated that a total of 560,000 persons were enrolled and about 50,000 completed the course in 1965. Like schools in other sectors of secondary education, these schools nearly doubled their enrolment figures from 1957 to 1965; but even so, about 40 per cent of the teachers have no degree.

To sum up: in 1965 approximately 560,000 persons annually passed out from the secondary school system; two-thirds from general secondary schools, one-fourth from professional (technical) training establishments, and slightly less than 10 per cent from teacher-training schools.

University education is also being enjoyed by an increasing number of students. An estimated 71,000 persons graduated from Latin American universities in 1965, the rate of increase in the last few years being very high, from 8 to 9 per cent annually.

About 15,000 were trained in education and the humanities: nearly 3,000 in the fine arts and architecture; some 9,500 studied law, and a like number other social sciences; slightly under 4,000, natural sciences; about 8,000, engineering; over 20,000, medicine and related fields; and slightly more than 2,000, agricultural subjects.

These and other background data on the formal school system are well known. These general figures are recorded here as a basis for the comments on future expansion needs made in other sections of the present study. Meanwhile it is useful to examine other background information on the extramural training system whose contribution to the training of skilled manpower is not always sufficiently stressed.

Extramural training services

The training of university professionals, intermediate-level technicians (industrial technicians, accountants, agricultural experts etc.), and primary and secondary teachers is obviously the prime responsibility of the formal education system. On the other hand, many institutions outside that system have a part to play in the professional training of urban and rural workers, business employees, government officials, and managerial and executive personnel.

In practice, workers and intermediate-level personnel in the industrialized countries are largely trained empirically by various methods, mostly on-the-job in the enterprise itself. In Latin America many private institutions are also playing an increasingly important part in manpower training at various levels in different economic sectors; these include industrial, business and agricultural enterprises; banks; public services; the armed forces; trade unions; entrepreneurs' associations; cultural associations; productivity centres; certain private schools which, by the nature of the instruction they impart, are outside the formal educational system; and specialized professional training institutions.

The last named have developed in Latin America only since the Second World War. They run on up-to-date lines and have spread quickly in countries whose relatively rapid industrial development necessitated recourse to new means of training skilled industrial manpower. While industrial training was the prime motive in the development of consistent extramural training systems, once it had taken root it tended to cover the skilled manpower needs of other sectors. The original radius of action was fairly limited, but later extended both vertically—to include not only skilled and semi-skilled workers but also supervisory personnel, foremen and production specialists—and horizontally—to embrace a wider range of technical skills in industry and other fields.

These specialized institutions, some of which are well known by their abbreviations or initials, include the following: SENAI and SENAC (Brazil), SENA (Colombia), SENATI (Peru), INCE (Venezuela), and INACAP (Chile). Other organizations with similar functions are CONET (Argentina), and the Universidad del Trabajo de Uruguay. Some of the more recently established institutions are Rapid Manpower Training (Adiestramiento Rápido de la Mano de Obra—ARMO) in Mexico, the National Apprenticeship Institute (Instituto Nacional de Aprendizaje—INA) in Costa Rica, and the Ecuadorian Vocational Training Service (Servicio Ecuatoriano de Capacitación Profesional—SECAP).

It is important to note that the institutionalization of extramural professional training at a level higher than for operatives is at a less advanced stage of development. To some degree this function is performed by national productivity centres through the organization of seminars and courses for the managerial staff of enterprises and other administrative levels.

Varying contributions to these activities are made by the State, entrepreneurs and trade unions. For example, the specialized institutions in Argentina, Chile, Mexico, and Uruguay are controlled mainly by the State; those in Brazil and Peru, by entrepreneurs' associations; while a balance is struck between the two in Colombia and Venezuela. The trade unions form part of the governing council of SENA (Colombia) and have a representative on the council of SENATI (Peru). The national productivity centres are mainly under the jurisdiction of the State in Argentina and Chile, and of entrepreneurs' associations in most of the other Latin American countries. In any case they are institutions which generally enjoy considerable administrative autonomy and operate very flexibly in regard to programmes and types of training. In short, extramural training is the result of action by a wide range of institutions of different origin and with differing aims as well as widely varying types of training.

Unfortunately there are no comparable data available to measure the scale of extramural training in quantitative terms. At a conservative estimate, about 250,000 workers could be trained under present conditions through crash programmes or relatively long courses at the specialized institutions alone. In all probability several times that number receive some type of training in the enterprises and services in which they are employed, though the procedures and methods may vary widely.

At any rate these figures are large enough in absolute terms to make it quite clear that extramural training makes a significant contribution to Latin America's development needs in terms of human resources training. Thus it seems unwise for the link between extramural training services and the formal education system to be so tenuous, or for the former to continue to be excluded from the formulation of educational policy and plans. On the other hand there is still the big, unsolved problem of setting up a well-organized and sufficiently comprehensive system of training and retraining through extramural methods—thus complementing the on-the-job training—for the highly skilled technical and managerial personnel that is required not only to develop industry but, more than that, to put it into proper shape.

3. PROSPECTIVE DEVELOPMENT OF THE PROFESSIONAL AND EDUCATIONAL STRUCTURE OF THE LATIN AMERICAN LABOUR FORCE UP TO 1980, AND ITS FINANCIAL IMPLICATIONS[9]

(a) *Projection assumptions*

Projections of the professional and educational structure of the labour force have to be based first upon assumptions regarding the rapidity of economic

[9] This section contains extracts from *Human Resources Training in Economic and Social Development of Latin America*, op.cit., and ECLA, *The Financing of Education and Human Resources Training in Latin America*, (ECLA/Ed.Inv./6g), presented by ECLA to the Regional Technical Assistance Seminar on Investment in Education in Latin America, Santiago, Chile, 5–13 Dec. 1966.

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growth, and second upon the predictable demographic changes influencing the size and the age structure of the future labour force and prospective school population. It is difficult to forecast the likely evolution of socio-economic factors shaping the specific patterns of economic development; the figures presented below should, therefore, be accepted with due reservations. However, the hypotheses set forth emphasize the magnitude of the problems involved, and may serve as a basis for specific policies on the education and training of human resources to meet the needs of developing economies. It need hardly be stressed that the general conclusions derived from the hypotheses presented, though fairly illustrative for Latin America as a whole, may be less valid when applied to certain individual countries.

A study of the likely demographic evolution leads to the conclusion that the population of the Latin American countries will be about 364 million in 1980. Given the changes in the age structure and other factors influencing the rate of participation of the population of active age in the labour force, which may increase slightly, in 1980 it would be about 120 million persons. This would represent an increment of about 44 million over the estimated figure for 1965, i.e. an average absorption of 2.9 million persons annually over the 15 year period 1965–1980. Out of this total job-creation need, manufacturing industry (meaning principally factory industry) would have to absorb an average of 630,000 persons, i.e. slightly over one fifth of the total.

The aggregate gross product for 1980 is calculated on the basis of the hypothesis that over these 15 years average productivity per employed person will increase at an annual rate of 2.5 per cent. Since the average gross product per employed person in Latin America as a whole in 1965 was about US$1,150 at 1960 prices, it may be assumed that the product per employed person will reach US$1,700 by 1980. This figure, taken together with the projected total employment figure of 120 million persons, would result in an aggregate domestic product for Latin America of approximately US $200,000 millions, or more than double the absolute figure recorded in 1965 (a little over US$88,000 millions).

The hypothetical growth of the main economic sectors, consistent with the assumed intensity of economic development, may then be estimated. Even on the basis of a *per capita* increase in the product of less than 3 per cent annually the over-all increment over the 15 years considered would be fairly substantial, and in any case large enough to lead one to expect significant changes in its composition by sector. These changes, of course, are dependent not only on growth in quantitative terms, but also on certain essential development policy factors, as well as some other less predictable elements. The general criteria adopted in the development hypothesis should, without going into too much detail, at least include some additional assumptions which, to a greater or lesser degree, would take for granted the influence upon economic development of widespread agrarian reform, of more progressive income distribution, and of closer economic links among the countries of the region. In those circumstances it would be difficult to envisage an agricultural production growth rate *per capita* of less than an annual average of 1.5 per cent; an increase in manufacturing industry equivalent to at least an elasticity of 1.3 with respect to the growth of the total product; and a comparable growth of basic services, probably somewhat slower for transport and relatively faster for the supply of electrical energy and other supplementary services. These and other similar criteria are conducive, in the last analysis, to hypothetical projections of the level and structure of the product, as set out in table 12. These hypothetical projections extend to an estimate of the employment structure that would be consistent with the foreseeable growth of the economically active popul-

TABLE 12. LATIN AMERICA: HYPOTHETICAL PROJECTION OF THE PRODUCT AND EMPLOYMENT, 1980

Sector	*Gross product (millions of US dollars at 1960 prices)*		*Sectoral composition of the product (percentage)*		*Employment (thousands of persons)*		*Employment structure (percentage)*	
	1965	*1980*	*1965*	*1980*	*1965*	*1980*	*1965*	*1980*
Total	*88,056*	*200,000*	*100.0*	*100.0*	*76,416*	*120,000*	*100.0*	*100.0*
Agriculture and fishing	18,917	36,000	21.5	18.0	35,221	49,300	46.1	41.1
Mining and quarrying	4,408	9,000	5.0	4.5	753	1,000	1.0	0.8
Manufacturing	19,620	58,000	22.3	29.0	10,546	20,000	13.8	16.7
Construction	2,661	7,000	3.0	3.5	2,969	7,200	3.9	6.0
Basic services	7,242	21,000	8.2	10.5	3,991	8,500	5.2	7.1
Other services (including unspecified activities)	35,208	69,000	40.0	34.5	22,936	34,000	30.0	28.3

Source: Human Resource Training in the Economic and Social Development of Latin America, op.cit., table 13.

ation and certain assumptions regarding productivity changes in each economic sector.

In all probability rapid growth may be expected, especially in manufacturing industry. Its product would almost treble in the next 15 years, at an average annual rate of nearly 7.5 per cent. This would at the same time involve the development of new, highly productive and technically complex activities, the modernization of traditional branches of industry, and the relative transfer of resources on an increasing scale from artisan and small industry to medium and large-scale manufacturing industry proper. The gradual incorporation of entirely new technologies, drawn from the broadening pool of universal technical knowledge, would also greatly contribute to industrial progress. As a result, the average productivity of the population employed in the whole manufacturing sector could be assumed to increase at least 4 per cent annually; a rate which would imply that a greater increment in this sector's share of total employment is hardly to be expected.

(b) *Human resources needed and professional structure in 1980*

From the foregoing considerations it can be concluded that the changes to be expected in the professional structure of the employed population definitely stem from two types of factors: firstly, the actual development process involves variations in the relative shares of the different economic sectors, in each of which employment displays a distinctive professional structure; and secondly, modernization and increased productivity give rise in each sector to greater needs in terms of professional skill.

The former effect might be illustrated by the hypothetical situations described as representative of Latin America as a whole, the occupational structures that were estimated for each sector in 1965 being applied to the sectoral employment figures projected for 1980. It will thus be noted that, even if the level of professional skill for each sector remained the same, there would be a change in the occupational structure of the labour force as a whole, owing to the differing scale on which the various sectors would necessarily expand, the sectors with the fastest growth rates generally being those requiring the highest levels of professional skill. Added to this are the results of the absorption of technical progress in each sector on a larger scale and at varying speeds, according to the expected or proposed rate of increase in productivity.

The combination of these two effects could determine sharp variations over a relatively long period, as can be inferred from table 13, which presents the results of a hypothetical projection of the occupational structure of the employed population in 1980 for the whole of Latin America. These figures take into account the projections for the product and employment referred to in the preceding section and some additional hypotheses regarding the repercussions of the assumed productivity increment for each sector in terms of the professional skills it requires.

If these projections are compared with the estimates set forth above in regard to the situation prevailing in 1965, the magnitude and composition of the expected changes can be appreciated in detail. The most significant changes relate in general to the considerable increase that would take place in the total number of university professionals, the even greater increase in the number of intermediate-level technicians, and the higher levels of skill in the category of operatives and artisan workers.

On a more restricted basis, if consideration is given only to the professionals with university training, the projections concerned would imply the

TABLE 13. LATIN AMERICA: HYPOTHETICAL PROJECTION OF THE OCCUPATIONAL STRUCTURE OF THE LABOUR FORCE UP TO 1980
(thousands of persons)

	Total	*Professional and technical personnel*			*Administrative and managerial personnel*	*Employees and salesmen*	*Operatives and artisan workers*				*Services personnel*
		Total	*Professional*	*Technical*			*Total*	*Skilled*	*Semi-skilled*	*Unskilled*	
Total	*120,000*	*6,310*	*1,190*	*5,120*	*3,705*	*14,820*	*80,485*	*12,800*	*31,660*	*36,025*	*14,680*
Agriculture and fishing	49,300	200	50	150	150	200	48,250	4,900	14,800	28,550	500
Mining and quarrying	1,000	60	30	30	15	70	825	120	350	355	30
Manufacturing	20,000	600	140	460	500	2,000	16,600	5,900	9,000	1,700	300
Construction	7,200	200	50	150	110	140	6,670	860	3,600	2,210	80
Basic services	8,500	320	70	250	210	1,530	6,100	680	3,400	2,020	340
Other services (including unspecified activities)	34,000	4,930	850	4,080	2,720	10,880	2,040	340	510	1,190	13,430

Source: Human Resource Training in the Economic and Social Development of Latin America, op.cit., table 14.

need for an increment of over 130 per cent in their total number between 1965 and 1980. Since the population will have increased by only 55 per cent during that interval, this would mean an improvement in the ratio of university graduates in the professional category to the total population, since the coefficient would rise from the present figure of 3.0 per mil to 4.5 per mil in 1980.

Besides this over-all increase, the category concerned will no doubt also undergo a change in internal structure according to the principal "professions" and "professional specialities". Some additional hypotheses would lead to consideration, for example, of the need to increase substantially the proportion of graduates in the natural sciences and engineering and, on a lesser scale, in economics and the social sciences; to maintain the proportion of graduates trained in the humanities, pedagogy, the fine arts and the medical sciences at approximately the same level; and to reduce the proportion of graduates in law.

The illustrative character of these considerations would not warrant extending the scope of the projections in order to relate them to more specific professions, even though such a course would help to clarify the basis of the over-all assessments by demonstrating their close relationship with the structural changes and improvements in the sectoral productivity alluded to above. At the same time, a more detailed analysis of the problem would provide criteria for estimating the changes that should be made in the ratio of professionals at the higher level to professionals at the intermediate level (the latter are included in the general category of technicians, although this designation is not entirely accurate).

(c) *Improvement and changes in the educational profile of the labour force in 1980*

Necessarily supplemented by that more detailed type of analysis (a description of which is omitted in order to avoid too lengthy a presentation of these hypotheses) the projections of professional structure serve as a basis for sounder projections of the educational profile of the economically active population which would be compatible with future development requirements. The problem thus encompasses the more direct concerns of educational planning, inasmuch as it might well become a quantitative framework which would help to determine the magnitude and orientation of the training policy which should be adopted.

This additional step is illustrated by the hypothetical projections of the educational profile of the active population in 1980, as set out in table 14. This involves far more than the mere arithmetical computation of the figures resulting from relating the projections of the future professional structure to present coefficients of "educational inputs" for each professional category.

For this purpose it would seem appropriate to take into account at least two considerations. In the first place, the educational profile that will be necessary in the future is not dependent only upon the changes expected in the professional structure, as deriving from the quantitative expansion of the various categories. It has seemed opportune in earlier sections of this article to emphasize a notable anomaly in the existing situation: the fulfilment of professional functions without proper training. In other words, the "internal" educational profile governing certain professional categories considered separately currently presents marked inadequacies in the scope and nature of the relevant school and vocational training. It is only right to expect, therefore, that this deficiency will be corrected in the future. This entails the need for an improvement in the general educational profile of the active population, regardless of the greater quantitative needs in terms of professionals in the different categories.

A second consideration relates mainly to the inevitably rigid nature of certain factors obstructing attempts to improve the educational profile of the employed population. A considerable proportion—probably about 30 per cent—of the active population in 1980 will in fact consist of persons already integrated in the labour force in 1965, i.e. survivors of the present employed population, whose educational profile is already determined and could be modified in some measure only through extramural training services. Even the educational profile of the new influx into the labour force in the near future will also be largely predetermined by existing educational conditions. Therefore the new human resources training activities undertaken from now on will come to influence the educational profile of only a proportion of the economically active population available in 15 years' time. This shows how important it is for educational planning to be based on forecasts of future requirements over a relatively long period.

These considerations, in their turn, give rise to certain conclusions which deserve to be emphasized. In the first place, they explain why the projections set out in table 14 continue to show a significant proportion of persons with little school training in the categories embracing professional workers, technicians, and administrative and managerial personnel, a fact which apparently conflicts with the aim of bringing the professional skills into

TABLE 14. LATIN AMERICA: HYPOTHETICAL PROJECTION OF THE EDUCATIONAL PROFILE OF THE LABOUR FORCE UP TO 1980
(thousands of persons)

	Total	*Professional and technical personnel*	*Administrative and managerial personnel*	*Employees and salesmen*	*Operatives and artisan workers*	*Services personnel*
Total	*120,000*	*6,310*	*3,705*	*14,820*	*80,485*	*14,680*
University education (complete or incomplete)	*2,432*	*1,554*	*485*	*393*		
Intermediate education	*25,476*	*4,144*	*2,250*	*6,613*	*11,251*	*1,188*
(a) Secondary general	*15,419*	*1,311*	*1,715*	*5,418*	*5,787*	*1,188*
(*i*) Complete	4,486	632	1,135	3,416	1,445	272
(*ii*) Incomplete	10,933	679	580	2,002	4,342	916
(b) Technical	*8,235*	*1,011*	*535*	*1,225*	*5,464*	
(c) Teacher training	*1,822*	*1,822*	—	—		
Primary education	*92,092*	*612*	*970*	*7,784*	*69,234*	*13,492*
(*a*) More than three years	57,517	454	695	5,665	41,830	8,873
(*b*) Less than three years or none at all	34,585	158	275	2,119	27,414	4,619

Source: Human Resource Training in the Economic and Social Development of Latin America, op.cit., table 15.

line with the functions to be carried out in the economic system. Moreover, a comparison between the projections of the desirable or necessary educational profile in 1980 and the present situation fails to reveal the true magnitude of the effort needed in regard to the educational system, since this effort must be measured in relation to the new contingents integrated in the active population, whose level of education should be much higher in order to offset the inadequacy of the survivors of the existing labour force.

(d) *The financing of education and training, and efficiency of the system*

In 1965 the total funds allocated to education and training probably exceeded US$ 3,000 million per annum, including current expenditure on education proper and on welfare services, investment, and other outlays on research and extension work, covering university, secondary and primary education, as well as extramural and informal educational activities. The aggregate sum involved represents a little over 3.5 per cent of Latin America's gross domestic product and is one of the largest proportions earmarked for a specific purpose.

About 90 per cent of the estimated total shown in table 15 corresponds to current expenditure on education and student welfare; within the former the major item is the remuneration of teaching and administrative staff, while the latter probably does not account for more than 5 per cent of total current expenditure. The investment figure given in the same table is a rough calculation based on incomplete data, which in all probability underestimates the real magnitude of the effort that is being made in this connexion.

The same applies to the figure for "other expenditures", whose main components would seem to be the funds allocated, at the university level, to research work and extension services; at the secondary level to extension services, experimental farms etc.; and at the primary level to literacy campaigns and continuing adult education. According to these same estimates, primary schooling

TABLE 15. LATIN AMERICA: ESTIMATE OF RESOURCES ALLOCATED TO EDUCATION, 1965
(millions of dollars at 1960 prices)

	Total	*Current expenditure*	*Investment*	*Other expenditures*
Total	*3,200*	*2,830*	*180*	*90*
University education	650	560	30	60
Secondary education	930	890	30	10
General		510		
Vocational		260		
Training of primary-school teachers		120		
Primary education	1,520	1,380	120	20
Extramural and informal educational activities	100			

Source: ECLA, *The Financing of Education and Human Resources Training in Latin America*, (ECLA/Ed. Inv./6.G), table 1. Paper presented at the Regional Technical Assistance Seminar on Investment in Education in Latin America, Santiago, Chile, 5–13 Dec. 1966.

apparently absorbs a little less than half the total resources allocated to education; approximately 30 per cent goes to the secondary level, at which in turn about 60 per cent is spent on general secondary education, less than 30 per cent on vocational education, and about 14 per cent on the training of primary school teachers. A little over one fifth of total current expenditure and investment outlays is earmarked for university education. The figure given for expenditure on extramural and informal educational activities is intended more as a reminder of the existence of the item than as even a rough estimate, in view of the almost total lack of reliable data in this connexion.

With due allowance for the largely hypothetical nature of the figures in question, it is enlightening to relate the estimates of current expenditure to enrolment numbers at the levels concerned. The results of this comparison are summarized in table 16, and lead to the conclusion that in present circumstances, in Latin America as a whole, annual expenditure per pupil in the entire educational system probably averages a little over 70 dollars. A preponderant influence on this average is exerted by primary education, which covers almost 85 per cent of the total school population; this again suggests that the general tendency of the estimates is to underestimate the magnitude of the problem.

TABLE 16. LATIN AMERICA: ESTIMATES OF ENROLMENT NUMBERS AND UNIT COSTS, 1965

	Number of students enrolled (thousands)	*Annual expenditure per student (US dollars)*[a]
Total	*38,800*	*73*
University education	800	700
Secondary education	5,100	175
General	3,300	155
Vocational	1,240	210
Training of primary-school teachers	560	210
Primary education	32,900	42

Source: The Financing of Education and Human Resources Training in Latin America, op.cit., table 2.

[a] Current expenditure only, excluding investment and other outlays.

An annual outlay of 42 dollars per primary-school pupil appears hardly likely to exceed the truth, while the much higher figures estimated for the other levels — 175 dollars in the case of secondary education and 700 dollars at the university stage — imply ratios to expenditure on primary education which seem to be corroborated by other estimates formulated independently.[10]

[10] See UNESCO, *Algunos aspectos del financiamiento de la educación en América Latina*, table 5.

The 1965 data presented may afford a basis for exploring the future development of financing requirements for education, assuming there are no significant changes in the structure, performance and productivity of the region's educational systems. In very broad outline, such an undertaking involves *(i)* the selection of a future period of the references; *(ii)* the projection of requirements in respect of the expansion of educational and training services in line with social objectives and the needs deriving from the development itself; and *(iii)* the prediction of certain changes in the absolute levels of specific costs, irrespective of any overhauling of the structure or policy of the educational services themselves.

For evaluating the situation that is likely to develop by 1980 in the light of probable population trends, reasonable objectives for the expansion of basic education must be established, together with hypotheses as to the growth of income and changes in the structure of the economy, with their repercussions on requirements in respect of technical and professional personnel at the various levels; in short, all the factors that would help to determine the educational profile of the population of Latin America by that date.

The implications of these projections in terms of demand for financial resources depend not only on the aggregate expansion envisaged but also on the changes in the composition of the student body by levels and specialities, as well as on factors that will inevitably make for a rise in unit costs.

To take the case of primary education (for which as we have seen, annual current expenditure per pupil is estimated at 42 dollars) it must be recognized that in the course of the 15 years covered by the projections the real remuneration of teachers will necessarily increase in at least the same proportion as average national *per capita* income. Some degree of improvement is also to be expected in the composition of primary education by purely basic and complete schooling, with the consequent effects on costs. Lastly, social objectives could not be attained without some increase in the proportion of current expenditure earmarked for welfare services. All this would seem to warrant the fairly conservative hypothesis of an annual expenditure of 70 dollars per pupil in 1980.

Secondary education will necessarily be influenced by the same and by other, additional factors. The foreseeable modification of the comparative importance of general secondary education as against intermediate-level vocational education — agricultural, technical, commercial — and the training of primary school teachers implies a relatively faster rate of expansion in those branches in which costs per pupil are higher. It is probable that at these levels too an increase in expenditure on welfare services—perhaps proportionally greater—will be required, partly with a view to increasing the number of scholarships, above all for particular specialities such as agricultural and technical education.

Much the same will no doubt take place in university education, especially on account of the increasing relative importance of scientific and technical training, which entails much heavier unit expenditure than, for example, education in economics, law or the humanities.

The results of these hypotheses are presented in table 17. In table 18 hypothetical estimates of investment and other expenditure are also presented in which ratios to current expenditure are kept more or less the same as at present, and account is taken of a few additional assumptions that seem warranted from several points of view.[11]

TABLE 17. LATIN AMERICA: HYPOTHETICAL PROJECTION OF ENROLMENT NUMBERS AND CURRENT EXPENDITURE ON EDUCATION BY 1980

	Enrolment numbers (thousands)	*Total current expenditure (millions of US dollars at 1960 prices)*
Total	*80,900*	*9,600*
University education	1,300	1,300
Secondary education	9,600	3,400
General	4,400	1,100
Vocational	4,000	1,800
Training of primary-school teachers	1,200	500
Primary education	70,000	4,900

Source: The Financing of Education and Human Resources Training in Latin America, op.cit., table 9.

Total demand for educational financing in 1980 is estimated, on the basis of this series of hypothetical calculations, at an annual sum of about US $11,000 million. This would signify not only a considerable increase over present levels, since it would mean that the allocations registered in 1965 were more than trebled, but also a substantial rise in the proportion of national income represented by the resources in question. Even if the relatively optimistic hypothesis were adopted that by 1980 the total domestic product will be over twice as much, expenditure on education would come to represent no less than 5.5 per cent of the aggregate product.

[11] In particular, a more rapid increase in allocations for university research is envisaged, and it is assumed that extramural and informal educational activities will expand to a very marked extent.

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TABLE 18. LATIN AMERICA: HYPOTHETICAL PROJECTION OF TOTAL DEMAND FOR EDUCATIONAL FINANCING BY 1980
(millions of US dollars at 1960 prices)

	Total	*Current expenditure*	*Investment and other expenditure*
Total	*11,000*	*9,600*	*900*
University education	1,500	1,300	200
Secondary education	3,600	3,400	200
General		1,100	
Vocational		1,800	
Training of primary-school teachers		500	
Primary education	5,400	4,900	500
Extramural and informal educational activities	500		

Source: The Financing of Education and Human Resources Training in Latin America, op. cit., table 4.

Stress should be laid on the nature of these quantitative examples. They are not intended to justify a specific objective as regards the allocation of resources to education, for the decision involved could be based only on explicit definitions of several fundamental aspects of development policy, and furthermore would have to be adapted in each case to the special—and often widely differing—conditions prevailing in each individual Latin American country. All that is attempted is to foresee, in the light of the implications that would derive from the maintenance of the existing structures, guiding principles and operational patterns of the region's educational systems, certain orders of magnitude which help to place the problem of financing education in a broader context.

To judge from the illustrative estimates presented above the absorption of the accrued deficit and the maintenance of an educational structure in line with social aspirations and development requirements would represent, in the immediate future, a financial effort that hardly any of the Latin American countries is in a position to make for the time being. This confirms the assertion that the difficulty lies not merely in the proportion of budget allocations earmarked for education, but in basic limitations deriving from over-all national income levels.

The countries that are coping satisfactorily with the problem—European countries and the United States, for example—enjoy *per capita* income levels six or ten times as high as the Latin American average, and this disparity is necessarily reflected in similarly substantial differences in the resources available for meeting the requirements of development in general and education in particular. In many of the countries in question not only the levels but also the growth rates of *per* *capita* income are much higher than in Latin America, and as a rule the proportion of funds channelled through the public sector is also greater.

Population structure itself, from this standpoint, is one of the factors that aggravate the difficulties encountered by the Latin American countries. Whereas the proportion of the total number of inhabitants represented by the school-age population (5 to 19 years) is 29 per cent in the United States and 22 per cent in Western Europe, in Latin America it is nearly 36 per cent. This means that in the last-named region the scanty income of a smaller proportion of the economically active population has to defray the expenses of a larger proportion of school-age population. Thus demographic characteristics, in conjunction with the handicaps deriving from the absolute level and slow growth rate of income, decisively influence the Latin American economies' capacity to generate a larger volume of resources for education. At the same time the insufficient development of modern-type enterprises does not provide an adequate training ground for all the workers in need of professional upgrading through properly directed practical means.

Furthermore, the limitations stemming from these factors affect not only the financing of educational services proper but also the capacity of the population to make use of those services. To make matters worse, not only are income levels low in Latin America but, in addition, income distribution by population sectors and socio-economic strata shows a much higher degree of concentration than in the more developed countries, so that a substantial proportion of pupils with the proper intellectual capacity, including those with genuine talents, cannot make use of educational opportunities even when they are available for a large number of students.

To confront the tremendous difficulties of financing the educational and training efforts required is one of those problems which educational planning should do most to solve, not so much in terms of a better justification of the case for education in competing for larger resources as to promote the maximum productivity of the resources already assigned to those ends. There seems to be a fairly widespread consensus that the school system can be made much more efficient and its *per capita* costs lowered. An increase in the retention rates alone would mean a considerable reduction in unit expenditure in relation to the number of persons completing each stage of education. There would also appear to be certain possibilities of benefiting from "economies of scale", especially in the use of higher level educational facilities—laboratories and other teaching media, including certain technical courses—which could function separately or be combined according to the needs of educational centres. At other levels a proper co-ordination on broad and clearly defined lines would avoid the danger of duplication and enable the resources earmarked for research to be used to much better purpose. No less promising seem to be the possibilities held out by the effective integration of school and extramural training, which would make it possible to choose the most suitable training methods for certain specialities, and avoid excessive fragmentation in university studies and intermediate technical schools. Finally, the best methods should be devised and all available means utilized to adapt all enterprises or industries with a modern organization to be efficient training centres.

All that has been said here is enough to indicate but a few of the many lines of action that can be visualized. The important point is that future educational planning activities will have to face a most arduous and pressing task: the need to find a way of reconciling the overwhelming demand for the expansion and reform of the educational and training systems with disbursements of funds that are highly unlikely to increase on a comparable scale.

4. Specific problems related to the requirements of highly skilled manpower in industrial development in Latin America

(a) *The specific pattern of Latin American industrialization in the next decade*

Against the previously described industrial, professional and educational background of the region it is somewhat easier to tackle the more specific key problems related to the role of advanced skills and technologies in Latin American industrial development. To discuss these it is first necessary to distinguish the specific structural patterns of the development of manufacturing industry, taking into account its internal organization and technological characteristics. Because of the staggering complexity of the problems involved, this discussion cannot be reduced to the construction of simple development models that explain everything through the interrelation of a few coefficients from which some simple conclusions can be drawn. This would be a hopeless task and would run a serious risk of terminating in meaningless generalities or conclusions that are already to be found in innumerable documents presented to international conferences. The best way seems to be to develop a gradual approach from the general to the specific, step by step throwing a searching light on problems which may be discovered as relevant.

This gradual approach to the structural pattern of industrialization in Latin America (or any developing region) might well start with the simple subdivision of all branches of manufacturing into two main groups: the "dynamic" and the "vegetative" industries. The first consists largely (but not exclusively) of the new branches of industry with dynamic growth; the second refers (again not exclusively) to the traditional (mostly consumer) goods, and industries whose expansion is closely tied to consumption and is governed by the growth of the population and the slow changes in its consumption pattern. In Latin America it is easy to see how the different stages of industrialization in the developing countries are indicated by the relative gross values of the production of the dynamic and the vegetative industries. In 1960, in the three large countries which had already embarked upon the fourth stage of industrialization (Argentina, Brazil and Mexico), the relation was almost 50:50. In the five (mostly medium-size) countries which were in the third stage of industrialization (Chile, Colombia, Peru, Uruguay and Venezuela) the relation was 38:62. In the remaining smaller countries for which statistical data were available (Dominican Republic, Ecuador, Panama and five Central American countries) and that were at that time on the borderline between the second and third stages of industrialization the relation was only 17:83.[12]

Even this apparently over-simplified subdivision is very instructive, since it gives a good idea of the numerical magnitudes of the higher skills required, especially of engineers and technicians. To give an idea of relevant coefficients: in 1957 it was calculated that the average industrial ratio of graduate engineers to factory workers in 1956 was already 5.0:1000, of which 6.9:1000 were in the dynamic industries, and only half (namely 3.5:1000) in the vegetative industries. The projection for 1967 presented in the same study indicated the necessity of reaching an average ratio of 8.2:1000 for graduate engineers to factory workers, with as many as 11.6:1000 in the dynamic industries, and only 4.6:1000 in the vegetative ones.[13]

A similar type of estimate was made with respect to intermediate-level technicians. The overall figure for 1967 is fairly comparable with the industrial ratio of engineers to factory workers in the United States in the late 1920s, when it stood at around 10:1000. It has doubled and perhaps trebled since then.

A closer approach to the industrial development pattern with the probable figures for the engineers, technicians and industrial administrative staff needed may be achieved by dealing separately with the major groups of industry. On this basis, different stages of industrialization are again clearly distinguishable. As regards Latin America it can be seen that in 1960[14] the proportion of the gross production value of the metal transforming machinery and electrical equipment branches of industry in the industrial total was as follows: in the first, more advanced, group of countries, 25 per cent; in the second group, 13.6 per cent; and in the third group, 3.6 per cent. The regional average was 22 per cent. The respective ratios for the food, beverages and tobacco branches to the industrial total were: 27.0, 31.7 and 57.3 per cent, with a regional average of 29 per cent.

It was roughly calculated that with the doubling of the Latin American gross product and an industrial growth of 120 per cent above the 1960 level, the share of the metal-transforming branch would increase from 22 to 27 per cent, and that of the chemical and petroleum industries from 14 to 19 per cent, while the share of the food, beverages and tobacco branches would fall from 29 to 21 per cent.[15]

It is well known that the dynamic growth of the metal-transforming, mechanics and electrical equipment industry and of the chemical and related industries is a sign of industrial progress in the developing as well as in the developed countries, while industries utilizing simpler production processes develop more slowly. Nevertheless, some of the latter, during limited periods in which they may be given special opportunities for growth, may suddenly jump ahead and develop at an even greater speed than the most typical dynamic industries. In Latin America this may well happen in the next few years in the industries producing pulp and paper, rubber goods, cement and related products, and in some branches of industry processing vegetable and animal products, while new branches of industry may delay their appearance on the scene, and other typically dynamic industries may grow less rapidly than might have been expected from development models utilizing input-output techniques.

[12] *The Process of Industrial Development in Latin America*, op.cit., chap. II, table 13.

[13] ECLA, *Economic Development of Argentina*, Vol. II.B, annex A, "Investments in Technical Training".

[14] *The Process of Industrial Development in Latin America*, op.cit., chap. II, table 12.

[15] See *The Process of Industrial Development in Latin America*, op.cit., chap. IV, tables 41–44.

It is important to note the striking differences between the numerical requirements for higher skills in different industry groups and specific branches. The top groups as regards the ratio of graduate engineers to factory workers are the petroleum and chemical industries, followed by the electrical equipment, machinery and transport equipment industries. In all those modern-type industries the ratio of engineers to workers is close to or over 2 per cent and there are two to three times as many intermediate technicians. In some petro-chemical and special electronics plants these ratios may become even higher. Industrial automation naturally greatly increases such ratios.

At the other extreme, the foodstuffs, beverages, tobacco, clothing, leather, stone, ceramic, and glass industries utilize (and may well develop) with a very low ratio of engineers to factory workers, i.e. 0.3—0.5 per cent or less. The ratios of textile and timber processing industries are not much higher. In Latin America all these industries will for at least the current and the next decade, play a very important role in the process of industrialization, not only because of the immense and non-saturated internal markets but also because of the prospects for exporting consumer manufactures to other regions.

In any discussion of the structural pattern of future industrial development in Latin America a careful investigation must be made of the problem of the size of plants and enterprises. The same branches of industry may develop through large and medium-sized plants, while other types of commodities may be produced even in tiny units. The problem of choosing not only which industries to establish, which specific products and quality of commodities to manufacture, which technologies to apply, but also the preferable scale of production unit to promote, is already a considerable one for the Latin American countries and will become even bigger in future.

As we have seen[16], three entirely different industrial systems coexist in Latin America: the modern, the underdeveloped or intermediate, and the entirely primitive. If, through energetic effort, the primitive handicrafts and homecrafts were to disappear during the next decade, leaving in the field an artisan system adapted to modern conditions and needs, there would still be coexisting, on the one hand, medium and large-scale industry, modern or forced by circumstances to modernize rapidly, with all its high technological and know-how requirements; and on the other, a very large number of small industrial units, which would be compelled to continue to use rather simpler and cheaper-to-buy technologies while employing a very large number of less expensively trained personnel, who would also be led by a much lower proportion of highly trained technicians.

The maintenance of this dualism in Latin America will be both an economic and a social necessity in almost all the countries of the region. Only very gradually will the consistent policy of selective growth and modernization for such industries[17] bring them within approachable distance of an integrated economy.

The magnitude of the problems involved in the development of small industry in Latin America may be judged from the estimated employment figures for large and medium-scale industry, small-scale industry, and handicrafts and homecrafts. In 1960, for a total of some 9.5 million employed in manufacturing, there were some 4 million in large and medium-scale industry, about one million in small-scale factory industry, and some 4.5 million of handicraftsmen and homecraftsmen. Many of the latter can be imputed to small-scale industry, which would then expand to at least 2 million workers. In the rest of the artisan sector another 2 million may be considered as belonging to the primitive activities sector.

It may be predicted that in 1980 large and medium-scale industry, through modernization and a rapid increase in productivity, would absorb a total of up to 8 million persons: about 40 per cent of the assumed total industrial labour force. Out of the remaining 12 millions, if about one-half were engaged in handicrafts and homecrafts, there would be 6 million persons to be employed by small-scale industry—three times the 1960 figure.

The figure presented for employment in small-scale industry in 1980 would seem to suggest a strikingly different proportion than was apparently the case in 1960, but in reality it conveys a somewhat different definition of small-scale industry. There is at present a great deal of confusion about its definition, and the criteria for determining exactly what small-scale industry is vary from country to country and from one census to another in the same country.[18] In addition to the number

[16] See Section I, pp. 191—8.

[17] Cf. *Issues and Policies in the Promotion of Small-scale Industries*, (ST/ECLA/Conf. 23/L. 14.), submitted by the United Nations Centre for Industrial Development to the Latin American Symposium on Industrial Development, Santiago, Chile, March 1966; and P. C. ALEXANDER, *The Role of the Small Industries in the Global Development Strategies*, (ST/ECLA/Conf. 25/L. 10), submitted to the Seminar on Small-scale Industry in Latin America, Quito, 28 Nov.—5 Dec. 1966.

[18] For discussion, see *Issues and Policies in the Promotion of Small-scale Industries*, op.cit., chap. I, and P. C. ALEXANDER, *Definition of the Small Industry*, (ST/ECLA/Conf. 25/L. 2), submitted to the Seminar on Small-scale Industry in Latin America, Quito, 1966.

of employees by establishment, other economic criteria referring to capital intensity, production scale etc. are utilized, but in the case of Latin America, not very systematically up to now, and rather as a complement to the employment criterion. It may be assumed that the future policy of an intensive development of small-scale industries will evolve in accordance with planned employment policy[19], the clarification and standardization of the concept of what small-scale industry is, and that special attention will be paid within that redefinition to the techno-economic factors. A substantial proportion of what is now called medium-size industry, being poorly equipped and producing on a small scale, would then be classified under the heading of small-scale industry, while establishments with the same employment level but well-equipped and highly productive would qualify as medium-scale industry.[20]

The distinction would naturally be of great assistance in estimating the numbers of highly skilled professionals required, whose employment in the reclassified small-scale industry would be limited, while demand for them in the reclassified medium-size industry would undoubtedly be greatly increased.

A further step in the discussion of industrial development patterns in Latin America would be to analyse the prospective development of individual branches of industry and the future increase in production of the most important individual commodities. In this respect a great many studies have been prepared or are in preparation by the Economic Commission for Latin America (ECLA)[21], as well as a number of national studies. Many conclusions can be drawn from these studies regarding the present situation and future requirements of highly skilled manpower in each industry. In these cases the point is not to have a given number of persons in the country belonging to the general category of "engineers"; it is rather to have persons belonging to specific technical professions or, even better, with a specific type of specialization. In Latin America the situation in the latter respect is usually even more unsatisfactory than that in more general terms. The great shortage of highly skilled specialized personnel represents one of the greatest obstacles to developing, modernizing or increasing productivity in many branches of industry.

A striking case occurred in Venezuela, where "it was reported in 1962 that there was a specific shortage of petroleum engineers, although these were in particularly great demand in national industry; only 2 per cent of registered Venezuelan engineers were petroleum engineers and only around 100 of these were available to fill about 600 posts".[22]

The possibilities for Latin American industrialization within a short time are undoubtedly very promising, for a highly urbanized region with a population of 300 to 400 million, with a great demand for industrial commodities, richly endowed with natural resources and with a great many nascent industries, is in the process of going through a fairly complete "shopping list" of modern industries with good prospects of picking out of it a number of branches for regional development. The choice would be far from arbitrary.

The pattern of industrial development in Latin America in the near future, in terms of specific branches of industry and individual production lines, will depend on a series of factors. Some of the most important of these are presented below, but no attempt is made to estimate their relative influence on future changes in industrial structure.

(b) Factors influencing the prospective pattern of Latin American industrialization

Latin American economic integration is almost certainly one of the most important factors influencing the region's industrialization pattern in the present and next decade. It is generally recognized that economic integration is the only way to secure rapid and balanced industrial development in the region and practically all broader industrialization schemes of an international or even a national nature assume that some sort of integration will take place. The striking success of the Central American Common Market in the field of industrialization is a stimulating practical test of the tremendous advantages of well-conceived integration.

[19] Cf. *The Role of Small Industries in the Global Development Strategies*, op.cit., and *Role of Small Manufacturing Enterprises in the Balanced Economic and Social Development in Latin America* (ST/ECLA/Conf.23/L.52), presented by the International Labour Office to Latin American Symposium on Industrial Development, Santiago, March 1966.

[20] These modernized concepts of small and medium-sized industry would come close to the classification of mining enterprises under the Chilean mining code, which makes a distinction between small, medium and big mining enterprises on the basis of production volume.

[21] These studies mostly concern: the iron and steel industry; the non-ferrous metals industry; the chemical industry; the pulp and paper industry; the metal-transforming industries; and the textile industry.

[22] Aníbal R. MARTINEZ, *Nuestro Petróleo*, Geneva 1963, quoted in *Manpower Planning and Vocational Training*, submitted by the International Labour Organisation to the Latin American Symposium on Industrial Development.

The difficulty lies in the practical form to be taken by Latin American integration. The progress and pattern of industrialization greatly depend upon the accepted form of integration. It is true that there are innumerable formulas for integration, some independent, some complementary, but there are only two basic concepts of regional integration, namely, horizontal and vertical integration.

The present integration agreements, which led to the establishment of the Latin American Free-Trade Association (LAFTA, or ALALC in Spanish), have proved to be an ineffectual instrument for the development of industries that could reckon with duty-free regional markets. The main obstacle seems to be the lack of guarantees for the enjoyment of reciprocal advantages by all countries participating in the scheme, and as a result the progress made in abolishing industrial tariff barriers between LAFTA's member countries has been very slow, and has thus had little influence on their industrial growth.

It seems that the keys to successful industrial integration are the reciprocity of advantages gained through integration and the ability to establish a mechanism for the common planning of the distribution of productive industrial resources so as to ensure their efficient utilization along with reciprocity.

As a step towards successful regional economic integration, subregional integration schemes are now being devised in Latin America, mostly related to the formula of vertical industrial integration. The arrangements made between Argentina, Brazil and Chile for the exchange of the products of the automobile industry, later extended to other metal products, constituted one of the first schemes of this kind. Another probably much broader scheme would set up a series of industrial links, between all the Pacific and Andean countries from Chile to Venezuela. Joint plans for the co-ordinated development of a broad range of metal and chemical industries are being drawn up.

It is to be expected that when all these integration plans, mostly relating to industries which are utilizing advanced technologies and are therefore very heavy absorbers of highly skilled manpower, are put into operation, one of the first implications will be the development of special, as well as international, plans for the rapid training of skilled manpower.

Manpower and general employment policy will be very important factors in the years to come in the shaping of industrialization policy, and will largely determine at least some of its structural characteristics. If the present trend of a relatively slow increase in industrial employment prevails and, at the same time, the migration from rural to urban areas continues as intensively as at present, mass underemployment and open unemployment of staggering magnitude will make its appearance[23] in the towns, with unpredictable repercussions upon the maintenance of the law and internal peace in the region.

These gloomy prospects call for the establishment of a special employment policy, one of the key measures of which should be to promote and facilitate the extensive development of small-scale industries, supplying and providing work for the economically and geographically remote areas of Latin America. It would be entirely uneconomic however to discourage the modernization of medium and large-scale industries and their use of advanced technologies, especially in the range of high-grade industries which would have to make the most efficient use of the skilled manpower that will be in short supply for many years to come, and will become highly competitive within the integrating region.

(c) *Choice and application of technologies and highly skilled manpower requirements*

In this setting it is easier to measure the tendencies of Latin American industrial expansion and diversification against the choice of industrial structures and technologies to be applied, and the high levels of skill required. It is important to measure these skills not only in quantitative terms but also in terms of the substance and quality of education: the type and quality of practical training, and the selection of talents. Whenever purely quantitative estimates are prepared, irrespective of the exactitude of the forecasts of industrial needs of specific skill categories, they will always fall short of the real targets unless proper provision is made for achieving the indispensable quality standards.

The basis has already been given for establishing general figures for the present and prospective availabilities of university level scientists and engineers, as well as for the numbers required in industry. The general conclusion is that the present figure of about 40,000 university-level professionals (of whom only some 20,000 are engineers) is wholly inadequate for present needs, and that the attainment of the 1980 target of 140,000 university professionals (of which at least 80,000 should be en-

[23] See Z. SLAWINSKI, *The Structure of Manpower in Latin America: Evolution during the Last Few Decades and Long-term Prospects*, prepared for the Seminar on Long-term Forecasting of Manpower Requirements and Educational Policies, organized by OECD, Lima, March 1965.

gineers) would be a great strain on formal educational, as well as on extramural informal, training systems, and would also involve costly obligations.

Within the general minimum figures, an attempt can be made to determine the actual and the required numbers of skilled personnel corresponding to more specific types of skill; that is, in the specific professions and in the most important specializations (the latter in what may be called functional and technical specializations). While the problem of basic training for the professions is in all cases fundamental, the problems of specialization, though always important, are rather easier to solve over the short or medium term so as adequately to meet industrial requirements, because of the relatively high degree of horizontal mobility or "professional flexibility"—the ability of well-educated professionals to adapt themselves to diverse types of functions.

However, functional and technical adaptability depends very largely on the complexity and technological level of industry. With a simple organization and less advanced technology, such an adaptation of a well-educated professional is relatively easy. This is probably the answer to the apparent puzzle of how Latin American industry has been able to develop up to now, despite the acute shortage of specialized industrial high-level professionals. But with the increasing complexity of industrial organization and very advanced technologies, the adaptation of existing professionals to new technical or managerial functions may prove very difficult—as difficult as professional retraining to acquire entirely different specializations—and shortages would develop as a result.

In the field of specialized technical training the basic problem is that of the complementarity of techniques and skill requirements. The word "techniques" should be taken in its broadest sense as, apart from technologies, it should embrace managerial and all sorts of organization techniques. It will depend on technical complexities whether complementarity is achieved at a high or a relatively low level. In this connexion it is necessary to make a clear distinction between the two main types of complementarity, which are the direct and the indirect complementarity of productive techniques by skilled manpower trained to handle these operations.

Direct complementarity refers to complementarity of technical production processes; that is "technologies" by properly qualified technical personnel: equipment operatives, process operatives, technical supervisors, investigators, designers etc. Indirect complementarity refers to complementarity of the whole entrepreneurial apparatus by the managerial, administrative, sales and servicing staff.

Usually both complementarity levels are related, as the complexity of modern productive technology is matched by the increasing complexity of the whole production and servicing system, thus making it necessary to employ, together with high-level technicians, personnel that is equally well trained in non-technological matters. Otherwise the high productivity level of purely technical plan operations would be neutralized by all other types of entrepreneurial inefficiencies—which, incidentally, is a common situation in Latin American industries.

The most indirect complementarity with currently applied technologies is that of public economic administrators and industrial promoters in relation to the development of manufactures. Economic public administration, as well as the system of industrial promotion, may be extremely beneficial to the existing and developing industries but harmful to the cause of industry. This has very little to do with the quantitative supply of administrators and promoters, but is almost entirely a question of their quality. In Latin America, where the public administration is of chronically low quality, the provision of properly trained experts should be an important item in programmes of training for industrialization. Where this is disregarded, industrial expansion is inadequately promoted and, in addition, innumerable bureaucratic problems hamper the smooth operation and development of industry.

(d) Specific categories of highly skilled personnel required in the new stage of industrialization and new professional specialities

All the previous arguments indicate that industrial development in Latin America during the next decade will depend to a much greater extent than before on the capacity of the countries of the region to solve the problem of providing the necessary highly skilled personnel directly and indirectly related to industrial growth.

Many of these points also seem to indicate that new approaches should be looked for with regard to the determination of the professional categories required as compared with the traditional professions, and also to the necessity of developing new methodologies, to be tested and applied concurrently with the present system of professional education, for the education and training of those professionals.

The urgent need to seek a new approach in the field of advanced skills that are complementary to advanced technologies and managerial techniques in industrialization processes has already been pointed out. It should also be borne in mind that industrial development in Latin America suffers deeply from the lack of industrial tradition and from a general psychological attitude (closely associated with excessive individualism) that is adverse to types of activities that are highly organized, and that require a fair amount of discipline and the acceptance of a high degree of individual responsibility. To develop this new attitude among the working masses there must be genuine professional leadership, which cannot be provided by the present-day entrepreneurs who, besides being ill-prepared for this task, are themselves in short supply in the region. Industrial professionals would therefore have to bear the triple burden of carrying out their continuously diversifying professional technical duties, organizing the industrial medium, and giving the lower-level personnel proper training in their work.

The new approach to the necessary structure of professions should start with a redefinition of the broad professional families that are related to industrialization. A modern categorization of professional families would help to develop necessary new professions. Of the professional families conceivable, the most important for industrialization are the groups of engineers and scientists, followed by the group of economists, and the socio-technical group.

The list of specific professions should be enlarged by adding to the traditional professions new categories that, while possessing a more universal significance, will be specially important for industry.

In the engineering groups, besides the traditional professions of metallurgical, mechanical, electrical chemical and general industrial engineers, complemented by some semi-specialized professions (e.g. textile, paper making, automobile, aircraft, shipbuilding, petroleum and other engineers), new professions are being added such as: energy, electronic, precision instrument, petrochemical, top-level pharmaceutical and atomic engineers. In the economic category the profession of "industrial manager" is clearly emerging, as well as that of "industrial economist". Within the socio-technical family the idea of a new profession of "social organizer" may be important for industrial development. Lack of space precludes these concepts from being explained in greater detail here.

A number of specific specialized fields are gradually making their appearance within the more limited set of basic professions, following the development of new branches of industry and new fields of basic or applied investigation.

Within the new professions and semi-professions (i.e. professional specialized fields involving basic long-term training, which puts them on the borderline between professional specialities and genuine professions), those which are the result of a multi-disciplinary approach are particularly significant. This is of special importance in the economic family of professions, in the managerial group, in industrial administration, and in commercial fields. It may be claimed as a general rule that the higher the level in the industrial hierarchy, or the greater the complexity of the industrial problems to be dealt with in the frame of given professional functions, the more important it becomes to have a multi-disciplinary approach to the training of these professionals. Thus a new category of profession emerges, which is the blending of different disciplines that were traditionally taught to separate professions belonging to different professional families.

This fresh approach would be very important for the new stage of Latin American industrialization from two virtually opposite points of view: in the development of new, large-scale and highly complex manufactures, and in the promotion of small-scale industries.

The development of large-scale industries, and especially of the highly competitive industries working for the common market, would make it essential to use advanced managerial techniques and up-to-date sales systems, including extensive servicing of consumers of capital goods and of users of new technical products in general.

The necessary development of small industries on an extensive scale will involve highly intensive and skilled industrial promotion from the public administration and related promoting bodies, who would have to use much better trained high-level operational personnel than they do now, even though high levels of skill will be at a premium for a long time in small industry itself.

In general, a modern entrepreneurial class will have to be intensively developed in Latin America through the provision of modern multi-disciplinary managerial training to those already at work, and to the younger generation.

Finally, improved economic administration and operational planning at all levels will make it necessary to provide public administration and the banking system with high-level personnel that would understand industrial problems and be well prepared to help all types of industrial development.[24]

The new approach to the system of educating and training high-level professionals responds not only to the necessity of forming new professions but also (which is equally important) to the urgent need of improving the education and training of the traditional professions. Because of the chronically poor quality of education and training in most of the developing countries (and here Latin America is not an exception), the whole system of professional training, starting with the teaching of science at secondary schools, must be substantially improved.

A sound professional training is essentially a rigorous blend of basic secondary and academic education with post-academic professional and on-the-job training. In the present paper no more can be done than emphasize strongly the following points.

(i) In Latin American conditions the average low quality of secondary education, especially in science, is one of the major causes of the shortage of well-trained candidates for university careers in industrial engineering, science and modern management. Substantial improvements in the teaching of mathematics and science in secondary schools are necessary to pave the way for providing regional industrial development with high-level professionals.

(ii) The university education of the professions under discussion must be radically overhauled in Latin America and improved as regards the internal and inter-university structure of the technical science teaching, micro- and macro-economic studies, academic syllabuses, and the systems and qualities of the teaching itself.

(iii) A modern system of post-university, extramural professional training, complemented by on-the-job training for young professionals, and also accessible to all professionals in need of re-training, should be carefully designed and developed.

(iv) The on-the-job training of high-level professionals, especially in key enterprises, should be a subject of special attention by entrepreneurial and other industrial circles, and constantly improved in order to meet the new training requirements and rising industrial standards.

It is impossible to over-estimate the importance of the role of international and foreign technical assistance in increasing the output and improving the quality of the Latin American systems, by participating in the training of professionals, with special emphasis on what is important for the introduction of advanced technologies and managerial techniques and the development of high-grade industries.

This role is closely related to the international aid given in the transfer of technical know-how, but this refers to a different type, namely "how-to-train-people". The age-old experience and knowledge acquired by the more advanced nations in this respect should be accepted by all circles in Latin America and applied in practice, without the opposition and prejudice that stem from misplaced pride on the part of national universities and professional institutions.

Given the unavoidable shortcomings of the Latin American systems of education and training for highly skilled manpower, and the inevitable quantitative and qualitative shortages that spring from them (which are, moreover, very unequally distributed among the individual countries), the international and intraregional flow of specialized manpower will have to play a very important part in the industrialization effort.

In view of the importance of international technical assistance for the transfer of technical know-how and improved education and training, and of the complementary flow of skilled personnel, special studies should be made of these problems of international co-operation, and consistent plans should be worked out on a sound financial basis, as possibly the most efficient type of investment in Latin American industrial development.

5. IMPROVEMENTS IN METHODS OF INVESTIGATING THE INDUSTRIAL AND SKILLED MANPOWER SITUATION AND IN THE INFORMATION SYSTEM INVOLVED

In view of the need to clarify concepts and improve knowledge of investigation procedures related to the situation and needs of skilled manpower in the economy (and especially in the development of industry) it is proposed to discuss three important operational tools, whose improvement may help to find a practical means of remedying the scarcity of skilled manpower which is threatening to become a major obstacle to the high-level industrialization of Latin America. The tools are the methodology of analytical and planning models; the systematization of skilled manpower categories (manpower classification); and the system of socio-economic information that provides primarily facts related to industry.

[24] For discussion, see Marland A. RIKER, Jr., "Training the Government Administrator for Management of Industrial Development", *International Development Review*, June 1966.

(a) Macro- and micro-occupational analyses[25]

From what has been said above it may be concluded that the number and variety of independent factors involved in the determination of the real situation and skilled personnel requirements in industry make it imperative to seek a simplified, but not over-simplified, approach to the problem. The substance of this approach would cover the basic concepts of working models, within what is now termed the "methodology of human resources analysis and planning for economic development", but which, in order to become a fully operative and efficient practical tool for industrial development, still has to be revised and improved. In this connexion, two basic approaches should be clearly distinguished and treated as equally important, namely the macro-economic and the micro-economic. They may be used separately or in a complementary manner.

The macro-economic approach, which might be also termed the "macro-occupational" approach, would consist in determining the actual or proposed input coefficient of certain (usually broad) categories of manpower, on the basis of the numerical data corresponding to the selected factors of the more general type that are considered to be the most relevant in this connexion.

In the construction of macro-occupational models the first step consists of presenting the actual situation; the second step is the calculation of the optimum coefficient to be aimed at under present conditions; and the third step is the estimation of a specifically desirable future situation for the employed labour force as a whole, subdivided into given manpower categories. Special attention should be paid to the highly skilled categories of manpower. The techniques used in general employment projections must take into account the main factors that determine the labour absorption capacity of individual branches of activity.

The practical work would therefore consist of the following:

(i) Determining the professional groups or other manpower categories to be taken into account in a given case.

(ii) Establishing the main determinants of the inputs of these groups, by selecting the factors that are actually inter-connected or should become so.

(iii) Determining the method for the numerical evaluation of these factors.

(iv) Determining the type of quantitative relationship that should be used to link *(i)* and *(iii)*.

(v) Calculating the actual and currently desirable coefficients, and estimating the corresponding future coefficients.

With reference to the projection of the future coefficients of highly skilled industrial manpower, the "historical method", whereby projections are based on long-term trends observed in the given country or region, and the "comparison method", basing projections on comparisons with other countries, are both useful from the practical point of view. It should be added that the historical method may be more valid for traditional industries in given countries in which intrasectoral changes may proceed rather slowly, while the comparison method is better for the new, more dynamic branches of industry. When the comparison method is used for projections of certain categories of skilled manpower the comparison should preferably be made between the country under consideration and another country whose stage of development would roughly correspond to the level that the given country is expected to reach during the period indicated in the projections.

In the specific case of Latin America the projections of broad categories of skilled manpower for 1980 could be made through a comparison with some less developed European country or countries (Italy in 1950 and 1960 or Spain in 1965 might be suitable). Comparison with countries in a very advanced stage of industrial development should be avoided, especially those where a very large number of highly skilled personnel are employed in basic and industrial research. (The United States should be excluded in this respect as a basis of comparison.)

Throughout the planning process the target setting operation must be complemented by institutional planning, i.e. the planning of substantial changes in the whole institutional framework of the given sector or branch of industry, or the planning of the development of new institutional forms auxiliary to the fulfilment of production targets. New types of coefficients of necessary inputs of skilled manpower, relating to the proposed new setting, should be developed. The rational fixing of such new coefficients may be only partially based on past or present experience, or calculated roughly in an abstract way. Data derived from micro-occupational analysis of modern establishments, national or foreign, could be usefully employed in this connexion.

The fundamental points of discussion regarding the practical procedures of manpower planning at the (not always properly recognized) macro-economic level should be

[25] See *Manpower Structure, Educational Requirements and Economic Development Needs*, (ST/ECLA/Conf 10 L.36), prepared jointly by the ECLA secretariat and UNESCO, and presented at the Conference on Education and Economic and Social Development in Latin America (Santiago, Chile, March 1962)

(i) an adequate classification of economic activities, which in practice would have to be the same as for economic analysis and planning; and

(ii) an expression of the estimates of skilled labour requirements by means of a manpower classification system to be used in determining the professional education and vocational training needed.

It should be understood that the above-mentioned classification must also depend on the structure of the system of education and training for the working force. In certain practical applications of manpower planning techniques very simple procedures could be utilized to determine educational requirements. They would consist of estimating demand for a very limited number of skilled manpower categories, and determining the necessary level and number of years of training. On this basis, profiles of the professional levels of the working force could be constructed that would serve for a broad education and training strategy, somewhat in the same way as the method presented above in sections 2 and 3.

It is very difficult to devise a statistical table with which to measure and analyse, from different standpoints, the circumstances involved in the heterogeneous and excessively complex economic and manpower structure in the Latin American countries at the present time. Nevertheless, if statistical data (however fragmentary) were available they would provide an instrument that would not only facilitate the study of facts connected with the existence of very different economic systems but would also make for the establishment of new development planning strategies. Briefly, it would be a matter of determining the various labour-force profiles,[26] of which the most important are the profiles of the level of educational and vocational training, and the profiles of productivity, capital intensity (fixed capital per employed person) and personal income of the working force.

It is by these profiles that the distribution of the whole of the labour force employed in productive activities can be presented in the form of a graph with the following characteristics.

All the specific categories into which the labour force is subdivided may be presented in the form of a series of columns based on the *X* axis. The width of the columns represents the absolute or relative numbers of persons who belong to each category, from the point of view of productivity, fixed capital per person, income level, and training level. The average level of each category from the given standpoint is measured along the *Y*-axis. If the columns of labour categories are arranged in descending order, the labour force profile appears in the form of a series of steps moving down from left to right. The discontinuous profile may be smoothed to yield a continuous curve sloping down to the right—a generalized graphical presentation of the labour-force profile. Obviously the highest part of the curve, on the left side, represents the modern sector of the economy and the lower part, to the right, represents the primitive sector, while the intermediate part of the profile shows the underdeveloped sector.

In accordance with the quantitative and qualitative criteria indicated above, these profiles could be constructed for each individual group of industries, and even for each specific branch. This would make it possible to draw a clear distinction between the predominant structural characteristics of each industry or branch and to evaluate from a new angle the main factors influencing the over-all results, as well as the average figures per worker. The over-all profiles for the whole of industry, in their turn, would represent a combination of all the sectoral profiles, weighted by the relative importance of each branch.

Manpower profiles are essentially a tool of macro-occupational analysis, though they may be used in a micro-occupational setting.

The micro-economic approach, or what in manpower analysis might be called the micro-occupational approach, should be employed more intensively as a complement to the macro-economic analysis. It would consist of a detailed analysis of the occupational composition: *(i)* individual establishments or enterprises; *(ii)* within the framework of a specially selected productive organization covering certain production lines; *(iii)* within complementary enterprises, forming local or regional industrial complexes; or even *(iv)* within a specific activity concentrated in restricted areas of the country.

The increasing importance of micro economic, as well as micro-occupational, investigation is due to the fact that, with the rising scale of individual plants and enterprises, their relative importance within the total economy or total occupation greatly increases. Some key industrial establishments may carry greater weight than whole branches of activity. On the other hand, a more profound investigation into industries, leading to the determination of actual production functions and, for example, making it possible to relate over-all productivity to the availability of technical and managerial skills, requires a much more detailed and continuous flow of information than macro economic studies.

[26] See *Manpower Structure, Educational Requirements and Economic Development Needs*, op. cit. (Ref. to footnote No. 25)

The content and specific methods of micro-economic analysis would have to take into account the following factors at least:

(i) Economic and technological processes involved.

(ii) Technologies and type of equipment utilized.

(iii) Organization and productive processes.

(iv) Organization of non-productive processes.

(v) Administrative structure.

(vi) Specific production characteristics, including the volume and quality of the product.

(vii) Volume and structure of employment in general and by specific processes.

(viii) Value added in the production processes and the resulting or desirable productivity of related manpower.

The relationship of these factors to the employment of highly skilled personnel would be the subject of a special investigation.

Micro-occupational models derived from an analysis of this kind could then be used either as samples or —where it is possible to calculate input coefficients for relevant categories of personnel— in the macro-occupational models already discussed. They might also be used directly for skilled manpower planning purposes in some branches of economic activity; for example, when the complexity of the factors in the productive process and high capital-intensity justify the use of exact computational techniques. It is to be noted, however, that the organization of economic information must be good enough to enable micro-occupational development models to be used effectively.

(b) *Improved manpower classification*

There is at present a world-wide discussion on the need for an improved classification of categories of skilled manpower, based on the establishment of professional and functional groups, with the highest possible degree of uniformity in their basic education and type of training. The great difficulty in finding the proper solution lies in the need to devise a system which, on the one hand, would be extremely simple, easily understood by everybody (not only by highly trained labour experts), and handy for universal and continuous use, and on the other hand would make for the exact determination of the increasingly numerous specialized occupations requiring diversified preparation.

The solution does not seem to consist in introducing piecemeal improvements in the established occupational classification but in the development of an entirely new system based on a combination of three basic elements relevant to the determination of actual skills, namely,

(i) The training level, which implies the level of education or natural intelligence.

(ii) The type of basic professional training received, and the major function performed (what may be termed "professional-functional" classification).

(iii) Actual occupation within a specific economic activity.

These three main concepts should be used in determining the characteristics of the labour force at all levels.

The approach based on educational level has already been tested in many countries, especially in Europe, with more satisfactory practical results than the traditional approach based on classification of occupations.[27]

The optimum solution would involve the adoption of the following six main training levels, ranged from the highest to the lowest.

A. University-level professionals.
B. Intermediate-level technicians.
C. Practical technicians and highly skilled craftsmen and expert workers.
D. Skilled operatives.
E. Semi-skilled operatives.
F. Unskilled workers.

The upper levels would be subdivided into additional sub-levels. With reference to main level A, for example, these might be:

A.3. Recognized scientists.
A.2. Professional with higher scientific training; higher university degrees (Ph. D.).
A. Professionals, standard university degree.
A.½ Professionals, sub-standard university training.

A somewhat similar, though simpler, subdivision would be used for the main level B, namely,

B.2. Highly trained intermediate technicians, but without academic training.
B.½ Sub-standard intermediate technicians, or auxiliary technicians.

Highly skilled professional industrial manpower is principally at the A level though it enters into the B level as well. The latter either directly supplies the required advanced skills or, by com-

[27] These findings have been summarized in numerous OECD studies, in the series related to Education and Development, especially in the publications referring to the Mediterranean Regional Project.

plementing the work of A-level professionals, contributes to their more efficient utilization in industrial pursuits.

The professional-functional classification is derived from the concept of classification by professional levels but is complemented by the concept of main functional groups of manpower in the economy, operatives in big and small enterprises.

A classification system of this type[28] has been proposed, based on the following ten major groups (first digit group in a decimal classification):

(0) Managers and top-level administrators.
(1) Higher-level professionals.
(2) Intermediate-level professionals (technicians).
(3) Independent operators.
(4) Routine office workers and salesmen.
(5) Practical technicians and highly-skilled operatives.
(6) Skilled technical operatives.
(7) Semi-skilled technical operatives.
(8) Service personnel.
(9) Non-skilled workers, apprentices, students and non-trained persons looking for their first job.

A somewhat similar type of classification was devised by the OECD Mediterranean Regional Project, and used in various countries.[29]

The first two or three categories correspond to highly skilled industrial manpower: if it is mainly practical training that is being taken into account, the next three groups would also have to be reckoned with.

The further subdivision of high-level professions has been discussed in the previous section. Professional families, specific professions, and major professional specialities (semi-professions) would have to be taken into account.

The specific functions performed by persons at different levels should be separately classified for combination, if necessary, with the major professional-functional classification.

It is suggested that the following groups of specific functions performed should be adopted:

(0) Research and investigation.
(1) Design and product development.
(2) Non-routine technical operations.
(3) Non-routine non-technical operations.
(4) Routine equipment operations.
(5) Routine technical operations.
(6) Routine non-technical operations.
(7) Teaching and instruction.
(8) Management and administration.
(9) Other functions (including consultant work).

High-level industrial manpower would perform most of these functions, except groups 4, 5 and 6 (see table 19) while high-level scientists mainly perform the functions numbered (0), (1), (7) and (9) (consultant work).

Somewhat similar types of classification are used by the Economic and Research Branch of the

[28] See *Manpower Structure, Educational Requirements and Economic Development Needs*, op. cit., chap. III, "Skilled manpower planning", and table 1.

[29] See publications relating to the Mediterranean Regional Project in Southern Europe and Latin America (Peru and Argentina).

TABLE 19. DIVISION OF SPECIFIC FUNCTIONS PERFORMED BY PERSONS AT DIFFERENT PROFESSIONAL LEVELS

Professional level \ Type of function	0. Research and investigation	1. Design and product development	2. Non-routine technical operations	3. Non-routine non-technical operations	4. Routine equipment operations	5. Routine technical operations	6. Routine non-technical operations	7. Teaching and instruction	8. Management and administration	9. Other functions, including consultant work
A	×	×	×	×				×	×	×
B	×	×	×	×	×		×	×	×	
C		×	×	×	×	×	×			
D				×	×	×				
E				×	×	×				
F						×				

Department of Labour of the Government of Canada (11 typical groups) and by the National Science Foundation in the United States (six typical groups).[30]

The definition of actual occupation should be the last and most detailed step in manpower classification. A very simple method can be used for this, which eliminates the necessity of having a separate occupational classification.

The professional-functional classification could be combined with the codified expression of the specific activity classification and an even more detailed classification of productive processes. Thus a classification of the particular specialized skills which industry requires in order to perform a very great variety of tasks can be made inexpensively and simply by utilizing and combining precodified information containing all sorts of industrial data at the macro-economic or micro-economic level. After the necessary redefinition is finished and rational manpower classification introduced, the success with which an evaluation of skilled manpower is made and a practical policy framed will largely depend on how efficiently the general information system operates and supplies users with a flow of correct data.

(c) *Modernization of the socio-economic information system*

From the discussion and conclusions concerning the need for careful and detailed investigation of all factors relating the problems of skilled manpower to industrial development, another conclusion is inevitably drawn: that the value of such research in Latin America will very largely depend on a substantial improvement in the general system of socio-economic information.

In the last few years a general uneasiness has begun to be felt in economic circles about the chronic lack of important data, the long delays in publishing the results of censuses and statistical surveys, and the poor quality of the information available. It is believed that these are some of the major handicaps in economic research and actual development policy.

"Shortcomings in statistical and technical information" were lately presented as one of the main reasons for the incompleteness of planning systems in Latin America, explicit reference being made to "the lack of adequate information-collecting and research machinery", the lack of an "organization of a steady and timely flow of information" and "the lack of a clear definition of and research on the most suitable production techniques for developing countries."[31]

These weaknesses in the field of socio-economic information call for a special confrontation of the increasing daily complexities of modern industrial economies and of the magnitude of the losses and lost opportunities caused by wrong decisions (through insufficient knowledge because of the gaps in information) with the typical deficiencies of the actual statistical system. A critical confrontation of this kind should facilitate the discovery of correct solutions, some consisting in the improvement of traditional methods, and others in more unorthodox methods.

The traditional system of statistics offers a broad field for gradual improvement. The following are important in this respect: *(i)* the extension of data collection; *(ii)* better co-ordination between different data-collecting institutions, so as to avoid overlapping; and *(iii)* more rapid and generally efficient statistical operations.

A less orthodox approach would involve the fundamental improvement of classification method. and related code systems. The above system of classification for highly skilled manpower and the labour force in general points as a collateral conclusion towards the necessity of redefining the concepts related to activities performed. The development of some basic concepts for correlating and providing a common framework for the activities and the manpower classifications, which would also enable the working of industry to be analysed adequately and in more detail, would lead to a new systematization of productive processes and their combination with applied techniques. This would be a useful step forward in industrial studies.

The progressive approach towards a fully integrated modern system of socio-economic information should take into account and make co-ordinated use of all fundamental factors that can be brought into play in the reshaping of this basic tool for providing a modern, rapidly developing community with the economic, social and technical facts of interest to it. These factors are four in number.

(i) A broad educational effort aimed at creating a general consciousness of the meaning of and an interest in fact-revealing figures, as well as a willingness to co-operate in the collection of data.

[30] *Profiles of Manpower in Science and Technology*, National Science Foundation, Washington, D.C., 1963.

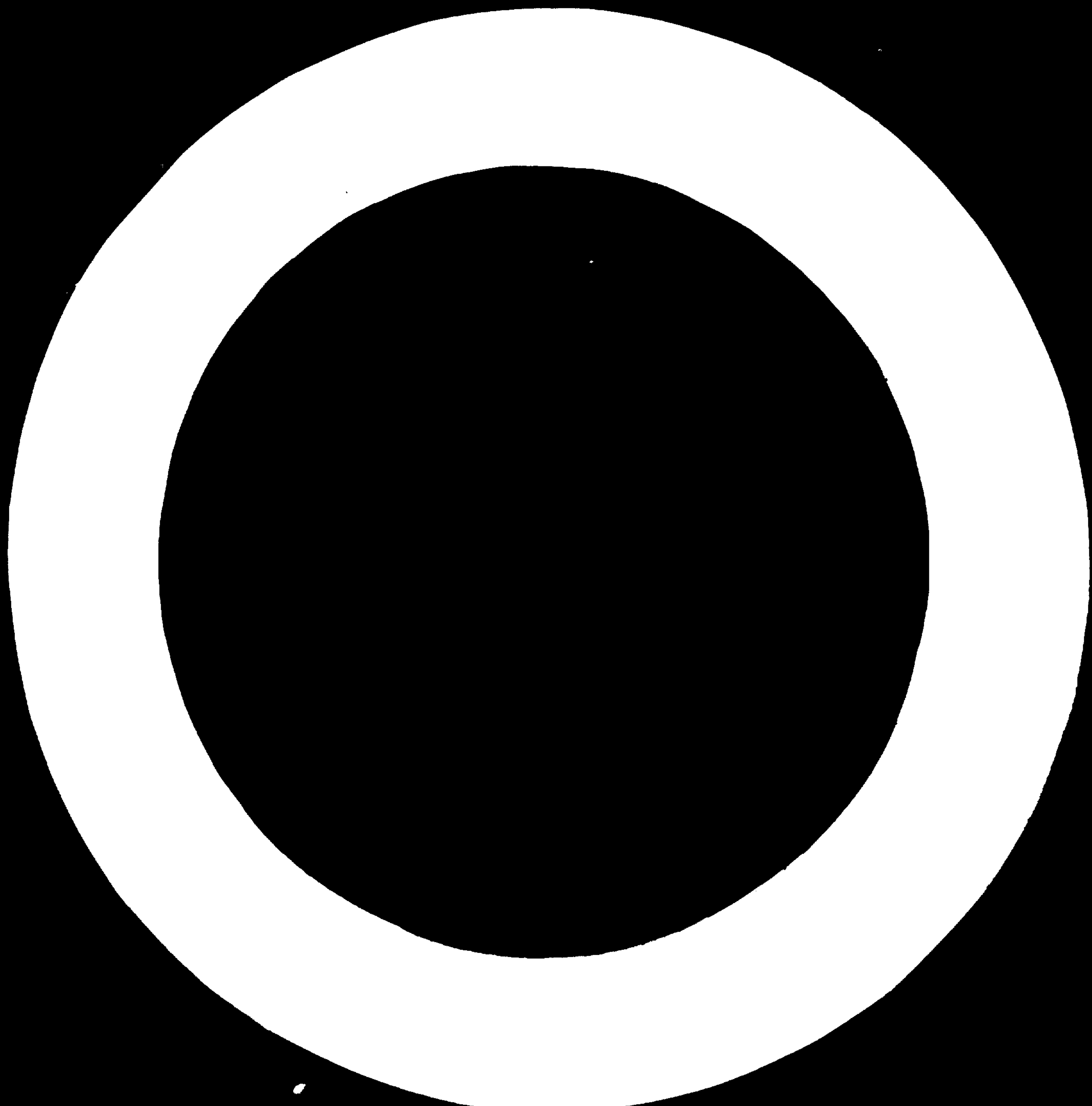
[31] See United Nations Committee for Development Planning, Report on the Second Session, Santiago, Chile 10–21 April 1967, *Plan Implementation*, section B, "Planning and plan implementation in Latin America".

(ii) The development of an advanced pattern of semantics for facilitating the proper understanding and transmission of actual figures.

(iii) The full utilization of electronic technology to be applied from top to bottom in the modern technical service of socio-economic information.

(iv) A comprehensively established institutional framework composed of the main producers and users of data. Within this framework the satisfactory co-ordination, with some degree of integration, of the macro- and micro-economic information systems should be achieved.

From this improved information basis it is hoped to obtain a regular flow of all significant economic data arranged according to specific needs (through a "tailor-made" tabulation). This would permit the development of new types of extensive and serious research required by a progressive economy, and especially by its most complex sector, which is modern industry. The improved knowledge of industrial economics and applied industrial sociology, with all the relevant facts, added to the advanced skills and technologies in the service of industry, will thus permit Latin American industry to make the best possible use of the internal and external resources available to it, and to take full opportunity of the economic integration movement in order to reach high enough development targets to ensure the prosperity of this great region. This optimistic picture can become reality in due course, provided that the Latin American governments demonstrate a sufficient understanding of these problems.



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