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CONSIDERATIONS ON SECTORAL GROWTH IN THE MANUFACTURING INDUSTRY [1]

by

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I N T R O D U C T I O N

1. CONCEPTS OF STUDIES IN SECTOR DEVELOPMENT

This Study tries to apply a new type of production function, which has proved useful on a macro-level and has led to highly significant results, to a lower level of aggregation, that is to say, to studying the determinants of sector output.

The concept of production function has so far been applied mainly on the highest level of aggregation, in order to define a country's economic output as a function of its main determinants. However several studies have recently attempted to use this instrument for describing the relationship between the output of sectors of industry and the inputs of their most important production factors.

It is interesting to begin with a short outline of the studies made so far. Obviously, we do not intend to present a complete list of the relevant literature including details of applied methods and results, for this would certainly be beyond the scope of this study. It does, however, appear useful and practicable to provide a general notion of the fundamental concepts underlying the research work done in this field by means of describing certain selected examples. This will also help to clarify in greater details in which respect our procedure corresponds to what has been suggested in earlier papers and where it differs from them.

Two fundamentally different approaches may be used in sector studies. One of them is demand oriented, describing the [illegible] products [illegible] case, [illegible] respec- [illegible] dependent variable, [illegible] determines [illegible] On the other [illegible] the attention is focus- sed on the estimation of [illegible] production functions. The sector output is still f o r m a l l y thought of as a dependent variable, in the sense that this variable appears on the left side of the equation. However, interpretation of the results of this estimation will lead us to a different understanding of the relationship which here may be understood as follows: The function does describe the relation between inputs and the output. Therefore, the relationship allows the evaluation of the output resulting from a certain input constellation. However, this knowledge may not be used for forecasts, since in the long run, the overall sectoral output will undoubtedly be determined by the demand. Still, such a production function can be of some interest for forecast purposes, as it answers the following question: Given a certain expected demand, to which extent must we expand the production factors in order to reach an optimal result? To a specific industry of a certain country or to an individual enterprise, the knowledge of such an optimal production structure gives a competitive advantage in that it leads to an increase in the market-share.

If several sector production functions are calculated, another question can be answered, which is without doubt of particular importance for developing countries: In which areas can a given factor potential be used to achieve the utmost advantage? The answer to this question follows from the fact that the production conditions are known for each industry. In deciding where our efforts should be directed to, it is thus possible to use best [illegible] of the [illegible] factor potential, since it can now [illegible] which the factor demand meets the supply [illegible] to the above mentioned question is obviously based on a further assumption, namely that an optimal use of the factors produces a competitive advantage which is relevant enough to justify the productive efforts.

A prominent example of a demand oriented study is the paper by Chenery and Taylor (5), which attempts to describe sectoral development essentially as a function of the overall economic development. It uses a broad data base which consists of both cross-sectional data and time series. The study succeeds in conveying a relatively consistent idea of the relationship between per capita income and output in different industries.

Our approach differs fundamentally from this study in so far as it does not use any demand components in describing the relationships but by trying to describe the production structure, it considers all relevant production factors instead. However, the two approaches resemble each other in methodology, as both try to use all the available information by relying on international cross-sectional data and on time series dating back as far as possible. But these problems of methodology will be dealt with later on in this study.

2. THE DIFFERENT INPUT FACTORS IN STUDIES OF SECTOR PRODUCTION

When trying to obtain an idea of the various studies in the field of estimating sector production functions, one will see that they are similar in many respects. In particular, they use one or several of the following factors: capital, labor, qualification, efficiency. It is mainly capital and labor that all the authors consider to be the principal determining factors of sector output. This is mainly due to the fact that the Cobb-Douglas Production function - a much used instrument in economics - takes account of these two factors.

The situation is different with respect to the two other factors. Either they are not used at all, or only one of them is considered. In this context two of the studies which try to introduce explicitly the qualification of the labor force should be mentioned. In one of his studies Fels (12) makes an attempt to supplement available estimates of the physical capital stock by estimating stocks of human capital. It becomes apparent that both factors combined are better suited to explain output differences than simple physical capital stock data. The report by Fels uses quite an interesting method for estimating human capital. We have used a very similar approach which will be described in more detail in the chapter dealing with methodology.

In the book "Manufacturing Production Functions in the United States 1957" (19) too, a qualification measure is explicitly introduced. The authors use however an entirely different method, for they make a distinction between two types of workers, i. e. "production workers" on the one hand and "non-production workers" on the other hand. Although we use a different approach in measuring qualification, our concept shows an analogy to the study, for we also distinguish between different types of activities, which also manifest themselves in separate factors: On the one hand, account is taken of the differences in skills of the workers as used in the information processing of the firms.

Moreover [illegible] determines the [illegible] making [illegible] function of [illegible] mentioned earlier in this study, i.e. efficiency, [illegible] one of the most important determinants of this factor is undoubtedly the different amount of management qualification which is able to make more or less effective use of the other production factors. The efficiency of factor use is explicitly determined in some studies, especially in studies using the CES-Function (1,6). Therefore, we may state that our concept, which will be described in the following, has many features in common with some very important studies in the field of sectoral production.

But this study also differs from previous research by introducing not only some of the factors capital, labor, qualification and efficiency, but all of them. The introduction of all of these components is of decisive importance. This is demonstrated by the result of our studies made so far, in which we have succeeded in explaining the differences in economic output of countries, by the different amount of their input of the factors mentioned above. We have thus arrived at the mathematical formulation of a "General Production Function". This relation, which has been derived from international comparisons, is our chief working hypothesis for studying the determinants of sectoral output and will be described in the following chapters.

[illegible]

1. [illegible]

The development of the General Production Function is based on a certain understanding of the functioning of societal systems in general. Therefore, we think it will be useful to start with some remarks on the underlying concept. At first, it should be noted that society can be thought of as a complex, multihierarchical system. This system is characterized by the interaction of a great number of subsystems, and it is this interaction which enables the overall system to function. Economy is one of these subsystems. Therefore, if we want to understand how this subsystem works, we must go beyond the economic sphere proper and consider also the interrelations with other subsystems.

Society has another characteristic feature in common with other systems, namely its ability of processing energy and information. The economic output of a social system is therefore governed by its capacity to cope with these two fundamental processes. Argumenting in such a way we are applying a concept which clearly shows the influence of K. W. Deutsch (9), who understands society as a self-developing cybernetic system: Superimposed on a control system, in which the material processes take place, there is a system of information receptors, information channels, information storing units and logical units. This network receives information on the actual situation, on environmental changes, and on the internal structure of the system. It then processes this information using additional information stored in the past. This process gives [illegible] to new information which regulate [illegible] to be taken, that is to say the commands [illegible] to the [illegible] mechanism.

The energy processing capacity of a system as well as its capability of material information are not sufficient to determine a system's economic output. A third component is needed to describe adequately the complex processes just mentioned. On the one hand, this third factor reflects the objectives toward which the efforts of this system are directed. On the other hand, however, the way the system is organized, i. e. the regulation and coordination of the energy and, in particular, the information processing operations, also ought to play a certain role. These two components are the chief determinants of the third factor, i. e. structure. This factor, thus describes the objectives of the system and the organisation of its energy and data processing subsystems, that corresponds to these goals.

This model, of which only a short outline has been given here, has served as a basis for the investigation of the societal subsystem economy. The chapters which follow will show how a country's economic performance can be described as a function of its energy and data processing capacity and of its structure.

2. THE FACTORS INFLUENCING ECONOMIC DEVELOPMENT

Applying the concept described above to the study of economic development we are led to formulate the following hypothesis:

$$y = F(m, b, p, r)$$

per capita income (y) = economic output

energy consumption ( ) (capital) = energy processing capacity

education ( ) = data processing capacity

structure ( ) = values, type of organisation, types of behavior

and mineral resources (r)

The use of some of the above mentioned production factors is more or less common practice.

2.1 Capital

The factor capital - which, as will be shown below, shows a close correlation with energy consumption - constitutes a common component of almost any economic production function. The relationship between capital input and economic performance has been dealt with in a great number of previous studies, and we find also attempts to measure this relation on the basis of international comparisons. A study by Galenson and Pyatt (15) is such an attempt to test the assumptions underlying the theory of growth by means of an international comparison. Thereby it has become apparent that *too simple assumptions are not suited to explain the international differences in economic growth.*

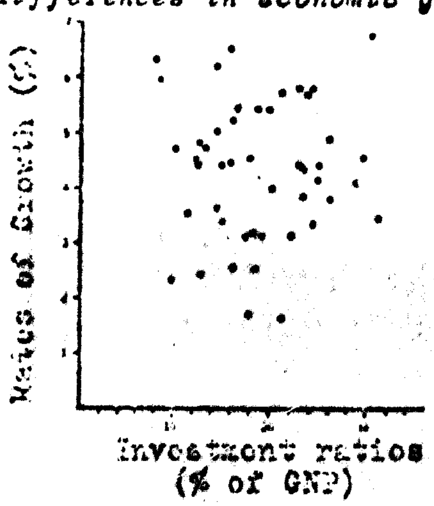


Fig. 1: Investments and growthrates in the countries of the world

Obviously this study has run into difficulties. The authors are confronted with problems which are very similar to those encountered in many other studies, relying on international comparison as a means of testing their hypotheses. For the most part these studies have not succeeded in taking account of the great number of geographical, cultural, climatic and political differences among the individual countries of their sample. In other words, the observed differences in income (dependent variable) result from heterogeneous influences which cannot be adequately explained by differences in capital inputs. They must be explicitly controlled and entered separately into the study. Not taking care of these influences corresponds to a non-fulfilment of the ceteris-paribus-condition.

2.2 Structure

This gives rise to the demand for an efficient methodology which takes account of these various influences. One such method would undoubtedly consist of forming groups of countries within which the combined effect of these non-observed but relevant influences on each country is nearly constant.

An important clue for the formation of such groups of countries could be provided by observing the health development in the different countries of the world since the beginning of this century. The time series from all countries of the world for which figures are available have shown, that the development of health is fairly uniform within groups of countries, these groups being at the same time sensible geographical aggregates. The differences between [illegible] groups are big enough to decide to which group a specific country actually belongs.

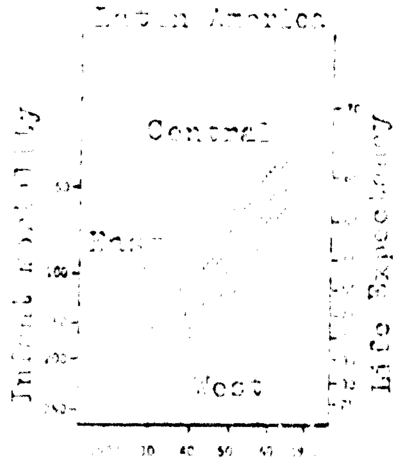


Fig. 2: Health development in South America.
There are three distinct zones, the La Plata States, the Central American States and the rest of South America (Andean States).

Without going into details of the problems encountered here, we may interpret this observation as follows: Health statistics provide one very fundamental indicator of the development of a society. Here we are measuring the "pulsation" rate of the societal system as it were. It is governed by many factors which cannot adequately be measured directly. We may consider the adoption of medical innovations as one part of a more general social process, which is the adoption of innovations in general and which we call "learning process" - this hypothesis will be supported below by international comparisons of the relationship between education and economic performance. Thus, the regions differ as to their readiness and capability of adopting innovations. This general statement is based on the observations made in one subsystem of the society, namely the health system. For it is the greater or smaller readiness to adopt medical innovations that is responsible for a more rapid or slower improvement of health conditions.

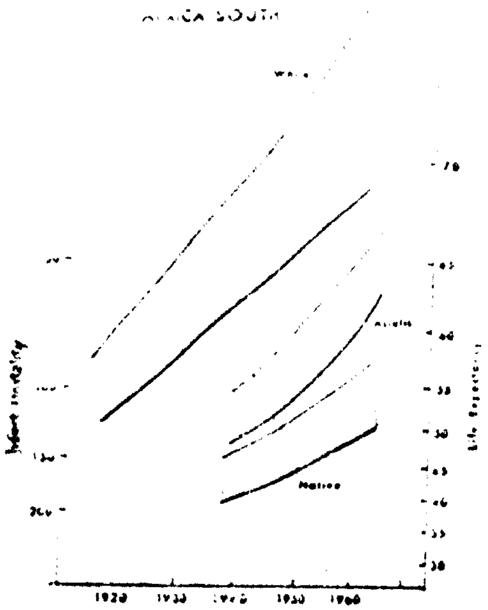


Fig. 3: Health development of the African, Asian and European population groups in South Africa

The diagram refers to the situation of countries whose population comes from three different civilisations.

The differences in health development in the various groups of the population are striking. The development in each of the groups resembles that of the corresponding region from which the groups originated. This leads to the interpretation, that *the "structure", i. e. the value system, the patterns of behaviour and the types of organisation constitute an important factor* responsible for the differences observed with regard to the development of health.

The European countries can also be classified into zones according to their different health development.

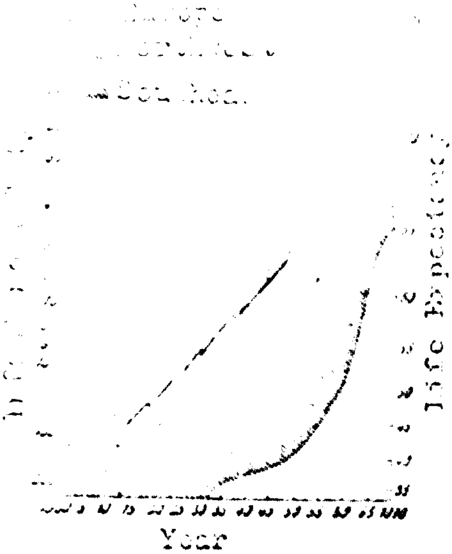


Fig. 4: Health development in Europe

There are three zones, Northwestern Europe, Southern Europe and Eastern Europe. Southern Europe and Eastern Europe show much the same development.

Applying the classification in groups of countries as presented in Fig. 4 to the data of Fig. 1 in order to separate the two groups of European countries we arrive at a meaningful relationship:

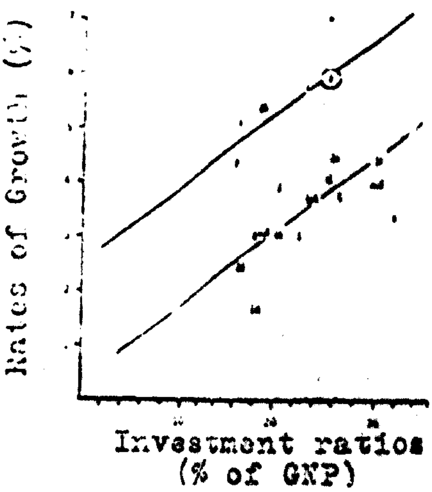


Fig. 5: Investments and growth rates in two groups of European countries

The observations in this diagram are data taken from Fig. 1. They show, that meaningful relationships exist within groups of similar countries.

The regression lines showing economic growth per unit of investment lie on different levels in countries with different political and cultural system.+ This observation suggests, *that the differences of the political and cultural structure affect the effectiveness with which capital is used*, thus the energy processing capacity. In addition to this factual finding, the evidence presented gives rise to the methodological remark, that reliable results in international comparisons can only be obtained if due account is taken of the ceteris-paribus-condition.

2.3 Education

The majority of the studies made so far have considered man as an element of an undifferentiated factor "Labor" and have used just the number of people in the working force as one of the input factors. Various abilities, differences in the level of education (which correspond to differences in information processing capacity) have so far been neglected or have not been examined in relation to the other factors. But if we take a look at Fig. 6 we find, that it is obviously *a country's level of education* which happens to be *very significantly correlated with its economic performance* and that, therefore, this factor has to be included in a production function.

+ A relationship similar to that presented in Fig. 5 has been pointed out by Krelle (26) to confirm the close fit between capital investment and economic growth as formulated by the theory of growth. This study used essentially data from industrial countries. This, however, corresponds without being spelled out explicitly to the classification of countries according to the criterium of similar structure.

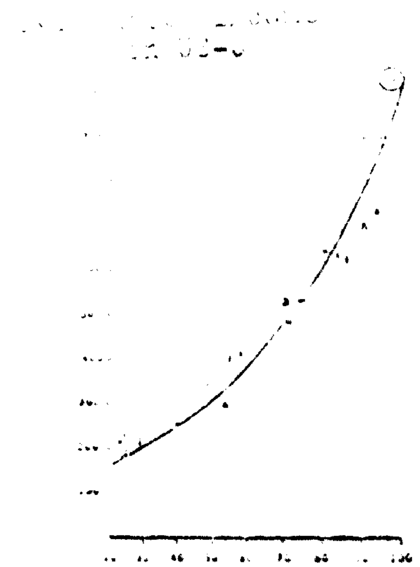


Fig. 6: Per capita income and literacy rates in groups of countries with similar structure

The diagram shows the close fit to the exponential relation between the economic output and level of education.

Closer examination of the relationship between education and income in a cross-section of countries reveals that the aggregation of countries according to the criterion of similar health development is also a good criterion for this purpose. The regression coefficient of the education is practically the same in all the regions.+ The intercepts of the regression lines however differ from one zone to the other. Significant differences however do occur only between five large zones of the world.

The evidence presented thus far can be summarized as follows: There is sufficient empirical support for concluding that a country's ***economic performance is mainly determined by three factors, namely capital (energy), education (information) and structure.***

+ Regions are defined by the criterion of equal health development.

[illegible]

[illegible]xamination of the o[illegible]put differences among the countries of the world reveals, that, apart from the factors discussed so far, the occurence of *mineral resources is an additional relevant factor*.

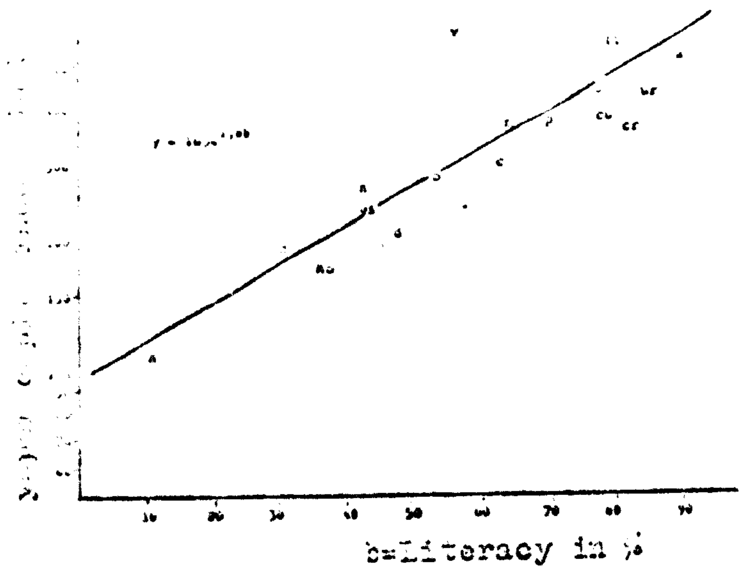


Fig. 7: The special position of Venezuela, Trinidad and Tobago in the comparison of per capita income and literacy in South America

Venezuela's large deviation from the regression line is very striking and can be explained, even quantitatively, by this country's important oil production.

The important influence of mineral resources on the level of economic output is supported by observations in other regions, in particular in the countries of the Near East and in Africa.

2.5 Combining the factors

If we now combine all the individual [illegible] mentioned separately so far we end up by [illegible] a functional relation-

... which explains the international differences in economic performance very well. The combination of capital, education, structure and natural resources has a much higher explanatory power than the simple regression on a single factor. This is demonstrated graphically in Fig. 8.

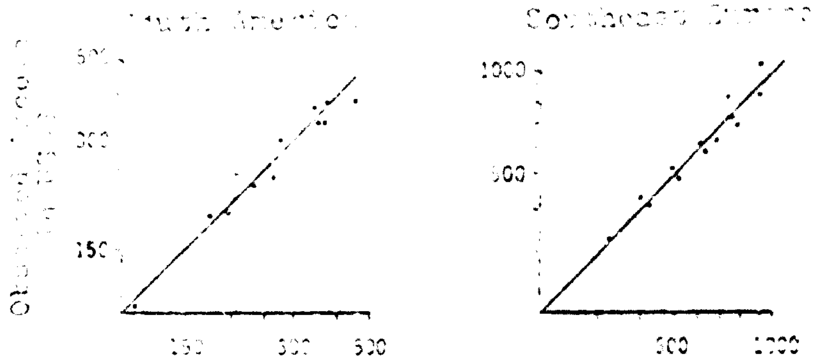


Fig. 8: Comparison of observed per capita income and its estimated as calculated value when account is being taken of all the factors

All factors combined yield a much higher explanatory power. Discrepancies between observed and calculated values are insignificant.

The individual factors are combined by means of the so-called General Production Function, which will be described mathematically in the paragraph which follows.

3. MATHEMATICAL EXPRESSION OF THE "GENERAL PRODUCTION FUNCTION"

$$y = p_{t,z}\, m^{\frac{1}{4}}\, a^{\frac{3}{4}}\, e^{b} \left[\frac{1}{2} \left(\frac{m^{0,25}}{e^{b}} \right)^{-\rho} + \frac{1}{2} \left(\frac{e^{b}}{m^{0,25}} \right)^{-\rho} \right]^{-\frac{1}{\rho}} + 0,8\, r \quad (1)$$

- y ... per capita income, measured in US-dollars per inhabitant (annual)
- $p_{t,z}$ .. efficiency parameters
- a ... employment ratio
- m ... per capita capital input, measured by means of energy indicators

n ... [illegible] educational [illegible]

r ... [illegible] value produced by [illegible] operations, etc.

Expression [illegible] This describes [illegible] of additional input units of capital or educational effort when departing from the optimal relationship (see below).

The exponent of m and the coefficient of b have been estimated in a cross-section of countries by econometric means. While the parameters are not exactly 1/4 or 3, respectively, they do not depart statistically significantly from these values used for the sake of simplicity.

A closer look at this equation reveals an interesting relation between the General Production Function and the well known Cobb-Douglas Function which is of the type most frequently used in computing and estimating macro-economic production functions. It has been estimated for the first time for the United States and describes the relationship between both capital and labor inputs and income. *The Cobb-Douglas Function can be regarded as a special case of the General Production Function:* if the two factors education and structure remain constant (social technology, organisation and management, values system etc. remaining static). In this static case the General Production Function becomes formally identical with the Cobb-Douglas Function.

If we convert the per capita relationships of equation (1) to total values, while assuming no major departure from the optimal relationship (leaving out the expression for complementarity) and disregarding natural resources, we get

$$y = \frac{Y}{V} = P_{tz} \left(\frac{M}{V}\right)^{\frac{1}{4}} \left(\frac{A}{V}\right)^{\frac{3}{4}} e^{b} \; ; \; Y = \underbrace{P_{tz}\, e^{b}}_{\text{constant}} \cdot M^{\frac{1}{4}} A^{\frac{3}{4}} \qquad \text{(1a)}$$

capital letter ...... total value

V ...... population

[illegible] of American production from [illegible] to [illegible] (Cobb and Douglas) could equally well be [illegible] the general production function, assuming education and structure to have remained more or less constant over this period. As a matter of fact (as can be seen in Fig. 9) the education explosion in the USA started after 1[illegible]. Similar observations might be true about the structure which possibly began to crumble and become dynamic only with the onset of the Depression.

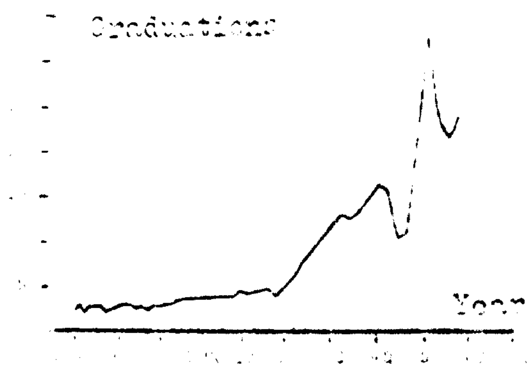


Fig. 9: Number of college graduates in the USA for the years 1870 - 1970

It is clearly evident from this diagram that the education explosion in the USA began only after 1920.

4. CONTRIBUTION OF INDIVIDUAL FACTORS TO THE PERFORMANCE OF THE ECONOMY

4.1 Education as a factor of production (qualification of labor)

When it came to the task of measuring the information processing capacity of the system - which is closely tied to the qualification of labor - figures pertaining to the educational structure were used. These figures were derived from enpertinent data in three different levels. They represent the amount of primary, secondary and higher education in the respective countries.

Education appears to be a more reliable measure of qualification of labor than, say, length of employment - which could be taken as an indicator for learning-by-doing. This is so because the latter is not simply time-dependent, but is highly modified by the native intelligence, educational level, and willingness to learn of the person subjected to this process. If one, on the other hand, uses educational statistics as indicators, one arrives at a measure probably containing all the components just mentioned. Such educational data not only state mere length of training, but also - as a result of drop-outs and retardation - the components "adaptability" and "willingness to learn".

Summarizing the empirical evidence concerning the relation between education and the other factors of the General Production Function we may state: first we find an *exponential relationship between the qualification of labor (i. e. education) and economic performance;* then we observe that there exists a certain amount of *complementarity between qualification and capital;* and finally we see that a similar relationship holds for the subfactors of education, i. e. *primary, secondary and higher education are substitutable only in a very narrow range.*

4.1.1 Exponential relationship of education and income

As opposed to those concepts which understand the contribution of education to income as the rates of return to human capital (i. e. capital accumulated in the process of education), [illegible] very strongly the existence of an exponential relationship between the two variables. That is to say, that a *linear increase in education produces an exponential increase in the economic output*. If we interpret, moreover, education as an indicator for the information processing capacity of the system, we see that this exponential relationship can be deduced from the basic concepts of information theory.

4.1.2 Time-lag between education and its economic effect

Another important aspect to be dealt with when scrutinizing the relationship between education and economic output is the fact, that *a time lag of ten to fifteen years exists* between an "injection" in one of the categories of education and its eventual effect on the economy. It is this time lag which makes a trial-and-error control of the educational system via the labor market so extremely difficult and which makes this type of empirical market feed-back so prone to oscillations.

4.1.3 Complementarity of factors

The factors education and capital do not occur in random combination, but we observe only a limited degree of substitutability between these factors. This implies, that *the information processing capacity is tightly connected to the energy processing capacity*. An expansion in one sector only produces a deviation from the optimum relationship. Such a deviation is characterized by a suboptimal use of the factor which is in surplus.

Empirically, we have arrived at the following optimal relationship:

$$m^{1/4} = e^{b} \qquad (2)$$

A departure of either education or capital from this optimal relationship results in *the relatively smaller of the two inputs becoming a bottleneck for the economic performance of the system.* In such a case, increasing the proportionately larger input will not yield a significant increase in production.

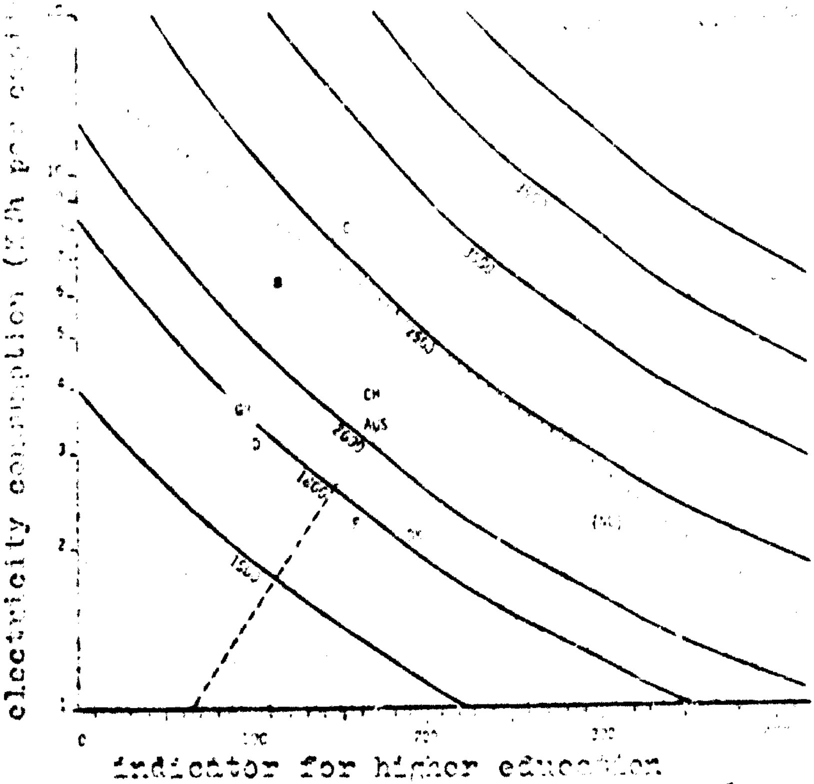


Fig. 10: Limited substitutability of education and capital. The curvature of the isoquant describes the limitation of substitutability of the two factors. Unlimited substitutability would correspond approximately to the dotted tangent of curve 2500. The interrupted line represents optimal relation.

4.1.4 Complementarity of subfactors

The concept of limited complementarity can be meaningfully applied also to the various categories of education. It turned out that the numerical relation between the various educational categories differed from one group of countries to the other. *Furthermore, there exists an optimal relationship, in the case of which the economic effect of education...*

(as a whole) is reached. If one of the educational categories is less developed, than this optimal relationship demands, this level becomes a bottleneck of education. Such a bottleneck exists e.g. in the Arabic countries in the field of primary education, while with the Latin-American nations the shortage is in secondary education. The latter applies to the countries of Southern and Eastern Europe, too. Great Britain and her former colonies show such a bottleneck when it comes to higher education. Investing in that category of education which represents a bottleneck yields the highest returns. An identical investment in a "surplus category" produces much smaller gains.

4.2 Capital as a factor of production

In order to estimate the General Production Function the energy processing capacity is measured on the basis of data for the total energy consumption of a country as well as by using the figures for electric power consumption. In using these measures it became apparent, that for countries, for which capital stock time series exist, these time series have a remarkably high degree of correlation with an indicator reflecting the changes in total energy consumption and in the use of electric power. This can be expressed in the following relationship:

$$k = m_1^{0,5} \cdot m_2^{0,25} \qquad (3)$$

k = capital per capita
m_1 = energy consumption per capita
m_2 = consumption of electricity per capita

The fact that energy consumption turns out to be such a useful capital indicator has its deep-lying causes. Introduction of "artificial" energy into the production process was the characteristic feature of the First Industrial Revolution. If one wanted to put a point on it, one might even go as far as saying that capital stock were an indicator for the utilization of "artificial" energy in the production process. In any case, however, "artificial" energy turned out to be the prerequisite of mechanisation. This - at least in part - explains the close relationship between energy utilization and capital.

The contribution capital makes to the economic output remains more or less the same, regardless of whether we use the General Production Function or the Cobb-Douglas Function in its computation. Furthermore, in the General Production Function it corresponds at least approximately to the contribution of capital to output arrived at by using the Marginal Productivity Theory and assuming perfect competition , when viewing capital's empirically observed returns.

Another such observation relates to technological development in the production process. Looking at the world-wide development over time, the relation of electric power used to total energy consumption is changing, since the use of the former increases by a square ratio to the increase in total power needs. This relation of electric to total energy consumption is frequently used as a measure for the technological level of the stock of capital (machinery, etc.). Thus it is related to capital-induced technological progress. One study by P. B. Du Boff (10), amongst others, seems to support this interpretation. In dealing with the development of the United

States in the years from [illegible] to 1962, Du Boff states: "... technological innovation frequently is difficult to measure quantitatively. Output per unit input does rise for non-technological [illegible] ... but there must be important cases where the reverse is true. One such case seems to be electrification of manufacturing industries. Here the rate of technical change can be reasonably well measured in terms of horse power capacity of power equipment and consumption of power. Furthermore, this 'revolution' in the application of power can be viewed against the background of clear, known changes in manufacturing productivity ...". And, after dealing with the various functions and uses of electric power in plant modernization, he states: "Electric power affected the whole scope of these processing services, by revolutionizing the application of energy to materials."

Summarizing we can say that *energy indicators can be used for measuring capital stock*. Doing this, we take, moreover, into account actual utilization of capital, which corresponds to what Solow calls "Employed Capital". It encompasses only that part of capital defined as "active" capital stock (viz. plant and machinery excluding buildings).

4.3 Structure as a factor influencing the production

4.3.1 Static features

Measured in a cross-section, the efficiency parameter $P_{z,t}$ of the General Production Function is the same for all countries belonging to one group at a given time. As previously stated, analizing efforts in the field of health makes a division of countries in 14 distinct groups possible. Some of these groups have very similar efficiency parameters and thus can be aggregated into Greater Zones. The characteristic trait common to all component states of each Greater Zone is a constant relationship between capital and education effort on one and economic performance on the other hand. *Countries within each zone are using capital and education with equal efficiency.*

In the mid-sixties, using these criteria, the world could be divided into five Greater Zones with differing efficiency parameters.

Fig. 11: A map of Greater Zones

It is interesting to note that Greater Zones with differing efficiency parameters - which were calculated using only the data for per capita income, education, capital and natural resources- strongly resemble the various groups of countries and areas of a map showing dominant religions. The zone of maximum efficiency consists almost exclusively of Protestant nations, the one ranking just below it of Catholic countries - including Greek Orthodox and formerly Christian countries of the Mediterranean region. This would seem to indicate that Max Weber's theories could be to some extent empirically verified (51). The results of McClelland's(31)research can be interpreted in a similar way.

The delineation of these Greater Zones of varying efficiency leads one to suspect that religion is of decisive importance [illegible] comes to economic development, i. e. that marked differences in efficiency are [illegible] behavior pattern and their appropriate structure of social organisation.

4.3.2 Dynamic feature

In a chronological analysis of world-wide development, or of the development of a specific group of countries, changes of the efficiency parameter over time become apparent. This – compared to the old residual factor of the Cobb-Douglas Function – *new residual factor of the General Production Function reflects world-wide increases in efficiency.* These increases result on one hand from the development of new technologies and their adaption to the production process and on the other from improvements in the organisation structure. The differences in the development of the efficiency parameter over time that exist between the separate groups of countries result from varying changes in the structure, i. e. the culturally determined behavior patterns and corresponding forms of social organisation.

4.3.3 Complementarity between production factors and structure

It is highly likely that the complementarity mentioned in 4.1.3 also exists between the production factors capital and education on one side and the structure of the system on the other. This means that *a quantitative increase in the factors capital and education must be matched by corresponding progessive changes in the structure of organisation* in order to enable the system to process and utilize effectively ever increasing quantities of data and energy. Changes in values and attitudes on one hand make changes in the structure of organisation possible, on the other hand they themselves actively contribute to such changes. When structures have become rigid, and values are formally maintained, they soon become either hollowed out or changed from inside.

4.4 Natural resources as an input factor

Natural resources are taken into account according to an index based on the total value of mining and crude oil production. Using regression calculation, one finds that *approximately 80 % of the value of natural resources are added to the income determined by the other factors.*

5. SUMMARY OF THE RESULTS HITHERTO OBTAINED

The results thus far obtained by our method can be summarized as follows:

The effectiveness of the social sub-system economy can be described by the General Production Function, which shows certain characteristic traits. It describes economic output in terms of both material and non-material inputs, as well as of systemic structure. The input factors are related to each other according to limited substitutability (partial complementarity).

The concept of defining society as an energy and information processing system with varying structure has turned out to be extremely useful in international comparisons on country level, aimed at describing and explaining their varying economic performance. It is only natural that one should want to broaden this successful concept by adapting it to

other investigations. A particularly important aspect is in this connection the question, if and to what extent the General Production Function can be meaningfully applied to describe the output of individual branches of production or sectors of industry.

II. TRANSFERRING THE CONCEPT OF THE GENERAL PRODUCTION FUNCTION TO SECTOR PRODUCTION FUNCTIONS

1. IS AN INDUSTRY A MEANINGFUL AGGREGATE FOR THE ESTIMATION OF PRODUCTION FUNCTIONS?

1.1 The concept of energy- and information processing applied to sectors of production

Countries are societal systems as defined above. They have a clearly marked area of autonomous decision-making, well delineated structure, governing the formulation of goals and decisions, and are sufficiently set off from surrounding other entities to develop specific attitudes, modes of behavior and forms of organisation. None of these criteria, however, apply to the entity "sector of industrial production", because the individual branches are n o t societal systems. They are, rather, the sum of social systems, namely firms, to which the above criteria d o apply.

Thus our considerations are dominated by the question, whether by aggregating firms their properties as social systems are being lost or whether *the basic relations between energy and information processing remain intact* also in the aggregate. Naturally, for the time being, we must forego entering the immanent problems of aggregation in detail.

1.2 A pragmatical point of view

We prefer to state more or less pragmatically that for the purposes of broad research into economic interrelations, using other data than country-studies and going into greater detail than the latter, the industry level seems to be the nearest - if not the sole - meaningful level of aggregation. Widespread *representative data on efforts and achievements of a majority of individual firms are simply not available.* In the following, we shall attempt to muster some additional reasons why - beyond the pragmatic point of view - the use of branch figures appears advisable.

1.3 Additional influencing factors on the enterprise level

If we were to investigate individual firms in order to discover the connection between their economic performance on one hand and their structure as well as energy and data processing capacity on the other, we should undoubtedly have to consider two more factors: *technology applied and the size of the enterprise.* Technology presumably influences predominantly the relationship between the inputs "capital" and "education", while differences in the size of enterprises would find expression in the relationship between the structural factor and the other two factors. - Now in what way does aggregating individual firms into branches of production influence these variables?

1.3.1 Sectors of industry as aggregates of enterprises with "similar" technologies

Among the two influencing factors, technology is doubtlessly the factor which is more difficult to quantify. Yet - even with all due statistical reservations - it appears to be exactly [illegible] factor which can be in [illegible] way inter-preted as being the reflection of the aggregation [illegible] into sectors of industry. Two [illegible] which affect dif-ferences in the technology are differing materials on one hand and differing ways of transforming them on the other. But exactly in these two respects the individual sectors differ from each other. Their very names signify that they generally use different raw materials or categories of semi-finished inputs. As for what is done with the materials, we can at least distinguish between two major groups: branches that transform raw materials into materials or finished products, and others whose technology is primarily geared to the shaping (casting, forging, punching, milling, etc.) and combining (laminating, coating, etc.) of materials. This leads us to believe that the definition of industries tends to result in aggregates with similar technologies. Thus it is *safe to assume that firms within a branch are using more or less the same technology* - if that concept is defined as losely as we have above. This would mean that parameters estimated for the branch would also be applicable and meaning-ful in describing relationships within the firms.

1.3.2 Varying size-structure

The bias introduced through aggregation that results from the varying size-structure of enterprises from one country to another is an entirely different matter. These differences will be important inasmuch as size of enterprise tends to influence the organisation of energy and information proces-sing, and thus the structure of the firm as well as the significance of its management. Therefore, in a sector study we should be able to control this factor. Consequently, such an undertaking would have to aim at either suppressing or taking account of the influence of differences in size-structure of enterprises on the results obtained.

1.4 Conclusion

In summing up we note, that, in spite of all justifiable theoretical objections, estimating sector production functions - for purely pragmatic considerations - appears to be a priori meaningful. Aggregation takes into account the influence of technology in such a way, that the influence of this variable is decisively reduced when estimating sector production functions. Doubtlessly, one of the main remaining problems is adequate consideration of the differing size-structure of the different observations - be it in time series or cross-sections.

The following parts of this study shall deal with the problems arising when transferring the successful concept of the General Production Function to the development of sector production function. In doing so, we pre-suppose the following analogies:

General Production Function:	Sector Production Function:
Education	Qualification of labor: social information processing and work-related skills
Capital	Capital
"Structure" (cross-section)	Management, human relations, organisational structures
"Structure" (time sequence)	Technological progress and adaptation of organisation

All values are calculated on per capita basis. This leads to the following analogy:

Population x employment ratio	Labor force

2. THE GENERAL PRODUCTION FUNCTION AND THE INPUT FACTORS OF SECTORAL PRODUCTION

2.1 Qualification of labor

2.1.1 General considerations

In contrast to the Cobb-Douglas and other similar production functions the General Production Function has in addition to the generally used factors the term

$$e^{b}$$

This expression represents a measure for the qualification of "labor", which in many other production functions is expressed purely quantitatively and without any attempt to measure quality. In our international comparisons this measure of quality could be expressed quantitatively by the amount of educated people in the respective countries, and interpreted as data or information processing capacity of society as a whole.

In all considerations regarding the transfer of the qualification measure used in the General Production Function to sector production functions the question soon arises whether the concept of social information processing is valid and meaningful on the sector and individual-enterprise level, too. To what extent is it feasible - within the area of qualification - to measure or quantify sub-categories on the basis of available empirical data, is one question, and "should the concept be widened" the other.

We are inclined to think that the application of our concept (social information processing)is useful also on the individual-enterprise level, since the production process is guided by decisions arrived at by processing information according to [illegible] "[illegible]", i.e. an organisation structure allocating responsibility to various persons. Sub-categories, however, distinguishing between primary, secondary and higher education as we used on country level, can at present not be measured on sector level by the use of available statistical data.

The further question of whether the concept of social information processing in its present form is sufficient and adequate to describe qualification satisfactorily for sector production has to be answered. Our basic concept, which defines society as a learning system, leads us to considerations which make a further subdivision of qualification desirable, when a development at the sector level is to be studied. This subdivision derives from the varying functions and positions of personnel within the information processing system of the individual enterprise and from the interaction of capital and labor in the production process. For the description of these interactions we need the definition of a new type of capability: "skills". "Skills" are those capabilities directly needed in the production process, say in the operation of machinery. This new factor "skills" obviously constitutes a second category of qualification, which, however, is closely related to the first, which is social information processing capacity and has already been described above. We shall attempt to demonstrate the usefulness of this approach in the course of our treatise.

In summing up we can state that the measuring *not only of the social data processing capacity but also of work-related skills* yields suitable indicators for the description of "quality of labor" within a given sector.

2.1.2 Work-related skills

Here we are dealing with such *skills as are required to effectively connect the information processing subsystem to the energy processing subsystem.* Thus they are skills exercised in close relation with the input factor capital. Persons possessing these skills are the "operators" who - in a twofold way - represent a juncture point of the system: On one hand we find a close interaction between man and machine, in which man represents the data processing part of this closely defined production system, while one of the functions of the machine is to provide the energy required. On the other hand, the operator is closely tied to the social information processing system: we can go as far as seeing in the operator its output unit.

Communication between different individuals employed in this category is comparatively limited, while relatively narrowly defined goals are the objective of their activity. Learning-by-doing plays an important role in expanding the faculties of the operators. Thus it seems advisable to provide training in and for these qualifications somewhere near the site of production, preferably in facilities owned by the firm or closely related to specific sectors.

It is interesting to reflect - taking into account the two fundamental functions of the factor labor just outlined - what task training in vocational schools seems to perform. This type of education would, so to speak, provide the basis for linking the "operators" with social data processing - simply by giving the student the theoretical background for understanding his own role or function. Thus, vocational schools provide a "common language" for both operators and social data processing. This is important, since we can regard each operator as an outpost of the data processing system.

After all, the operator d o e s have an important function as "information receptor" in the production process. Taking this view, vocational schools would primarily have to provide their students with the answers to the WHY of their eventual work, rather than stressing the HOW. The latter could be taken care of - as mentioned above - in various types of on-the-job training. It is exactly this knowledge of HOW, the skills which are of a great importance in many countries with an economic system not yet fully developed. Therefore, if we look at the historic development of industrialized countries we find, that before the Industrial Revolution the prevalence of skills was mostly decisive for regional economic success, whereas in the process of industrialization the importance of social information processing became ever increasing.

The historical observations suggests also the hypothesis that the mastery of specific skills can be tied to comparatively narrowly limited local conditions. This often finds expression in strongly locally rooted traditions of certain professions (artisans, craftsmen, etc.) and partially explains the often dominant role certain branches of production play in a specific region. It is the qualification of workers which would appear to be a suitable indicator for this category of qualification of labor .

2.1.3 Social information processing within the enterprise

The social information processing capacity is responsible for the over all control of the production process and for its integration into the respective markets.

Here we are dealing with the area that *describes the ability of the system to handle, transmit and store information and to effect decisions*. With this factor we describe the efficiency of that part of the system which controls its entire production. This subsystem e. g. takes care of the following activities: research and development, constructive preparation of production as such, inventory control, accounting, marketing, promotion and advertising, on-the-job training, etc. The efficiency of this subsystem is strongly influenced by interpersonal relations among the people sustaining this process, since the exchange of information is a necessary prerequisite for its processing. The overall performance of social data processing cannot be viewed as the sum total of the efforts of a number of individuals - actually, it is the product of the interrelationship between their efforts. Social data processing appears to require general qualification and abilities which can be taught independently with regard to either enterprise or sector of the economy. They are, however, closely related to certain attitudes and patterns of behavior. These, in turn, are determined by the country's structure. A suitable measure for social information processing capacity within the individual enterprise seams to be the qualification of its employees.

2.1.4 The interrelationship between social data processing and the skills of the working force

It is assumed that a semi-limitational relationship obtains between these two categories. That would mean that *an increase in production under conditions of static technology can only be achieved by a balanced increase in both inputs.* It is to be expected, however, that the equilibrium-relationship between the two categories would be changed or somehow affected by a dynamic change in technology, i. e. a change of technology over time in one sector of production would result in a shift of this optimal relationship.

In the course of a continuing change in technology, the importance of the social data processing capacity will increase at the expense of the volume of work-related skills. If this assumption holds, then a change in technology would normally and generally find its expression in a decreased demand for the "work-related skills", whereas the scope of social data processing would grow.

2.2 Capital input and technology

2.2.1 General considerations

We have already pointed out that the General Production Function is similar to other production functions in that it uses capital as one determining factor of economic performance. Moreover the relationship between the two variables is similar to the one estimated using other approaches. There are, however, differences in the way capital has been evaluated, since the General Production Function has been estimated using data for energy consumption. This concept seems to be promising and can be transformed to the estimation of sector production functions. Finally we see, that one concept of subdividing the production factor "labor" into two subfactors gives new insight into the mechanisms of interaction between capital and labor. In fact we observe a substitution process between capital and skills in the process of technological development, this being accompanied be a "balanced" increase of energy and information processing capacity reflecting a complementary relationship between capital and social data processing capacity.

2.2.2 Capital and energy

For the estimation of the General Production Function the dominant problem was to measure energy processing capacity and to determine its relation to economic performance. As we progressed in our investigation, it became apparent that the development of energy processing capacity is closely related to the amount of effective capital in a given country. However, since in a study focussing on individual sectors of the economy the problems of technology assume greater importance, we shall deal in this part of our study with the factor "capital" - and not just with energy processing - in greater detail, at the same time attempting to somewhat analyse its function.

Without doubt the Industrial Revolution was characterized by the use of "artifical" energy in the production process and by the subsequent tremendous increase in the utilization of this type of energy. The use of more and more machinery kept step with this trend, and - necessarily - the capacity of the economy to utilize energy is expanding proportionally.

2.2.3 Capital and skill

The industrial development leads to the following phenomenon: *The scope of "skills" the capital can perform is constantly increased.* Thus the function of capital can be divided into two main components: on one hand capital is used to process energy, and on the other hand it takes over "skill" functions from the labor input. "The power-engine as a source of motive capacity had to be ... linked to a machine performing the work ... Only after these two were linked came the next big step forward in the fruitfulness of crafts production." (41 p. 80).

The concept of capital taking over certain skills gives new insight into the problems of capital-induced technological progress. With increasing mechanisation the "taking over" of skills by capital takes the form of "information storage",

e. g. by the use of casting molds, shaped metal punches, or controlled mechanical advance at lathes. In the case of automation, the machine also takes over the control function from the operator. A fully automated production facility no longer has need for operators (in the sense in which we have hitherto employed this term), but still for social information processing. One can state quite definitely that one of the components of capital-induced technological progress is the take-over of skills formerly in the domain of the operator by the machine. Thus, as technology develops and progresses over time, a substitution of *capital*-related skills for *labor*-related skills takes place.

To avoid giving the impression that we are oversimplifying matters, it should be pointed out that the "take-over" of "skills" is only o n e of the aspects of capital-induced technological progress. There are e. g. kinds of progress in which other production inputs are dropped or reduced. In such cases we are dealing with technological progress, i. e. based on economizing on energy or material.

2.2.4 Capital and social information processing

The described process of substitution, however, does n o t affect, i. e. reduce, the information processing capacity of the system in the same way. Among the corollaries of an increase of the capital input are both an increased use of energy and thus an expansion of the production level. This expansion in turn can only be meaningfully effected by increasing the social information processing capacity adequately - especially in such areas as marketing, research, inventory control, accounting, etc. - Thus the substitution of capital for labor as part of economic development emphasized by all the traditional theories does not necessarily contradic our observation, that energy and information processing capability of a system are tied together in a more or less complementary relationship.

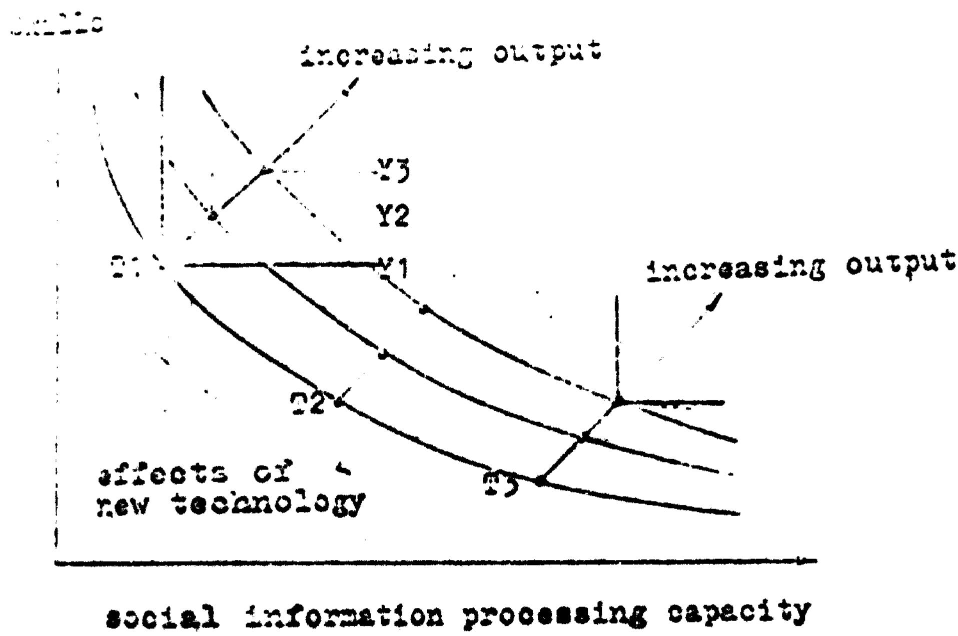


Fig. 11: Substitutability and complementarity of the two types of qualification of labor

With increasing output and constant technology we expect complementarity between "skills" and social data processing capacity. It is technological progress which brings about (through capitalization) an effect which resembles substitutability between capital and skill and in this way between the two types of qualification.

In recent development we find another type of substitution processes which affect the information processing subsystem. A new type of capital, i. e. computers, takes over some routine functions of the individual. This is revealed by the fact, that computers are mostly used in those sectors, where the proportion of employees - our measure for information processing capacity - is relatively high.

2.3 Management

2.3.1 General considerations

The General Production Function makes the effectiveness of production factors dependent upon the efficiency parameter. In transfering this concept to the situation in a specific sector of production, this efficiency parameter is related to the tasks of management. The tasks of management - which must not be related to ownership of an enterprise - consist, aside from determining the amount of factor input, in the determination of aims and goals, in decisions pertaining to the type of technology used, and in the design of structures for social information processing. In other words: management must determine the WHAT and HOW of production. The WHAT is expressed in terms of goals of production; the HOW means - within the enterprise - decisions on suitable technology and development of corresponding organisation structure for their implementation. Externally, the HOW governs competitive strategy, sales and promotion. An important task of management lies in the field of innovation, i. e. the aquisition and adaption of new techniques and technologies and the harmonious adjustment of organisation structure to the resulting changes.

In terms of cybernetics, production goals and their selection can be likened to the establishing of desired points of operating. The realization of these targets is controlled by the information processing system guiding the production system. Aside from establishing goals and determining the scale, on which factors of production are used, management must also draw up the schematic of social data processing, and bring about and cultivate attitudes and patterns of behavior adequate to and consistent with this schematic. In this process human capital is, so to speak, the raw material, from which management builds the social information processing system and its interfaces with the production system proper. The efficiency of the production system depends on the control system management has provided.

The General Production Function has not been integrated into a closed model of economic development. This means that exogenous variables not further explained or defined enter into this function. These are the factors of production "capital", "education" and "natural resources".

In a sector study of production, the situation is only partly similar. Among the similarities is the fact that the volume of factors of production employed all over the world in one specific branch is exogenously determined. Worldwide demand for the products of a sector is the exogenous variable that determins factor use on the global level. Within this exogenously given global demand one has to deal with and consider the different amounts of resources allocated in the individual countries and - within the countries - in individual firms in response to that demand. An explanatory variable for these aspects of distribution could be e. g. the degree to which the optimal combination of factors of production is achieved. The combining of production factors in a relationship that - to a greater or lesser degree - approaches the optimal is a task of the management in that country, determining the relative success or failure of that country in competing on world markets. Thus, in addition to the exogenous factors - e. g. natural resources and supply of labor of a certain level of qualification, which can be assumed to be exogenously determined for a given country - and branch-specific world demand, management determines the extent to which factors of production are used in a given industry in any given country. Similar considerations determine the position of a firm within a branch of production.

[illegible] for the [illegible] - most important - for the [illegible], that *ultimately determine* [illegible] *factors are utilized.*

[illegible] in efficiency "intensive growth" and [illegible] of the factors of production used extensive [illegible] to adopt [illegible] terminology, then [illegible] for intensive as well as extensive growth - [illegible] dynamics of the functions of management. The ability to [illegible] these two responsibilities is the [illegible] proof of competent management.

[illegible].3.2 Management [illegible] efficiency and the zone efficiency parameter

[illegible] responsible for economic efficiency [illegible] question arises, [illegible] this management-determined efficiency [illegible] related to the different efficiency parameters of the general production function that have been found for the five Greater Zones of the world. - We think it is a reasonable working hypothesis to assume, that *zone efficiency represents the average value of the efficiency prevailing in the various subdivisions* (e. g. sectors of production). Those are dependent on the kind of structures management has been able to build, and which - in turn - lead to certain attitudes, i. e. to a certain "climate" or "atmosphere" within the individual enterprise. Using this concept, it can be stated, that structure (values, patterns of behavior, organisation) of a country constitutes something like the mean of the "internal climate or atmosphere" of **a l l** enterprises in this country.

The "climate" of one enterprise does not depend exclusively on management decisions of this enterprise: On the one hand the various "internal climates" of the enterprises within one country tend to converge over time, and on the other hand all these climates are influenced by the structure, i. e. the culturally determined attitudes and behavior patterns prevailing within the country. Finally these patterns - in turn - originate, partially at least, from the mutual adaptation of attitudes within the smaller sector units (e. g. the individual enterprises) and eventually grow into transsectoral modes of conduct.

2.3.3 Management and technological development

Innovation, i. e. the adaptation of new technology to the production process and making the corresponding changes in organisational structure has been called an important task of management. Innovation, however, is closely tied to technological progress resulting from inventions. Expressed in terms of the General Production Function, technological progress (resulting in increased factor efficiency) means, that the efficiency parameter p_z - which, in cross-sectional comparison within a group of countries, remains constant - increases over time. The speed of growth of the efficiency parameter depends on the propensity for expansion of knowledge (invention) and the propensity for innovation.

In a similar way, the technological development of industries does also depend on the two components just mentioned: Knowledge of new technologies can in principle be assumed to be available the world over. The actual technological development of a sector in a certain country, however, does not only depend on this technological progress but is very severly influenced by the readiness to innovate. It is actually management which is responsible for this latter innovation activity.

2.3.4 The optimal factor combination

Any sector study must be aimed at finding out for a given branch, how the factors of production are combined in those countries that are competing on world markets with particular success in that specific industry. Thus one would arrive at optimal factor combinations for that sector, similar to the optimal relation of energy and information processing described in the General Production Function.

At this point of the study it seems to be useful to distinguish explicitly between differences in efficiency due to the fact that countries belong to different zones , i. e. to different structures, and those differences in effective factor use due to the degree to which their combination approaches optimality.

This distinction can be made in analogy with the General Production Function. Efficiency paramters vary according to Greater Zone , while the optimal relationship remains the same all over the world. Accordingly, it is tc be expected, that - in drawing up branch or sector production functions - the efficiency parameter will vary among the 5 Greater Zones and, beyond that, even among the firms in one given country. The optimal relationship of input factors, on the other hand, probably will remain globally constant for every sector. The optimality will differ from sector to sector.

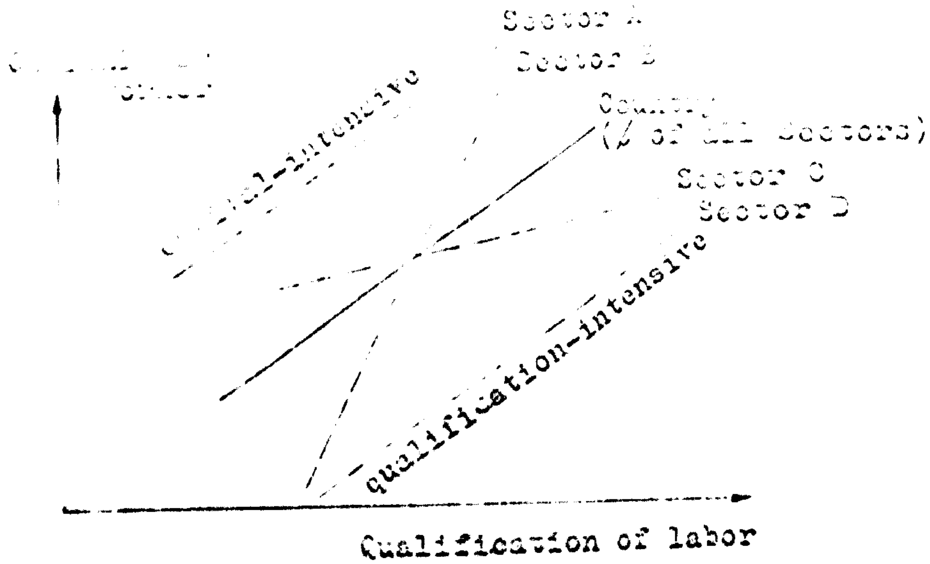


Fig. 13: The optimal relation of capital input and qualification of labor in different industries

Probably we will find capital-intensive industries (A) as well as qualification-intensive sectors (D) and finally sectors which move from one side to the other (B, C). The optimal relation for a country can be seen as the average of the corresponding optima of the different sectors.

The degree to which individual nations have either achieved or failed in achieving this optimal relationship of factor utilization in a certain sector determines their relative position in international competition in this industry.

We must, however, also consider the possibility, that the optimal relationship is not only determined by the branch investigated but by the scale of enterprise or size of firm, too. A further observation to be fitted into this context is the fact, that the General Production Function assumes a certain complementarity between the scale of factor use and the organisational structure. In transposing this assumption to the study of individual industries, this would mean, that - with bigger volumes of factor use, i. e. in bigger firms - demands on management will be strongly increased. If this turns out to be true, then not only the optimal relation between factors of production, but also the relationship between factors on one hand and demand on management on the other vary according to firm size. It is for this reason that it would seem desirable in all sector-related studies to form sub-aggregates consisting of firms of near-equal size.

2.4 On measuring the output of industries - how to deal with intermediate goods and services

In order to estimate the General Production Function in a cross-section comparison, we have used either Gross National Product or National Income per-capita figures to define economic performance. These figures should be understood to be gross production values, since they include intermediate goods and services not to be explained by the value of productive factor inputs. Mainly two types of variables belong in this category: a deficit in the balance of payments and natural resources. Natural resources fall in the category of intermediate goods, inasmuch as they represent values put at the disposal of a country by nature itself, quite independently of the use of the input of productive factors. If we now transform the equation (1) by substracting 0.8 r from each side, we get

$$y-0.8r = P_{tz}\, m^{\frac{1}{4}}\, a^{\frac{3}{4}}\, e^{b} \left[\frac{1}{2}\left(\frac{m^{\frac{1}{4}}}{e^{b}}\right)^{-\rho} + \frac{1}{2}\left(\frac{e^{b}}{m^{\frac{1}{4}}}\right)^{-\rho} \right]^{\frac{1}{\rho}} \qquad (4)$$

This relationship describes how a country's "value added" is explained in terms of inputs of productive factors. This model is now to be used for the estimation of sector production functions. In these, the economic performance of an industry is represented by the value added - this being the difference between its gross production minus the input of intermediate goods and services. Net production is explained in terms of inputs of productive factors. In this type of computation, however, valuable information is lost by eliminating the component of intermediate goods and services. It goes without saying, that the proportion, in which they enter the value of production, is a key to the understanding of the production conditions in a given branch or sector. It is i. e. conceivable that a material-intensive mode of production is correlated to a type of capital-intensive production, in which the role of social data processing is a comparatively minor one. Such a situation could obtain e. g. in such areas of production in which - in comparison to other industries - the optimal relationship is marked by a fairly dominant position of capital, which is yet strongly increased by continuing technological development. We could interpret this as a special complementarity, namely between capital and material inputs of intermediate goods or natural resources. The qualification of social data processing here is relatively insignificant. This, on the other hand, means, that the efforts in research, market research, planning, promotion and advertising or distribution are proportionally lower. A capital-intensive production of this type will have to operate near the cost margin, since - from the side of qualification of labor - there is practically no limit to supply. Thus the value of production is progressively more determined by demand. This can possibly lead to ruinous competition, in which advantages of location, connected with natural resources, can be decisive, since they, in turn, account for a great portion of gross production value.

For this reason one has to be aware of the fact, that intermediate goods - although being eliminated through the use of value added as dependent variable - still have an influence on the parameters of the sectoral production function.

III. TRANSFER OF THE METHODOLOGICAL CONCEPTS USED FOR ESTIMATING THE GENERAL PRODUCTION FUNCTION TO THE EVALUATION OF SECTOR PRODUCTION FUNCTIONS

1. A first hypothesis on the form of sector production function

Taking into account the considerations described thus far and the results obtained in country comparisons which are summarized in the General Production Function, we may tentatively formulate a Sector Production Function of the following type:

$$\ln y = \ln k_o + k_1 q_1 + k_2 q_2 + k_3 \ln c \qquad (5)$$

y = value added

q_1 = amount of skills (see chapter II/2.1.2)

q_2 = qualification for social information processing (see chapter II/2.1.3)

c = capital (see chapter II/2.2)

(All the variables are calculated on a per capita basis)

The problem now arises how the different independent variables in equation (5) ought to be actually measured. That will have to be the topic of this following chapter.

2. MEASURING THE FACTORS OF THE SECTOR PRODUCTION FUNCTION

2.1 Qualification of labor

Our experience with the General Production Function, as well as observation of the relationship between income and education on the individual level

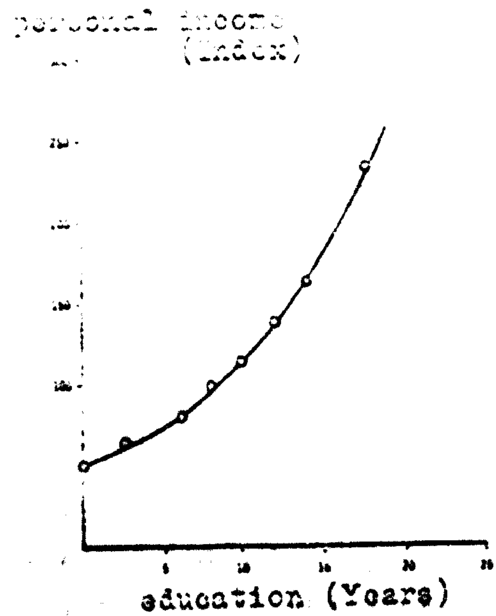


Fig. 14: A graph showing this relationship for individuals in the USA

lead us to the assumption that the qualification variables q of the Sector Production Function will have an exponential relationship to output:

$$Y = c \cdot e^{q} \qquad (6)$$

While in the General Production Function the relative complexity of this term was taken into account by measuring stocks of education on three levels (elementary, secondary and higher education), only the bottleneck factor in education (the least developed of the three) is used in the actual computation of the function. Thus, in the country comparison the assumption of a very strict limitationality is made, because exclusive consideration of the bottle-neck factor implies the assumption, that, ceteris paribus, expanding educational sectors, which are overdeveloped to begin with, had no or - if the expansion is achieved at the expense of other levels of education - even negative effects on the product.

Thus, this simplified method, using only the relatively smallest educational category, doubtlessly is incomplete. If one aims at a more accurate representation of reality, one would have to always include a l l (three) qualification categories into one's observation. A similarly sophisticated approach would be the goal in analyzing sectors of industry, too.

In empirically measuring qualification in a branch-comparison study we have followed a suggestion implied by Fels (12). His basic assumption is, that the difference between the actual sum total of salaries and wages and a hypothetical figure derived from multiplying the wages for unskilled labor and the number of people in the working force makes a suitable measure for determining qualification of labor - in his terminology "Human Capital". "Human capital data had to be estimated. The method applied is based on the consideration that the difference between the actual wage bill and a fictive wage, in which labor input is valued by the wage rate for unskilled labor, can be regarded as a return to human capital."

This mode of computation is, however, only valid if one can rightly assume, that the various wage and salary rates are actually strongly influenced by corresponding differences in qualification. Only in such a case could the available statistical data on returns to the factor labor fairly be used in determining the measure of qualification.

Based on the non-linear relationship hitherto found to obtain between qualification and economic efficiency (and which we assume to be valid on the industry level, too), we have come to the conclusion, that it might be more meaningful to somewhat modify the above measuring device. We are using not the difference between the two magnitudes used by Fels, but the *ratios*. That this quotient provides a better indicator for qualification of labor than the difference approach mentioned, can be deduced from the relationship observed between average income and average qualification of individuals *(see Fig. 14)*.

The wages of an unskilled laborer (L_u) depends on his qualification (q_u), which constitutes so to speak a minimun prerequisite for the use of manpower in a given country.

$$L_u = e^{q_u} \quad \text{or} \quad \ln L_u = q_u \qquad (7)$$

The analogous relationship for a skilled worker looks like this:

$$L_s = e^{q_s} \quad \text{or} \quad \ln L_s = q_s \qquad (8)$$

If we furthermore define the qualification of labor as the difference between skills and abilities actually available and the minimum requirements, we arrive at the following relationship:

$$q = \ln L_s - \ln L_u \quad \text{or} \quad q = \ln \left(\frac{L_s}{L_u}\right) \qquad (9)$$

This expression, however, is identical to:

$$q = \ln \left(\frac{A \cdot L_s}{A \cdot L_u}\right) \qquad A = \text{number of persons working} \qquad (10)$$

from which it becomes apparent, that the logarithm of the quotient of actual total salaries and wages and manpower [illegible] extent to which qualification in the average [illegible] of the work force [illegible] requirements.

The use of a quotient, in any case, has the advantage of excluding all those factors leading to wage and salary differentials not based on differences in qualification. These other components could be due e. g. to differences in capitalization or differences in the qualification of management. In summing up, we can state that computing the measure of qualification by the above method yields indicators adequate and useful in inter-branch comparative studies.

The method for arriving at qualification measures described can be used to estimate the amount of skills of workers as well as for the information processing capacity of employees. In measuring these two magnitudes we are using an idea of Hildebrand and Ta-Chung Liu suitably adapted to our concept. Hildebrand and Ta-Chung Liu, however, operate by trying to derive a measure for differences in the level of technology from the ratio in which workers and employees are used in the production process: "The task, then, is to devise some simple proxy or dummy variables that would reflect changing technology to a significant extent. We think it reasonable to assume that no important change in the level of technology employed in an establishment is possible without it being reflected in the following: "... (iii) a change in the ratio of technical and professional personnel to production (manual) workers, ... reflecting 'technology intensity'" (19, p.40 sq)

Thus we should like to state that computations of the measure of qualification should be made for two groups: workers on the one end employees on the other hand.

An additional means of adjusting available figures would seem to be possible in the realm of social information processing capacity. In order to make these indices comparable, even on the international level, it would seem desirable to weight these values with the measure of education in the country under consideration (see equation (10)). This figure would then also be an indicator for the varying basic or minimum qualification of the units of social information processing in each country. For developing countries we used literacy as this measure. That the ability to read and write is of decisive importance in this area can readily be understood from the fact, that each person possessing this qualification can communicate with any other person similarly qualified (leaving considerations like language barriers, etc. aside). A person thus qualified is no longer dependent on personal contacts for conveying information - he becomes a more highly qualified information channel. The added consideration of this would result in making our indices comparable between different industries as well as different countries.

In contrast with the above, international comparability of the qualification measure pertaining to skills is relatively reliable, without any additional information being required.

Thus, in summing up, we should like to catalog the data that would be actually required to quantify our function:

W_1	Total of wages
W_2	Total of salaries
L_1	Number of workers
L_2	Number of employees
[illegible]	Minimum wage of unskilled workers
[illegible]	Literacy rate of the population in the respective country

[illegible]

On the basis of [illegible] specified by the General Production Function [illegible] expected, that capital can be defined using the [illegible] energy consumption on the industry level, too. [illegible] consumption is an excellent index for [illegible] proven also by the results of other investigations [illegible] (14), by using time series for productive capital and energy consumption in the USA from 1880 to 1948 and in the United Kingdom for the years from 1865 to 1914, shows impressively, that these two magnitudes are extremely closely related. In a similar study, Jim Taylor (50) demonstrates, "... that the amount of active capital stock (viz. plant and machinery excluding buildings) in five main industry groups within the manufacturing sector can be accurately estimated for the United Kingdom from statistics of industrial electricity consumption". This Taylor explains as follows: "Industrial electricity consumption is complementary to the use of capital equipment because it is an important fuel input. Practically all mechanical power is now derived from electricity ...".

From such empirical data, as well as from our own investigations, it can be concluded that energy consumption, especially that of *electric* power, is an excellent indicator for the amount of capital in use - also when it comes to sector comparisons.

If we use our experiences in international comparison as the point of departure for a hypothesis on the suspected relationship between economic performance and energy processing capacity, then we may expect, that - also on the sector level - relationships obtain which can be represented mathematically as a linear relationship between the logarithms of the variables (e. g. value added and capital or energy consumption respectively).

Since the close fit between productive capital and energy consumption in time series analysis only reflects a relationship between the rates of change of these two variables, one must combine these energy time series with investment figures, if one wants to get nominal capital stock time series. It would be ideal for this type of computation to have at one's disposal the figures for net investment for a given year. Since, however, that kind of data might be extremely hard to obtain, one shall have to content oneself with the figures for gross investment. Wherever and whenever additional capital stock time series are available they naturally should be used in the investigation.

Basically there are three different ways to estimate time series of capital in money value using the development of energy consumption over time, which also may be combined:

If we know the money value of the capital stock at a certain point in time and the development of energy consumption, we get to an estimation of a capital stock time series by the following procedure:

$$c_i = k\, m_i \qquad k = \frac{m_i}{c_i} \qquad c_t = k.m_t \qquad (11)$$

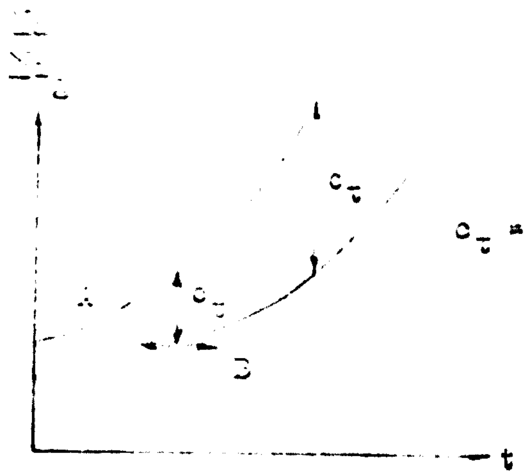
c_i = Capital in terms of money value at period i
m_i = Index of energy consumption at period i

Another possibility to deal with this problem is to use data for the development of energy consumption and net investment data. In fact net investment is an indicator for the actual change in capital stock in terms of money value, which may be related to the corresponding change of energy consumption.

$$i_{ni} = k\,(m_{i+1} - m_i) \longrightarrow k = \frac{m_{i+1} - m_i}{i_{ni}} \longrightarrow c_t = k.m_t \qquad (12)$$

i_{ni} = net investments in the period i

The last procedure uses time series for energy consumption and gross investments and is moreover based on the only assumption that the economic lifetime of capital goods is constant over time. The stock of capital can be seen as the difference between the summation of gross investments i_g (curve A) and the summation of the worn out capital (the depreciation d_t, curve B) over time. The assumption of a constant life time τ of capital implies that the curves A and B representing the two variables are parallel.



$$c_t = \Sigma i_{gt} - \Sigma d_{t-\tau} = k m_t$$

Fig. 15: A method for estimating capital stock time series

Moving B horizontally changes the lifetime of capital which is reflected by a changing vertical distance from A and B which is a measure for capital. In this way we get different possible time series for capital. The one which happens to be proportional to the time serie describing the development of energy consumption, will be the best estimate of capital stock in terms of money value.

In time series analysis, the ratio of electrical energy consumption to total use of energy would seem to be a useful index for technological progress (see p.). Accordingly, in the General Production Function different means of measuring capital have been used for cross-section and for time series analysis. In both cases we use a multiplicative relationship of total energy consumption and use of electric power as index.

$$m = m_1^a \cdot m_2^b \qquad (13)$$

Depending on whether we are dealing with a cross-section or time series, different values for a and b are to be expected. This can best be explained by the fact that in the time series capital-induced technological progress becomes an additional influence.

Summarizing we need the following data for a quantitative description of the input factor capital in our function:

m_1 ... total energy consumption
m_2 ... electricity consumption
I ... investment (gross investment i_g or net investment i_n)
c_t ... time series of capital stock

When it comes to measuring technological development we should like to refer our reader to page 23 and to page 61, where different approaches to deal with this problem are described.

2.3 Management

2.3.1 General considerations

The measurement of the production factors qualification of labor and capital can be achieved through the direct use of adequate data. As opposed to that, the direct measurement of the influence of management does not seem to be possible for lack of adequate data. We can, nevertheless, try to take [illegible] of [illegible] output of a sector [illegible] would consist of taking [illegible] in the residuals of a sector production function of the type of equat.(5), which are [illegible] of capital and qualification of labor on sector output.

2.3.2 Management-induced efficiency

Management-induced efficiency is measured as the residual in a cross-sectional analysis on the country level: If the above method is used to describe the influence of capital, qualification of labor,and raw materials on value added , on the basis of an equation which is valid for all countries, then the calculated output does not correspond exactly to the actual observations for all countries. The difference between the two i. e. the residual of the regression, can be explained by the influence of management on efficiency as well as by the relative influences of values, patterns of behavior and organisational form in the Greater Zones. If the latter influence is to be eliminated, two possibilities offer themselves: The residual can be related to the efficiency parameter of the Greater Zones, i. e. the residual is divided by the efficiency parameter for the zone in question (see equat.(1)). - The other method involves setting up dummy variables for each Greater Zone describing the status of the individual country as member of one of the Greater Zones. Theoretically speaking, both methods should provide identical results, as long as the Zone Efficiency Parameter is the mean of the efficiency parameters of all aggregated units. This would mean, that - as stated above - "structure" (values, attitudes, organisation) constitutes the average of the atmosphere ("climate") prevailing in all the firms within the aggregate (see chapter II/2.3.2).

2.3.3 Management and technological development

In the highly-aggregated General Production Function, the (autonomous) expansion of knowledge can be assumed to be a function of time, identical the world over. The differences in the growth rates of efficiency to be found between the various Greater Zones result from structurally caused differences in the degree of innovation.

Measuring technological progress in a sector study modelled after the General Production Function makes use of the residual in a time series analysis: This residual contains both the influence of invention and innovation. (We refer to the residual resulting when one uses a sector production function obtained by cross-section analysis to explain the development of an industry over time.) In order to split this residual into its two components we may proceed - in analogy to the General Production Function - as follows:

The worldwide average of the time series residual is closely related to the expansion of knowledge for that sector of production, while departures from this average residual value in the various countries must be ascribed to their respective propensity for innovation. These changes fit corresponding changes of the efficiency parameter, which cannot be attributed to technological progress, or, more specifically, to expansion of knowledge. Rather, these changes must be attributed to management and its ability to incorporate innovations into the production process. As a result of these changes, a time series of cross-sections shows country-specific divergences from the sector-wide average of the efficiency parameter discussed under II/2.3.2 also change.

[illegible]

[illegible]

[illegible] be measured as the re- [illegible] intensity, qualification of labor [illegible] and social information proces- [illegible] goods and services or raw materials, respectively [illegible] corresponds approximately to the factors used in determining the optimal relationship of the General Production Function. If we assume that combining the factors in an optimal way leads a country to compete successfully on world markets, then we may use the relation of factor input of those countries which are successful in a specific sector to evaluate the optimal relation in that industry.

Such data as the growth rates of exports of the products of a sector to total exports of that country, or changes in the share of a country in the international market for an industry, could serve as indicators for relative success or failure in international competition.

Getting additional information on the optimal input factor combination for different sectors will be a valuable contribution to the better unterstanding of the degree of substitutability or complementarity between these factors.

3. MODIFYING THE FORM OF SECTORAL PRODUCTION FUNCTIONS

Taking into account the considerations made in this last chapter concerning the measurement of the explanatory variables, we may proceed to reformulate the Sector Production Function and write as a tentative modified approach:

$$\ln y = \ln k_o + \ln p_z + k_1 q_1 + k_2 q_2 + k_3 b + k_4 \ln c \quad (14)$$

y = value added

p_z = efficiency parameter (see II/2.3.2 and III/2.3.2)

q_1 = skill (see II/2.1.2 and III/2.1)

q_2 = social information processing capacity (see II/2.1.3 and III/2.1)

b = measure for the level of education of the different countries (see III/2.1)

c = capital (see II/2.2 and III/2.2)

It is to be expected that this concept, too, will have to be broadened, especially through the introduction of additional information concerning the optimal relation of factor inputs within sectors and the behavior of the function if input combinations deviate from this optimum. At this point, however, it is not possible to give a mathematical formulation for these aspects, although we expect the General Production Function to be of use in the formulation of hypotheses.

4. CONCLUDING REMARKS ON METHOD

An investigation into the most important determinants of a sector production function, too, should rely on the methods of research that have been successfully applied when estimating the General Production Function on the country level. The individual steps of our cross country study become apparent in Fig. 15.

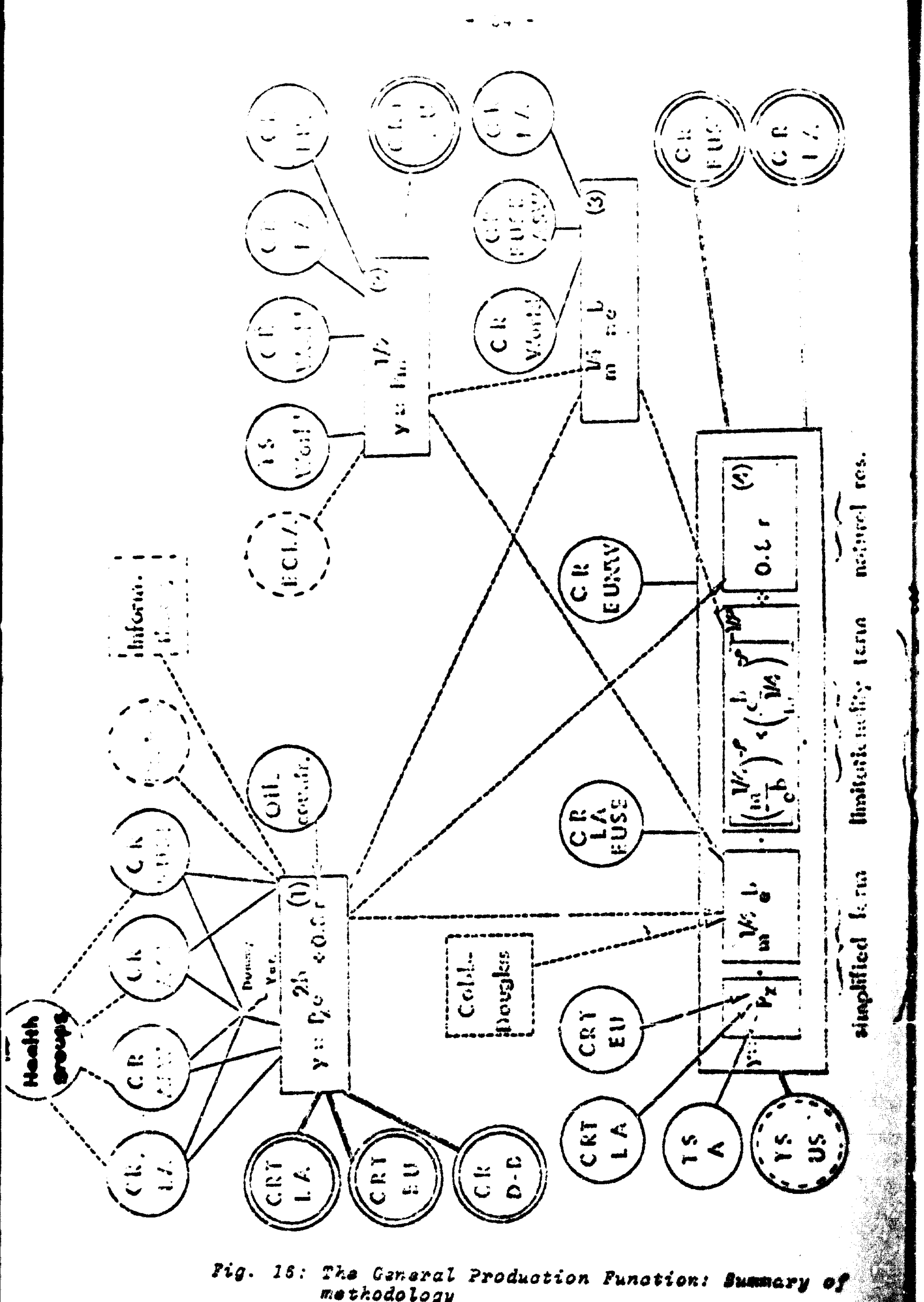
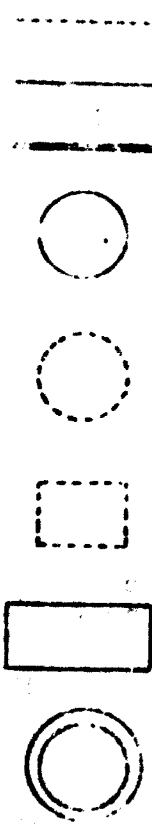


Fig. 16: The General Production Function: Summary of methodology



Hypothesis

Initial testing of hypothesis

Secondary testing of hypothesis

Empirical data base

Empirical data base from other sources

Theoretical source of hypothesis

Results

Empirical data base for secondary testing

ASE	*Asia East*
ASW	*Asia West*
EU	*Europe*
EUNW	*Europe Northwest*
EUSE	*Europe Southeast*
LA	*Latin America*
D - B	*Districts of Brazil*
A	*Austria*
US	*United States*

CR	*Cross section*
TS	*Time series*
CRT	*Cross section combined with time series*
K	*Korrelation*
P	*pattern.*

This concept would appear to be applicable also to sector studies.

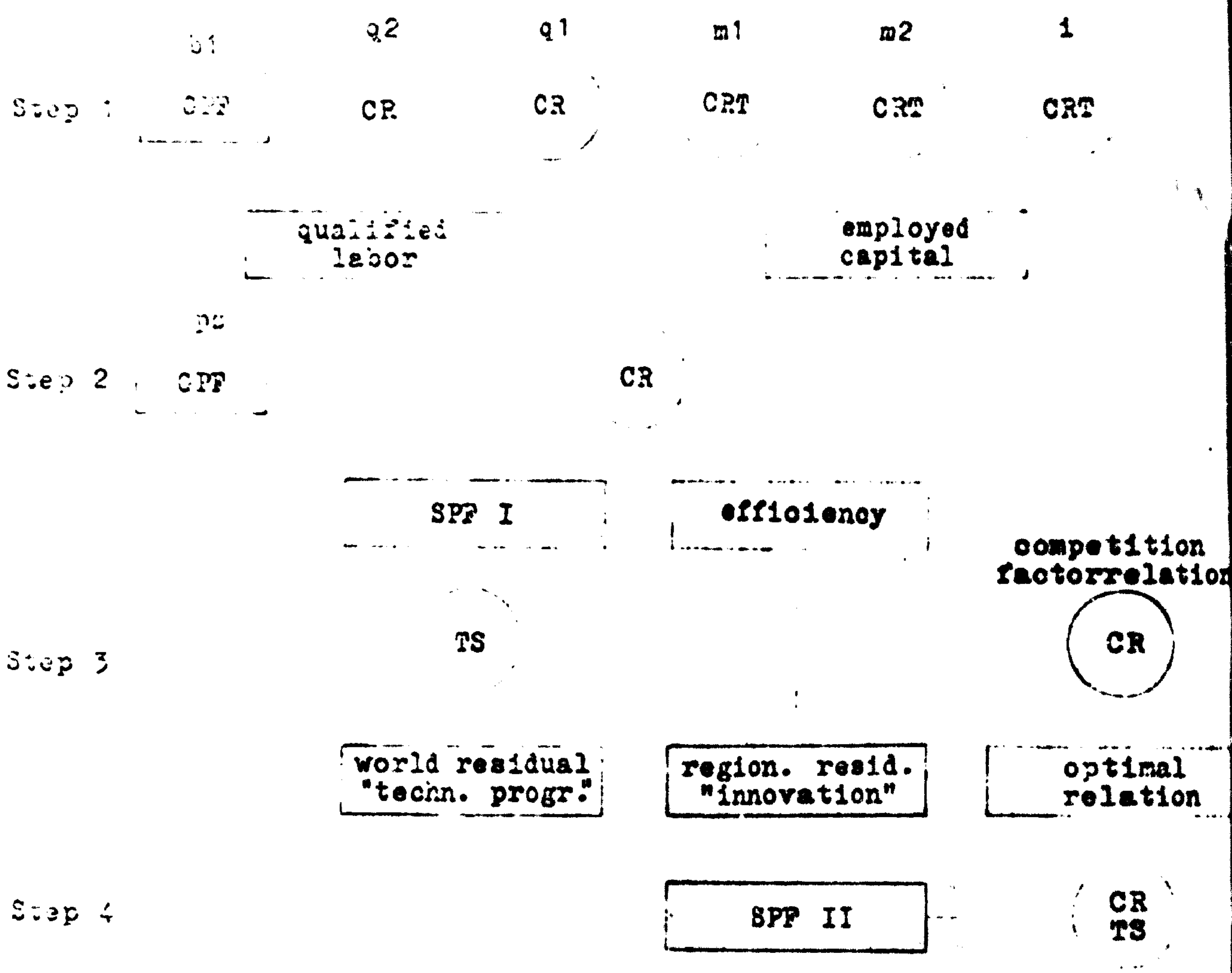


Fig. 17: A graphic summary of methodology

The first step will consist of measuring capital (using energy and investment data) and qualification of labor in two categories and of trying to estimate the relation of these variables with sector output based on international cross sections within industries. In step 2 the sector production functions (SPF I) are estimated using the results of step 1 and the hypotheses derived from the General Production F notion. The deviations of calculated from observed values are used for considerations concerning efficiency. Then, in step 3, the sector production function arrived at in cross section analysis is applied to time series of the development of the sectors. By observing worldwide sector development and the different developments inside countries we may differentials between technological progress and innovation. Additional information comes from analyzing competitive advantages. Finally in step the information thus far arrived of has to be gathered in a revised version of sector production functions (SPF II).

It is important, however, to emphasize the step-by-step nature of our method. Its basic principle is the interaction between hypotheses arrived at in theory and the empirical testing of these hypotheses against reality, which in turn should lead to a modification, sophistication or correction of the hypothesis, which then again, in its revised form, must be put to the test of reality, etc.

This kind of procedure can become successful only if an extremely wide scope of data is available. In principle, one should attempt to check and test every assumed or found relationship empirically in a variety of ways. Thus, the goal has to be an over-defined system of information. This requires not only the mustering of sufficient empirical data, but also - and this is important - taking into consideration all previous studies which investigate more specific areas, as well as the results from consulting experts in various fields of specialisation.

Thus, all the thoughts hitherto formulated and the hypotheses posed and assumptions made for the investigations of individual industries within the framework of our study should be considered only a first cursory question put to the amount of empirical data that must be made available. We are dealing here with the formulation of primary hypotheses, with the definition of the point of departure for intensive research into the conditions under which sectors produce. We think, however, that we have been able to establish a reasonably consolidated point of departure for such an investigation, since the assumed and suspected relationships are all derived from observing and analysing the differences in the economic performance and their underlying causes.

Nevertheless, it should be pointed out that we are not attempting to put - in this first step - a complete and complex model to the test, but that we are here primarily concerned with establishing and testing the various relevant interdependencies and relationships. Only after the relationships of the individual factors with economic output have been clearly demonstrated, can the second step - computation of a complex model - be taken.

It is consistent with our criterion of over-definition that such an investigation is to be based b o t h on cross-section comparisons as well as time series studies. Cross-section analysis compares different countries in one and the same branch of production, while the time series studies are to compare the situation of a specific branch of production over time.

Summing up, the method of investigation suggested requires collecting and compiling an absolute maximum of pertinent data on one hand, and a step-by-step process in developing the model on the other. The underlying assumption is that the model eventually arrived at will show marked similarity to the General Production Function we have found in our studies on the country level. In this sense the concept of General Production Function may serve as a framework to join the different approaches mentioned.

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