OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

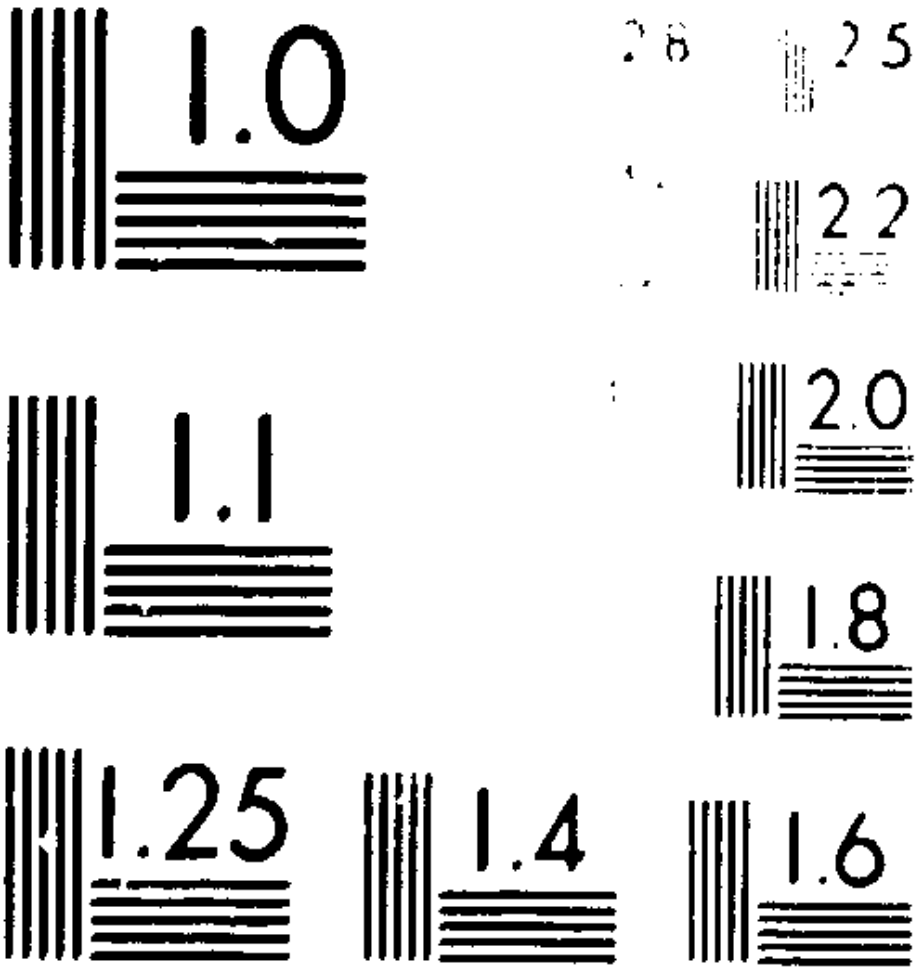
FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

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


1.0
2.5
2.2
1.1
2.0
1.8
1.25
1.4
1.6

11716

Distr.
LIMITED
UNIDO/IS.333/1
30 July 1982
ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

TECHNOLOGICAL PERSPECTIVES IN THE MACHINE TOOL INDUSTRY

AND

THEIR IMPLICATIONS FOR DEVELOPING COUNTRIES

PART I

Global study of the machine tool industry and a case study of the Indian machine tool industry*

by

S.M. Patil
UNIDO Consultant

90...27

* This is an advance edition of a UNIDO publication to appear in the Development and Transfer of Technology Series. A summary has already been issued under UNIDO/IS.230.

V.82-29242

EXPLANATORY NOTES

References to dollars ($) are to United States dollars, unless otherwise stated.

The views expressed in this document are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Mention of firm names and commercial products does not imply the endorsement of the United Nations Industrial Development Organization (UNIDO).

References to rupees (Rs) are to Indian rupees. In 1980, the value of the rupee in relation to the dollar was $1 = Rs 7.95.

In addition to the common abbreviations, symbols and terms and those accepted by the International System of Units (SI), the following have been used in this study:

AJM	abrasive jet machining
ATC	automatic tool changer
BHN	Brinell Hardness Number
CAD	computer-aided design
CAM	computer-aided manufacture
CBN	cubic boron nitride
CHM	chemical machining
CIRP	International Institution for Production Engineering Research
CMEA	Council for Mutual Economic Assistance
CMTI	Central Machine Tool Institute
CNC	computer numerical control
CPU	central processing unit
CRT	cathode ray tube
CUPE	Cranfield Unit for Precision Engineering
dB	decibel
DC	direct current
DCs	developing countries
DCS	diagnostic communication systems
DNC	direct numerical control
DRO	digital readouts

EBM	electron beam machining
ECG	electrochemical grinding
ECM	electrochemical machining
EDM	electron discharge machining
EEC	European Economic Community
EMO	European Machine Tool Organization
ENIMS	Experimental Scientific Research Institute of Metal-cutting Machine Tools
EPROM	erasable and programmable read-only memory
FMS	flexible manufacturing systems
GM	General Motors
GPMs	general purpose machine tools
HIP	hot isotatic press
HMT	Hindustan Machine Tools Ltd.
IBM	ion beam machining
IC	integrated circuit
ICAM	integrated computer-aided manufacturing
IMTMA	Indian Machine Tool Manufacturers Association
LAFTA	Latin American Free Trade Association
LBM	laser beam machining
LSI	large-scale integration; large-scale integrated circuits
MDI	manual data input
MVA	megavolt-ampere
NC	numerical control; numerically controlled
NICs	newly industrializing countries
NMTBA	National Machine Tool Builders Association
OBI	open back inclinable presses
PAM	plasma arc machining
PC	programmable controllers
PM	powder metal(lurgy)
PROM	programmable read-only memory
PSI	pounds per square inch
PUMA	programmable universal machines for assembly
RAM	random access memory
R&D	research and development
ROM	read-only memory
rpm	revolutions per minute
SCFMO	Syndicat des Constructeurs Français de Machine-Outils
SCR	silicon-controlled rectifier

SIP	Société Genevoise d'Instruments de Physique
UAW	United Auto Workers
UCIMU	Unione Construttori Italiana Macchine Utensili
UMC	unmanned machining centre
UMS	unmanned manufacturing systems
USM	ultrasonic machining
VLSI	very large-scale integration; very large-scale integrated circuits
VUOSO	Research Institute of Machine Tools and Machining
WJC	water jet cutting
WJM	water jet machining

CONTENTS - PART ONE

A GLOBAL STUDY OF THE MACHINE TOOL INDUSTRY AND A CASE STUDY OF THE MACHINE TOOL INDUSTRY IN INDIA

Chapter		Page
	Preface	x
	INTRODUCTION	1
I.	OBJECTIVES OF THE STUDY	8
II.	BACKGROUND OF THE MACHINE TOOL INDUSTRY	13
	Definition of a Machine Tool	13
	The Importance of the Machine Tool Industry	17
	The Need for Developing Countries to Establish a Machine Tool and Machine Tool Building Industry	19
III.	THE WORLD MACHINE INDUSTRY - A BRIEF REVIEW	22
IV.	THE MACHINE TOOL INDUSTRY IN SOME OF THE LEADING MACHINE TOOL PRODUCING/EXPORTING COUNTRIES	34
	The Machine Tool Industry in the Federal Republic of Germany	36
	The Machine Tool Industry in the United States of America	44
	The Machine Tool Industry in the Union of Soviet Socialist Republics	52
	The Machine Tool Industry in Japan	61
	The Machine Tool Industry in Italy	73
	The Machine Tool Industry in the United Kingdom	86
	The Machine Tool Industry in France	91
	The Machine Tool Industry in the German Democratic Republic	100
	The Machine Tool Industry in Switzerland	106
	The Machine Tool Industry in Czechoslovakia	112
	The Machine Tool Industry in Poland	116
V.	A BRIEF STUDY OF THE MACHINE TOOL INDUSTRY IN SOME OF THE LEADING DEVELOPING COUNTRIES	
	The Machine Tool Industry in China	119
	The Machine Tool Industry in Brazil	125
	The Machine Tool Industry in the Republic of Korea	131
	The Machine Tool Industry in Argentina	137
	The Machine Tool Industry in Mexico	141
VI.	A CASE STUDY OF THE MACHINE TOOL INDUSTRY IN INDIA	146
	Industrial Base of India	147
	Early Years	157
	The Industry in the Post-war Years	160
	Decade 1950-1960	163
	Decade 1960-1970	165
	Decade 1970-1980	169
	Technological Advancement	171
	Structure of the Industry	176
	Ancillaries	179
	Exports	180
	Research and Development	185

CONTENTS - PART TWO

PROSPECTIVE TECHNOLOGICAL DEVELOPMENTS IN THE MACHINE TOOL INDUSTRY IN DEVELOPED COUNTRIES

Chapter		Page
	Preface	x
	INTRODUCTION	193
I.	MACHINE TOOL MECHANICS AND DESIGN	201
	Structures	202
	Fabricated steel structures	203
	Concrete	203
	Granite	204
	Guideways and bearing surfaces	205
	Rolling element guideway bearings	206
	Hydrostatic oil bearings	207
	Aerostatic bearings	208
	Spindle systems	209
	Feed drives	209
	Mechanical drive elements	211
	Accuracy aspects of design	211
	Modular construction	213
	Computer-aided design (CAD)	21
	Conceptual design	21
	Estimation and design analysis	216
	Computer-aided drafting	218
	High-speed machining and its implications for the design and mechanics of machine tools	218
	Ergonomics, noise and safety	224
	Energy management in metalworking	228
II.	CUTTING TOOL MATERIALS AND TOOL DESIGN	231
	Introduction	231
	Tool materials	234
	Cast alloys	234
	Cemented carbide	236
	Coated carbides	240
	Ceramics	242
	Diamond	244
	UCON	246
	Cubic boron nitride	248
	Tool design	248
	Chip breaker	248
	Tool geometry and configuration	249
	Wave-shaped insert design	250
	Kenturn tooling system	250
	Qualified tool holders	251
	Major constraints in tool design	252
III.	MACHINE TOOL CONTROL SYSTEMS	255
	Introduction	255
	CNC system	258
	CNC capabilities	263
	MDI controller	264
	Direct numerical control (DNC)	266
	Recent trends in NC of machine tools	269
	NC perspectives	272
	Machine design to suit NC/CNC	280

CONTENTS - PART TWO, contd.

Chapter		Page
IV.	NON-TRADITIONAL MACHINING METHODS	283
	Electron discharge machining (EDM)	286
	Electrochemical machining (ECM)	290
	Chemical machining (CHM)	294
	Ultrasonic machining (USM)	296
	Abrasive jet machining (AJM)	297
	Laser beam machining (LBM)	298
	Electron beam machining (EBM)	303
	Plasma arc machining (PAM)	305
	Ion beam machining (IBM)	306
	Water jet cutting (WJC)	306
V.	METALFORMING MACHINE TOOLS	312
	High-speed forming	313
	Cold forging	317
	Extrusion	317
	Upsetting (heading)	318
	Ironing	319
	Press equipment and tooling	319
	Fine blanking presses	321
	Tolerances	324
	A new era in NC punching	326
	Powder metal technology (PM)	329
	Non-traditional forming processes	330
	Rotary forging	331
	Roller spin riveting	333
	Orbital and radial riveting	334
	Metal spinning and forming	336
	Future of forming	336
VI.	TECHNOLOGICAL TRENDS IN PRODUCTION ENGINEERING	338
	Computers in manufacturing	343
	Integrated manufacturing	345
	Computer-aided manufacture (CAM)	348
	Economic factors	351
	Social factors	353
	Technological evolution	354
	Flexible machining systems (FMS)	357
	Group technology	363
	Computer control and inspection of machine tools	365
	Metrology and inspection	367
	Assembly	370
	Materials handling	372
VII.	AUTOMATION AND FUTURE TRENDS IN THE MACHINE TOOL INDUSTRY	373
	Robots	373
	Programmable Universal Machines for Assembly (PUMA)	379
	Unmanned machine work - unmanned factories	380
	Perspectives - future vistas	386
	Around 1985	391
	Around 1987	391
	Around 1990	392
	Around 1995	392
	Around 2000	392

CONTENTS - PART THREE

THE IMPLICATIONS OF TECHNOLOGICAL DEVELOPMENTS IN THE MACHINE TOOL INDUSTRY FOR DEVELOPING COUNTRIES

Chapter		Page
	Preface	x
	INTRODUCTION	393
I.	THE TECHNOLOGY GAP AND ITS IMPLICATIONS	396
	Metalforming	419
	Non-traditional machining	421
II.	ECONOMIC IMPLICATIONS	423
III.	RECOMMENDATIONS FOR THE DEVELOPMENT OF THE MACHINE TOOL INDUSTRY IN THE DEVELOPING COUNTRIES	440
	Newly industrializing countries	440
	Other developing countries	452
	Bibliography	468

Annexes

I.	Extract from Report by the Technical Policy Board	471
II.	Questionnaire	486
III.	Names of the companies and institutes visited and persons interviewed	492

Tables

Part one

1	World machine tool production and trade	24
2	Leading machine tool consumers	27
3	The machine tool industry in the Federal Republic of Germany: production, consumption and trade	38
4	The machine tool industry in the United States of America: production, consumption and trade	46
5	The machine tool industry in the Union of Soviet Socialist Republics: production, consumption and trade	54
6	Numerically controlled machine tools - world production - 1977	60
7	The machine tool industry in Japan: production, consumption and trade	66
8	The machine tool industry in Italy: production, consumption and trade	80
9	The machine tool industry in the United Kingdom: production, consumption and trade	88

CONTENTS - PART THREE contd.

Tables

Part one contd.		Page
10	The machine tool industry in France: production, consumption and trade	93
11	The machine tool industry in the German Democratic Republic: production, consumption and trade	102
12	The machine tool industry in Switzerland: production, consumption and trade	107
13	The machine tool industry in Czechoslovakia: production, consumption and trade	113
14	The machine tool industry in Poland: production, consumption and trade	117
15	The production and trade in machine tools from 1974 to 1979 in China	121
16	Development of the metalworking industry in Brazil	126
17	The production and trade in machine tools from 1974 to 1979 in Brazil	127
18	The production and trade in machine tools from 1974 to 1979 in the Republic of Korea	134
19	The production and trade in machine tools from 1974 to 1979 in Argentina	139
20	The machine tool park in Mexico, 1960, 1970 and estimates for 1980	143
21	The production and trade in machine tools from 1974 to 1979 in Mexico	144
22	The production of machine tools in India, 1941-1950	162
23	The production and trade in machine tools in India, 1951-1960	166
24	The indigenous production, trade and consumption of machine tools in India, 1961-1970	170
25	The indigenous production, trade and consumption of machine tools in India, 1971-1979	172
26	The indigenous production, trade and consumption of machine tools in India, 1962-1979	182

CONTENTS - PART THREE contd.

Figures

Part one		Page
I	World exports of machine tools	25
II	World machine tool consumption	26
III	Machine tool shipments of the nine leading nations	29
IV	The share of production of machine tools of the developing countries as a percentage of the world output	30
V	The share of export of machine tools of the developing countries as a percentage of world exports	31
VI	The evolution of exports and imports in France	95
VII	The growth in production, imports and exports of machine tools in India	173
VIII	The percentage of indigenous production in consumption in India	174

Preface

This study consists of three parts: Part I comprises a global review of the machine tool industry which includes a case study of the machine tool industry in India; Part II considers prospective technological developments in the machine tool industry of the developed countries and Part III discusses the implications for developing countries of technological developments in the machine tool industry and contains recommendations, annexes and a bibliography.

The study is based on replies to a questionnaire sent to leading machine tool manufacturers, designers, production engineers, machine tool technologists, researchers and teachers in production technology and machine tool users throughout the world. While preparing the study, the author attended the 30th General Assembly of the International Institution for Production Engineering (CIRP) held in Australia in September 1980 and he has drawn on the insights gained from discussions held with some of the members of the CIRP and from subsequent visits to machine tool research institutes. Annex I contains an extract from a report of the Technical Policy Board of the the Institution of Production Engineers, United Kingdom; the questionnaire referred to above is reproduced in Annex II and the names of the companies, institutes and individuals visited by the author are given in Annex III.

INTRODUCTION

According to one view, what developing countries need most of all is the provision of basic needs for the poor using simple, small-scale appropriate technology. An opposing view argues equally strongly that modern technology and rapid industrialization alone can solve the problems of the developing countries. Many countries in the third world see all the talk about basic needs as an attempt to deny them the benefits of modern industry. They see appropriate technology as backward, outdated technology and consider this approach particularly inappropriate at a time when developing countries like Brazil, Mexico, India and the Republic of Korea are becoming important exporters of industrial goods. It is argued by some that these concepts perpetuate the present international division of labour which allows the Western countries to undertake modern, highly productive industrial activities but advocates that the developing countries should concentrate on low paid, less productive labour-intensive work. Such a conflict-ridden debate is

meaningless. What is important however, is to bring production into the hands of the poor and thus raise a nation's production and productivity. The crux of the problem is to dilute the élitist control and urban predominance over the means of production and disperse its benefits amongst the rural poor.

The crucial task of the developing countries is to overcome their lack of technical development and raise the productivity of their labour to a level that would allow them to reach the major goal set at the Second General Conference of UNIDO held at Lima, Peru, in March 1975, namely that the developing countries' share in world industrial production be increased to the extent of at least 25 per cent by the end of the current century. How can this be done? Is it more sensible from a national economic standpoint to import ready-made technological innovations from the developed countries or to make use of scientific and basic research ideas and discoveries to develop technological innovations on a national basis? These seem to be two extremes of a whole range of possible solutions. Any cut and dried answer to the question formulated above would neither take into account the diversity of

the third world, with its disparate economic levels, nor the dynamism of the very task of reconstructing the national economy: for something that is right at one stage of development may prove wrong at the higher stage. It is important therefore to formulate general principles of approach to the solution of this problem.

In view of the present levels of scientific and technological capabilities of the developing countries, it would not be practical for many of them to believe that they can reconstruct their national economy on technical lines entirely on their own. No less a danger lies in the opposite view that the only way out is for the developing countries to perennially borrow scientific and technical know-how, technology and equipment.

The strategy of scientific and technological progress in developing countries should be based on a combination of national efforts utilizing the scientific and technical achievements of the industrial countries and international assistance which will open up the prospects for self-sustained growth in

the scientific and technological potential of the developing countries.

In general terms, the question could be asked what kind of a technology do the developing countries need? Such a question at first glance may seem to be somewhat surprising. As long as the developing countries intend to raise their standard of economy to a modern level, they need modern technology; namely, machine tools, equipment and technological know-how which are being used in the industrialized countries. This answer which is on the whole correct, however, requires some qualification.

Modern technology has evolved in the advanced countries where capital is abundant and labour is expensive. This technology as a rule is capital-intensive and labour-saving. The developing countries are faced with a different situation altogether. Typically, they are short of capital and have plenty of cheap unskilled labour. The optimal utilization of resources in this case obviously requires different inputs of human and mechanized labour, and would therefore call for other technological principles.

Besides, the technology of industrial countries is highly productive and is intended for mass production since capital investment and R&D expenditure which precedes it, can be recouped only if there is a fairly large market. The developing countries' domestic markets are very small and even the recent trend towards subregional and regional economic integration and co-operation has not so far changed this state of affairs. Export of manufactures too can only be done on a limited scale because of protectionist policies.

This is not to say however that the developing countries cannot use modern technology and therefore mainly rely on labour-intensive methods. Such a solution in fact perpetuates the third world's lack of technical development. [illegible] economic revival of the developing countries can be achieved through large-scale and highly efficient production based on the application of modern technology. Only this type of production will enable developing countries to raise their standard of living to a level which will mark the end of their economic dependence.

In most modern industries, especially those with continuous production cycles like steel-making, petrochemicals and fertilizers and cement production, electric power generation, the technical level and the type of technology are predetermined by the very nature of the production processes. This leaves very little choice. The relationship between the capital and labour input is virtually preset. But in some other branches of the economy, it is possible at a certain stage and expedient to use various technologies and types of machinery. The machine tool industry falls in this category to some extent.

In order to enable the developing countries to choose appropriate designs of machine tools and technology for indigenous production, it is considered advisable to study in greater detail the latest trends in the machine tool industry so that the developing countries are in a position to select suitable modern designs and production technology which will last for some reasonable period of time and not become highly inefficient, obsolete and outdated. These criteria

become doubly important when the resultant cost, quality, and above all export possibilities of machine tools produced in the developing world are taken into consideration.

I. OBJECTIVES OF THE STUDY

Steadily increasing production costs, a characteristic of most highly industrialized countries have led to a corresponding expansion of demand for more highly productive and more precise machine tools to the point where the industry in terms of its activity and technical standards has become quite an accurate index of the economic efficiency and productivity of the manufacturing industry. Many machine tools currently in use are clearly recognizable successors of basic designs. Some, however, are completely new in conception and involve machining methods, normally electrical, whereby the intense concentration of power (emanating from electric sparks, electron beams or laser beams) on a small area of workpiece causes the metal to melt and vaporize. A similar new concept is the manufacture of turbine blades by electrochemical techniques. Other machines are those used for electrolytic grinding for very hard metals and ultrasonic and abrasive jet machining.

In view of such rapid and innovative changes that are taking place in the areas of design and technology of machine tools, it becomes necessary for the developing countries to investigate thoroughly the question of obsolescence in the machine tool industry before acquiring designs and technology know-how from outside. The objective of this study, therefore, is to go into this question in depth and make a reasonably realistic forecast of machine tool technology for the future so that developing countries can go about the task of establishing their own machine tool industry in the proper direction, avoiding those designs and technology which are not suited to their needs, and those which could become obsolete in the near future. On the other hand, the investigation may reveal that as far as developing countries are concerned, it may not be advisable for them to go in for highly developed designs and technology in view of their local economic and social conditions and, more particularly, due to the high input needed to be invested in developing these complex machine tool designs and technology without any corresponding gains, and the absence of market demand for these types of machine tools in their own countries.

Furthermore the study may reveal that rather than expending resources in taking up outmoded designs and technology of machine tools only because of the simplicity and ease with which they could be introduced, the modernization of basic machine tool designs and technology in line with the trend in the developed countries could become more advantageous for the developing countries in the long run.

In between the two extremes i.e., on the one hand highly complicated and sophisticated designs and technology, and on the other old and outmoded machine tools and production technology of machine tools, the study could possibly indicate a midway for adoption by the developing countries so that their machine tools are modern and by using them, their manufacturing methods and production technology could become more productive and advanced and appropriately meet their local conditions and needs.

The study may throw some light on whether the process of organic development in machine tool technology which has taken the developed

world several hundred years should be repeated at all or whether there is also a possibility of leap-frogging, and avoiding the primitive and old designs of machine tools and technology, but taking up modern versions of these basic designs, and staying away from more sophisticated designs and technology in the machine tool industry of the industrialised countries as these may not be most appropriate for the developing countries.

In sum, the objective of the study is to make available to the developing countries adequate technological information as to the nature of technological development that could possibly take place in the field of machine tools in the 1980s and by the end of the current century. This may enable them to choose proper designs and technology for building their own machine tool industry taking into consideration on the one hand the likely technological obsolescence of some designs/types of machine tools and, on the other hand, their own future needs and technological and infrastructural capacities to assimilate modern designs and technology. In

broader terms, the study may indicate the implications for developing countries of the technological developments taking place in the advanced world in the field of machine tools and enable them to choose those designs and technology for building their own machine tool industry in a manner that their developments are in line with modern trends.

II. BACKGROUND OF THE MACHINE TOOL INDUSTRY

Since the beginning of history, human beings have used tools to make even better tools - starting with the Stone Age to the Iron Age. The culmination of these efforts are today's modern machine tools. These are machines that form the basis of much of modern industry, indeed even of civilization.

Definition of a Machine Tool. A machine tool is a power driven machine - not portable while in operation - which works on metals, wood, glass, plastic and similar materials for machining, forming, electrochemical processing or a combination of these processes. Machine tools range from simple drilling machines and lathes to complex, fully automated and computerised machines, machining centres with tool changers, multi-station machines, transfer lines and flexible machining system configurations capable of automatically producing work to consistent qualitative and quantitative criteria. Machine tools are essential to the manufacture of all metal products, providing the tools

of production of the manufacturing and engineering industry for a wide range of capital and consumer goods. Almost all metalworking machine tools produced are purchased by the metalworking industries like the vehicles and metal goods industries, and engineering and manufacturing industries.

It is not known for certain who made the first machine tool in the world and where and when it was made. But it is certain that the slide rest lathe was conceived and occasionally built centuries earlier than the best known early examples of Henry Maudslay's lathes in England built about 1800. The extraordinary skill thought necessary and the consequent cost of making highly accurate guides had always been a barrier to its widespread use. David Wilkinson of Pawtucket of the United States of America invented about 1794 and patented in 1798 a lathe that provided an empirical solution to these problems and made effective lathes commonly available.

Although Wilkinson's original lathe, which was about 20 ft long, contained the essential novel elements of design, viz., three-bearing points under

the slide rest and sufficient weight to keep them always in close contact with the bed, the arrangement was not such that its full potential could be realised. For the purpose of equipping a cotton mill in 1806, he built a second and much smaller lathe so useful that it was soon copied for another cotton mill. It then spread widely throughout the various industries.

When Wilkinson's patent expired in 1812, he was so engrossed in the prosperous manufacture of textile machines that he was indifferent to asking for an extension of his patent. Later in life when his circumstances were much reduced, he applied to the American Congress for a cash award based on the value of his inventions to the Government alone in its various workshops such as the National Armouries. He was awarded $10,000 in 1848 and he died in 1852 at the age of .. This then can be taken as the beginning of the romance of machine tools in the world.

There are presently two principal categories of machine tools viz., (i) chip-removing types, and (ii) forming types. In the chip-removing

process, there are ten main types: turning, milling, planing, shaping, drilling, boring, gear hobbing, tapping, broaching and grinding (cylindrical, internal, profile - external and internal and flat). Like all machine tool operations, the above ten processes depend not upon heat or pressure as do castings, forgings and stampings, but upon removing metal chips which range from the metallic gravel of planing to the fine dust of grinding and electrolytic chemical, plasma and laser machining etc. The variants and combinations of these and a few others could result in hundreds of different kinds of machine tools.

In the main category of forming machine tools fall all types of presses, forge hammers, explosion forming machines, welding etc.

While there is no substitute for machine tools, there is always a constant strife over technical attempts to substitute one type for another. This has given rise to literally hundreds of varieties and versions of machine tools, although machine tools currently in use are recognisable successors of basic types and designs.

Furthermore, operations like turning, milling, grinding and honing have remained basic processes of machining around which various types and innovative designs of machine tools embodying different types of production technologies have been developed.

The Importance of the Machine Tool Industry.

Few, if any, products and services of an industrialised country would exist if it were not for machine tools. There would be no trains, no ships, no aeroplanes and no cars. There would be no electric power plants, turbines and generators. And without agricultural machines, without modern transportation and communications and without refrigerators - all depending on machine tools - there would be no modern civilisation.

The industry's importance is strategic rather than quantitative. The machine tool is the mother of mass production and of modern industry itself, though the machine tool builders probably would never hope to become mass producers. Nearly every artefact of civilisation is either made

on machines or by machines that are made on machine tools. Yet such is the efficiency, productivity and longevity of the products of the machine tool industry that it has always represented only a small part of the total industrial output of any industrialised nation. For example, the entire world machine tool industry is smaller than many individual corporations in the United States which is why perhaps it remains unglamourous and does not so easily attract the attention of countries' planners, financiers, governments and politicians.

The machine tool industry is one of the main foundations of modern industrialisation. The industry's ability to produce the multifarious types of machine tools necessary for industrialisation is a vital factor affecting the economic and more particularly the industrial progress of any nation. Nearly most of the engineering industries viz., the machine building industry, electrical industry, automobile industry, telephone and communications industry, aircraft industry, ship building industry and products like rolling stock and locomotives, diesel and marine engines, bicycles,

sewing machines, structural fabrication, small tools and mining, building machinery etc., to name only a few, can only be developed with the aid of machine tools. The metalworking, manufacturing and engineering industries will of course have to reach a more advanced stage of development before the machine tool industry in general can begin to grow on a large scale.

The Need for Developing Countries to Establish a Machine Tool and Machine Tool Building Industry. Generally speaking, for industrial and economic development and technological self-reliance, the developing countries should consider establishing their own capital goods industry, the machine tool industry being one of the vital and basic industries. This is so because capital goods are the procreative property of industrial society - the manufactured goods' sole function is to produce and distribute other goods and services - and as such, they are basically responsible for raising productivity and national wealth. The chief economic difference between early primitive and modern civilized people lies in civilized peoples' facility in creating and using capital goods.

A nation must learn to create and increase a stock of these goods if it wants to progress; a nation that fails to replace or increase its capital stock begins automatically to regress. Secondly, capital goods in themselves constitute a sizeable and important part of the economy of any country.

Thirdly, what is vastly more important, capital goods play an economic role out of all proportion to their volume or value for they not only exaggerate but accelerate and sometimes lead the pace of the economy as a whole. When business in general falls off, the capital goods business tends to decline much more and thus intensifies the general decline. When business in general advances, the capital goods business tends to race ahead of it and thus intensifies the general rise. It is no wonder that the state of the capital goods market became a prime subject for the post-war planning movement that gathered momentum a few years ago and which originated during the Second World War. Without a virile machine tool industry, the production of capital goods is not possible.

In spite of such essential considerations for the economic prosperity of any nation, many developing countries have lagged behind in establishing their own capital goods industry in general and the machine tool industry in particular. However, countries like Argentina, Brazil, India, Mexico and the Republic of Korea have a sizeable capital goods industry of their own and a large machine tool industrial base. This base has given them a great advantage over other developing countries and they are today in a position to substitute imports of many items of consumer durables and consumer goods, capital machinery and engineering items. Some have reached a stage of development which enables them to export a variety of industrial products to support their international trade and maintain an equitable trade balance.

III. THE WORLD MACHINE INDUSTRY - A BRIEF REVIEW

The world machine tool industry, which consistently registered an increase in output from 1962 reflecting generally the industrial boom conditions in the main machine-tool-producing/using countries of the world, suffered the first set-back in 1974 due to the oil crisis. The rise in oil prices, unrelenting inflation and the confusion in the world money exchange market have had their repercussions on machine tool production and even though the world output picked up in 1975, it again fell by 1 per cent in 1976. However, the production rose again and registered a 19 per cent increase in 1979 over that of 1978 of total production of $22.7 billion. Even so, according to the National Machine Tool Builders' Association (NMTBA) of U.S.A., close to half of this increase is probably real. The remainder represents inflation and the bias introduced into the comparison by the problems of exchange rates.

The latest estimate of production of the 33 machine tool-producing countries in 1979 and the

revised statistics pertaining to 1978 are shown in .able 1. In the field of exports, the important machine tool-producing countries have a major share. The world exports of machine tools have risen steeply from 1964 and onwards as can be seen from Figure I. Similarly, the increase in the trend of machine tool consumption touched the $19.6 billion mark in 1979, see Figure II.

The machine tool industries of the developed countries hold a leading position in world machine tool production and trade. During 1979, 22 advanced countries viz., the United States of America, the thirteen member countries of the European Committee for Co-operation of the Machine Tool Industries (CECIMO) in Western Europe, the seven CMEA countries of Eastern Europe, and Japan accounted for about 93 per cent of the world's exports. These 22 countries consumed about 75 per cent of the world's total production as shown in Table 2. The United States was again the country with the most industrial investment

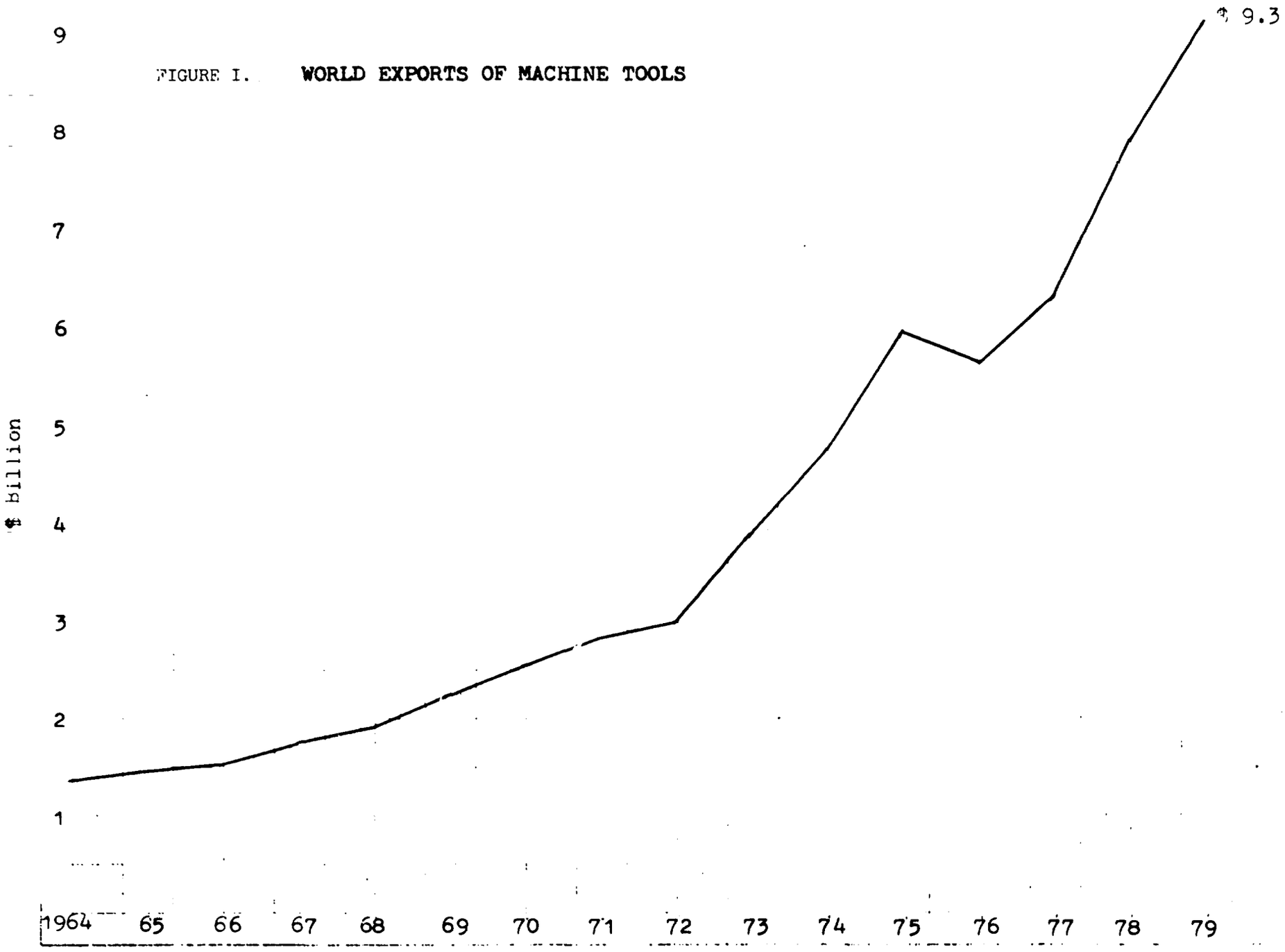
TABLE 1

World machine tool production and trade (millions of US dollars)

Country	1979 (estimated) Production Total	Cutting	Forming	Trade Export	Import	1978 (revised) Production Total	Cutting	Forming	Trade Export	Import
1. Germany, Fed.Rep.of	$4099.9	$2951.9	$1148.0	$2460.0	$541.2	$3396.4	$2373.8	$1022.6	$2122.3	$462.0
2. United States	3890.0	2940.0	950.0	660.0	1060.0	3004.3	2205.7	798.6	560.2	715.3
3. Soviet Union	2892.0	2234.0	658.0	350.0	800.0	2652.0	2056.0	596.0	332.0	803.0
4. Japan	2697.8	2081.5	616.3	1113.8	155.2	2350.3	1736.6	613.7	1017.5	119.9
5. Italy	1385.7	903.7	482.0	698.9	265.1	1060.5	698.3	371.2	596.2	194.4
6. United Kingdom	1106.4	872.3	234.1	468.1	574.5	821.4	639.1	182.3	426.0	399.2
7. France	918.1	586.2	331.9	479.8	352.4	723.0	535.7	187.3	382.7	289.6
8. German Dem. Rep.	805.8	636.7	169.1	661.6	243.8	698.6	552.0	146.6	547.9	217.8
9. Switzerland	797.1	677.5	119.6	677.5	139.5	768.2	652.8	115.4	652.8	124.3
10. Poland	684.6	600.8	83.8	190.9	518.3	678.8	594.9	83.9	163.4	595.8
11. China	420.0	315.0	105.0	28.0	60.0	405.0	305.0	100.0	20.0	65 0
12. Romania	403.6	359.7	43.9	130.7	381.2	294.3	268.0	26.3	88.0	339 0
13. Czechoslovakia	357.2	285.9	71.3	265.0	166.3	363.4	295.1	68.3	246.2	170.2
14. Spain	313.1	219.9	93.2	216.2	82.0	232.2	161.8	70.4	147.6	90 1
15. Brazil	239.8	191.8	48.0	33.0	136.0	255.3	203.0	52.3	20.1	226 2
16. Yugoslavia	222.5	121.0	101.5	50.0	150.0	173.5	105.1	68.4	41.7	150 2
17. Sweden	199.7	131.2	68.5	156.7	101.7	166.4	105.5	60.9	138.3	109 5
18. Other Asia	172.2	165.2	7.0	120.0	70.0	126.0	119.7	6.3	94.0	58 3
19. Austria	150.8	64.1	86.7	113.1	147.0	112.5	69.8	42.7	93.9	98 9
20. Rep. of Korea	150.0	107.0	43.0	22.0	140.0	95.0	68.0	27.0	5.0	156.0
21. India	129.0	112.9	16.1	31.0	55.8	111.8	96.8	15.0	24.4	48.8
22. Belgium	127.3	44.7	82.6	110.5	126.3	114.0	40.0	74.0	99.0	113.2
23. Hungary	115.9	107.3	8.6	89.8	123.9	109.3	101.7	7.6	84.2	112.7
24. Canada	110.3	64.6	45.7	66.4	330.2	84.8	47.4	37.4	52.8	228.0
25. Netherlands	75.0	50.0	25.0	39.0	102.0	66.5	43.9	22.6	34.7	90.9
26. Argentina	62.0	24.5	37.5	12.0	75.0	60.0	24.0	36.0	12.0	60.0
27. Denmark	48.0	26.0	22.0	25.0	42.0	45.3	24.9	20.4	23.7	39.8
28. Bulgaria	30.0	30.0	–	15.0	25.0	30.0	30.0	–	15.0	25.0
29. Singapore	21.3	19.3	2.0	27.7	92.1	12.0	10.4	1.6	18.8	46.8
30. South Africa	20.0	7.4	12.6	3.9	112.3	14.9	4.6	10.3	4.0	80.5
31. Australia	18.0	9.7	8.3	1.1	155.4	18.5	9.9	8.6	1.1	106.7
32. Mexico	15.5	7.5	8.0	1.5	85.0	13.6	6.6	7.0	1.3	75.0
33. Portugal	14.3	6.1	8.2	4.6	38.9	10.2	4.8	5.4	4.0	14.8
Total	**$22692.9**	**$16955.4**	**$5737.5**	**$9322.8**	**$7448.1**	**$19068.0**	**$14181.9**	**$4886.1**	**$8070.8**	**$6426.9**

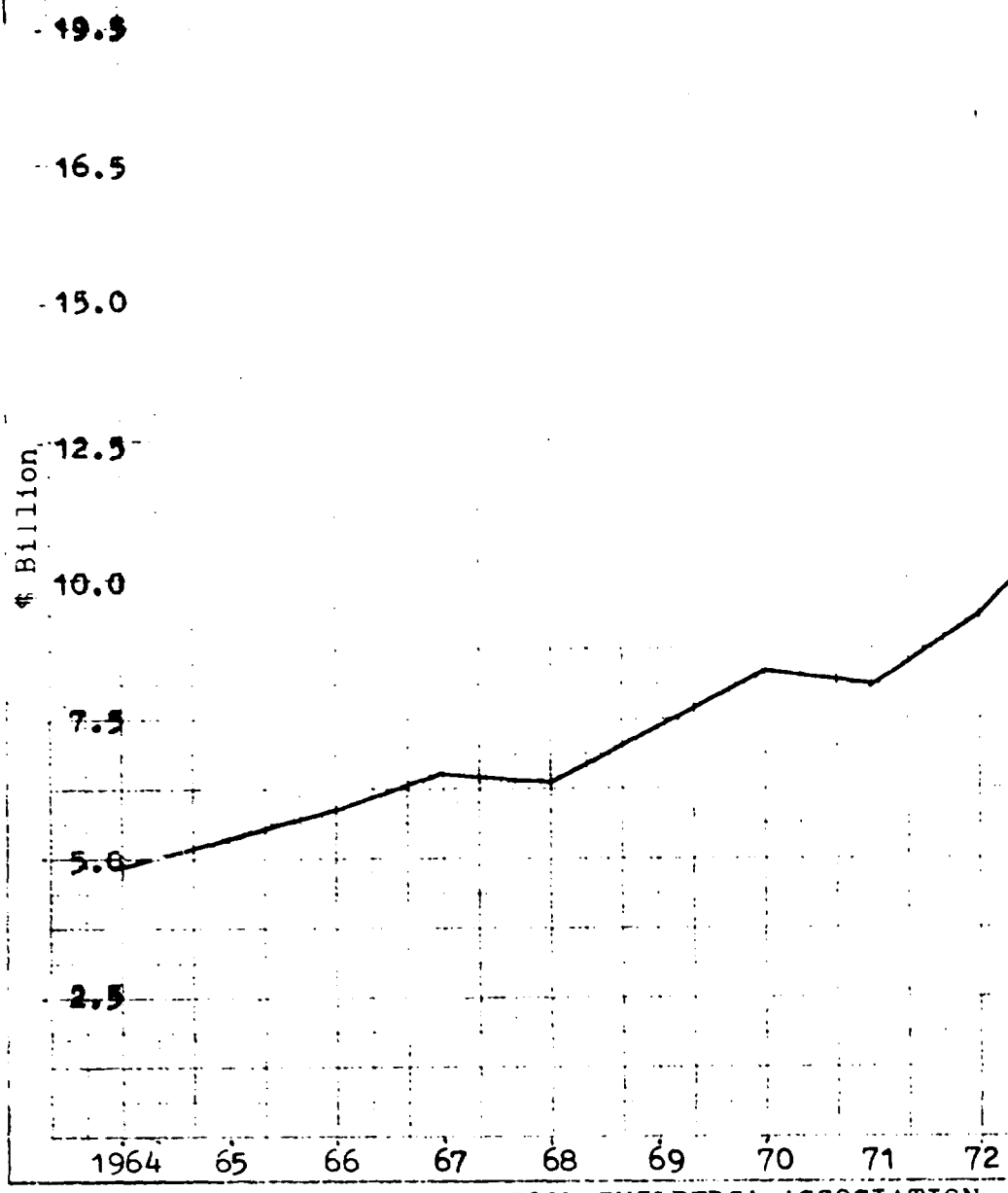
Source: AMERICAN MACHINIST, February 1980.

FIGURE I. **WORLD EXPORTS OF MACHINE TOOLS**



Source: NATIONAL MACHINE TOOL BUILDERS' ASSOCIATION.

FIGURE II. **WORLD MACHINE TOOL CONSUMPTION**



Source: NATIONAL MACHINE TOOL BUILDERS' ASSOCIATION.

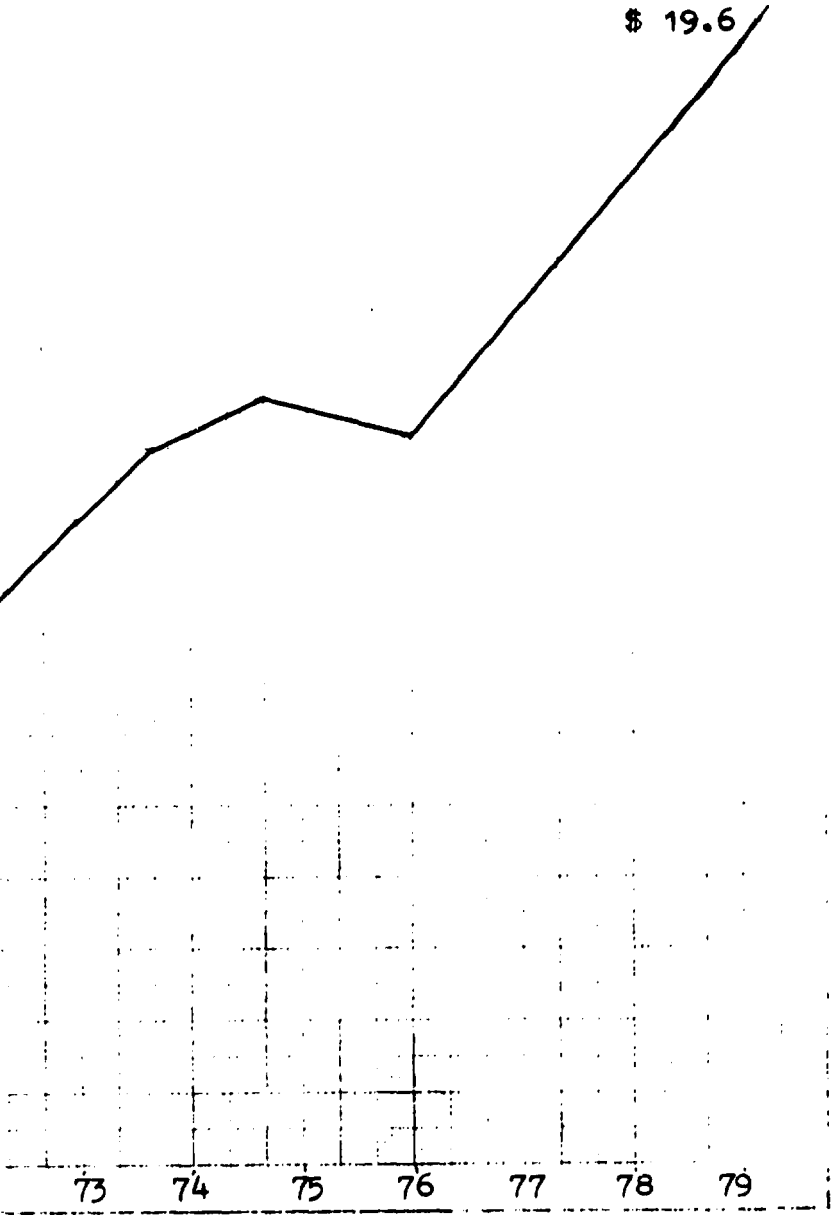

$ 19.6
73
74
75
76
77
78
79

TABLE 2

LEADING MACHINE TOOL CONSUMERS

(millions of US dollars)

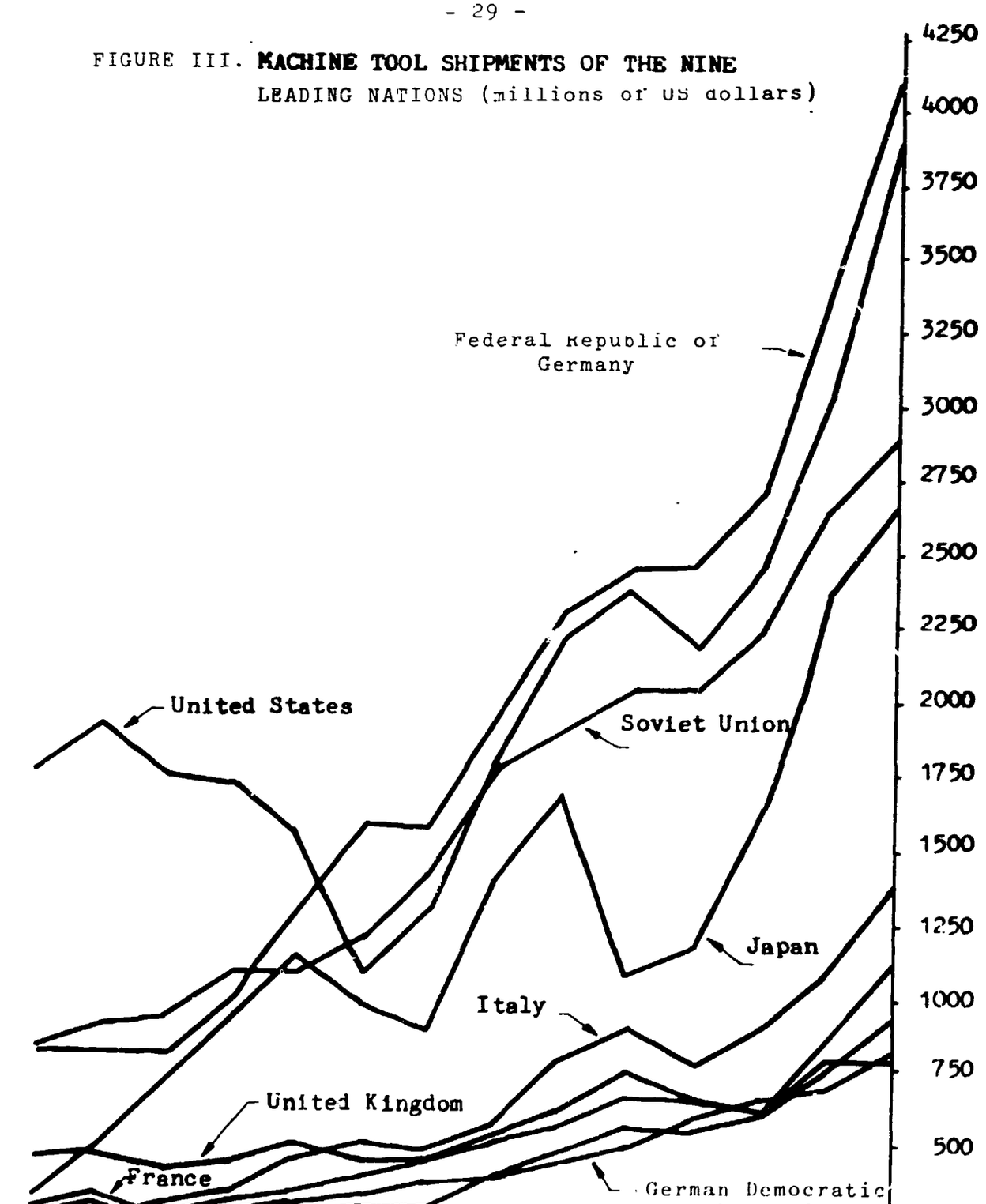
Country	1979	1978	Change before Conversion (per cent)	Change after Conversion (per cent)
1. United States	4 290.0	3 159.4	+35.8	+35.8
2. Soviet Union	3 342.0	3 123.0	+ 3.4	+ 7.0
3. Germany, Fed.Rep.of	2 182.2	1 636.5	+21.4	+33.3
4. Japan	1 739.2	1 452.7	+24.6	+19.7
5. United Kingdom	1 212.8	794.6	+37.7	+52.6
6. Poland	1 012.0	1 111.2	- 8.9	- 8.9
7. Italy	951.9	658.7	+41.3	+44.5
8. France	790.7	630.2	+18.1	+25.5
9. Romania	654.1	545.3	+20.0	+20.0
10. Brazil	342.8	461.4	-	-25.7
11. China	452.0	450.0	-	+ 0.4
12. German Dem.Rep.	388.0	368.5	- 4.1	+ 5.2
13. Yugoslavia	322.5	282.0	+16.5	+14.4
14. Czechoslovakia	258.5	287.4	-10.1	-10.1
15. Canada	374.1	260.1	+47.5	+43.9
16. Republic of Korea	268.0	246.0	+ 8.7	+ 8.9
17. Switzerland	259.1	239.3	+ 0.3	+ 8.3
18. Austria	184.7	117.5	+43.7	+57.2
19. Spain	178.9	174.7	-10.4	+ 2.4
20. India	153.8	136.2	+11.1	+12.9
21. Hungary	150.0	137.8	+ 6.0	+ 8.9
22. Sweden	144.7	137.6	- 0.5	+ 5.2

Source: American Machinist - February 1980.

and appeared to increase its lead over the Soviet Union which was the leading consumer of machine tools during 1978. Larger rates of increase in the consumption of machine tools, though from a smaller base, were recorded by Australia, Canada, Italy and the United Kingdom. It must be remembered that the rate of consumption of machine tools in any country determines the growth of manufacturing industries in that particular country. From this yardstick, the United States seems to have invested heavily in modernising and updating its various manufacturing activities besides adding to its existing capacity in this direction. This shows that machine tool production, consumption and trade are concentrated in these 22 countries. The machine tool shipments of the world are shown in Figure III. Incidentally, the Federal Republic of Germany, France, the German Democratic Republic, Italy, Japan, Switzerland, the Union of Soviet Socialist Republics, the United Kingdom and the United States also provide the technological lead in the field of machine tools. The developed countries' share of production and export of machine tools are shown in Figures IV and V respectively.

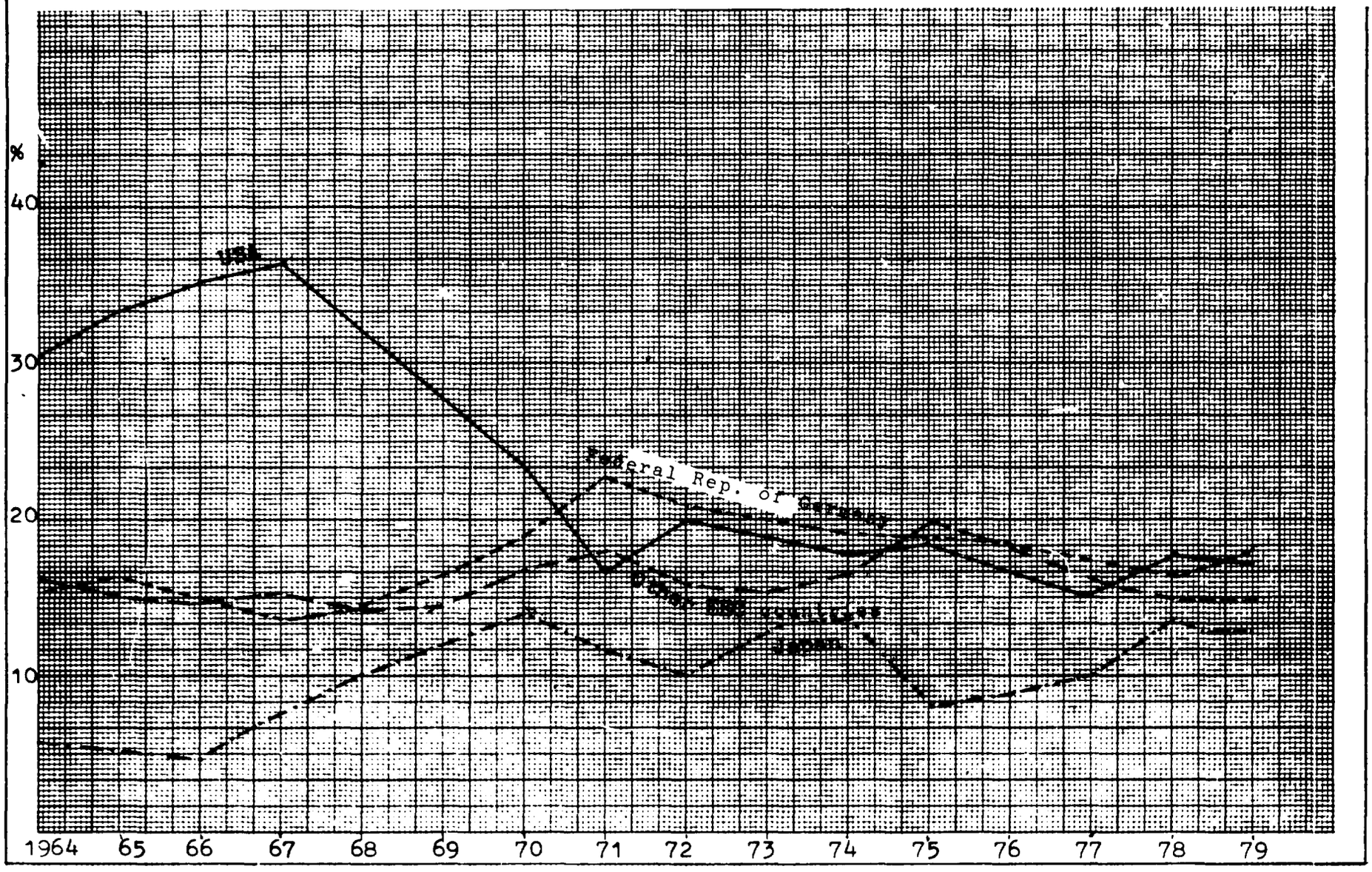
The high degree of industrialization of these countries, their monetary strength and their flourishing economies provide the basis for their strong

FIGURE III. **MACHINE TOOL SHIPMENTS OF THE NINE** LEADING NATIONS (millions of US dollars)



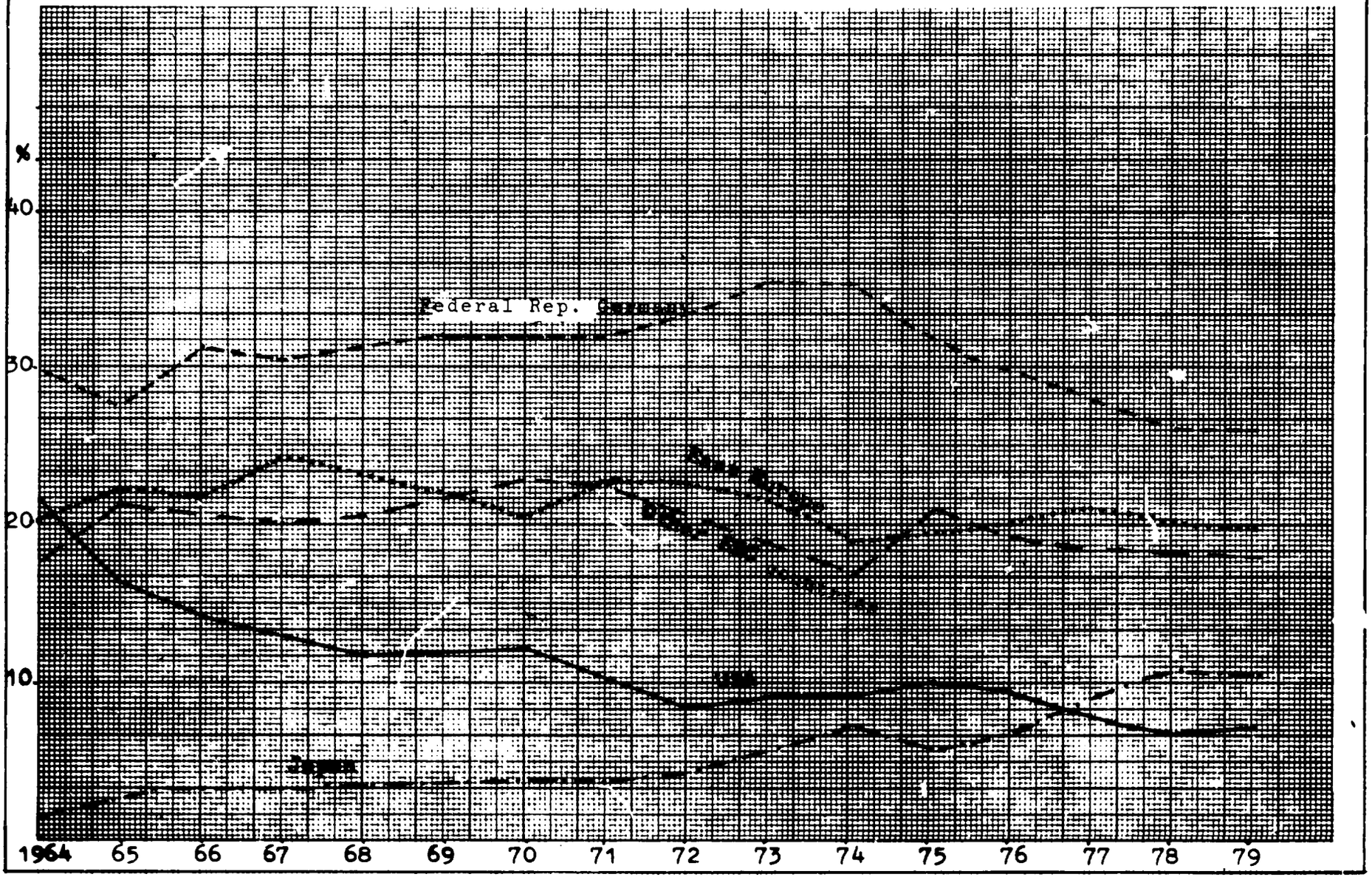
Source: AMERICAN MACHINIST, February 1980.

Figure IV. The share of production of machine tools of the developing countries as a percentage of the world output



Source: NATIONAL MACHINE TOOL BUILDERS' ASSOCIATION.

Figure V. The share of export of machine tools of the developing countries as a percentage of world exports



Source: NATIONAL MACHINE TOOL BUILDERS' ASSOCIATION.

machine tool industry. Traditionally, these countries have accounted for 80 per cent of the world trade in most industrial goods as well. Historically these developed countries have developed all the technological innovations in the realm of metalworking equipment. The advanced designs and technological developments in these countries have been more, in a way, an answer to their own requirements, viz., the speeding up of production and productivity and the progressive saving of labour.

The industrial boom in the developed countries has not only provided impetus for the growth of their metalworking sector, but even the higher level consumption of their societies demands that these growth rates are maintained to ensure continued affluence.

However, judging from their present level of energy consumption, some apprehensions are expressed that the developed countries may not register the same rate of economic growth as envisaged before because their industries and technology depend upon depletable energy inputs like coal and crude. But

since these countries have predominant technological power, resources and capabilities and the necessary infrastructure for R&D activities in almost all industrial disciplines, alternate energy sources may well be tapped by them much earlier than by the other countries of the world.

IV. THE MACHINE TOOL INDUSTRY IN SOME OF THE LEADING MACHINE TOOL PRODUCING/EXPORTING COUNTRIES

The machine tool industry in most of the industrially advanced countries has many common features. Even so, the developments taking place are not quite uniform. For instance, some countries like Switzerland specialise in producing super precision machine tools like jig boring machines, jig grinding machines, gear grinding machines, moving headstock automatics and machine tools needed by the watch industry. The United States has specialised in producing very high performance productive machines mostly with NC and CNC/DNC systems of controls, for small and medium batch quantity production, large batch production and mass production of single components (e.g. transfer lines). EEC countries and Japan and socialist countries, like Czechoslovakia, the German Democratic Republic and the Soviet Union produce heavy duty and high production machines needed mostly for general applications at very reasonable prices. This explains the fact that major machine-tool-producing countries have themselves been the principal importers

of machine tools. It is very common to see Swiss grinding machines, jig boring machines or gear grinding machines in the Federal Republic of Germany, Japan, or the Soviet Union. On the other hand, Switzerland France, Italy and the United States import a lot of machine tools from the Federal Republic of Germany for particular applications. No country in the industrialized world has ever attempted to be self-sufficient in its requirement of machine tools. Some developed countries in the socialist bloc which experimented with the concept of self-sufficiency to an extreme degree, had to give up eventually in order to improve the quality and productivity of their domestic machinery - products and equipment - and also to compete in the world market.

From these considerations and as guidance for developing countries, it is considered worthwhile to give the following brief accounts of the status of machine tool industries in some of the important industrialised countries.

THE MACHINE TOOL INDUSTRY IN THE FEDERAL REPUBLIC OF GERMANY

The machine tool industry of the Federal Republic of Germany rose from the ashes of a war-ravaged country in 1947 to grow and occupy a leading position in the world within two decades. Many attribute the economic miracle of of the country to the dynamism and phenomenal growth of its machine tool industry. For a few years in the late 1960s and early 1970s, the machine tool industry of the Federal Republic of Germany edged over the United States to the second place in the world ranking of machine tool-producing nations. The United States recaptured the first position in 1975 but the Federal Republic swung back to the first rank in 1976 and has held that place ever since.

The phenomenal growth of the machine tool industry in the Federal Republic of Germany was facilitated by two important factors: (i) Most of the capital equipment of the country and that of quite a few European countries was damaged during the Second World War. The rebuilding of the country hinged on making available the required capital equipment like machine tools for reconstruction. (ii) The destruction during the War provided an opportunity to equip machine

tool plants with the latest machinery, thus combining the advantage of higher productivity with modern designs. These two factors together with the generous assistance from the United States under the Marshall Plan for the economic recovery of Europe helped to rebuild modern machine tool factories all over the Federal Republic of Germany and Berlin (West). The hectic reconstruction of the industrial base of Western Europe and the favourable boom conditions over a long period provided the ideal setting for the country's machine tool industry to grow into a most powerful catalyst of industrialisation.

Production. The country's machine tool industry produced DM 6.8 billion worth of machine tools in 1978. The production rose to DM 7.5 billion in 1979. The American Machinist estimated that the production for 1980 might touch DM 8.2 billion. The production of metal-cutting machine tools in 1978 was worth $2,234.7 million, and metalforming machine tools $1,054.2 million, according to the American Machinist. The production, consumption, export and import of machine tools together with percentages of exports to total production and imports to total consumption from 1975 to 1979 are shown in Table 3.

Table 3. THE MACHINE TOOL INDUSTRY IN THE FEDERAL REPUBLIC OF GERMANY: PRODUCTION, CONSUMPTION AND TRADE

Value: in U.S. $ millions

Year	Production	Consumption	TRADE			
			Export	Percentage to production	Import	Percentage to consumption
1975	2 403.9	808.8	1 814.3	75.48	219.7	27.16
1976	2 410.6	909.4	1 738.7	72.12	237.5	26.11
1977	2 635.5	1 132.7	1 823.2	69.18	320.4	28.28
1978	3 396.4	1 636.5	2 122.3	62.48	462.0	28.23
1979	4 099.9	2 182.2	2 460.0	60.00	541.2	24.80

Source: American Machinist.

Exports and Imports. The Federal Republic of Germany's export trend from 1975 to 1978 indicated a fall in export of machine tools (see Table 3). The annual decrease in real terms is about 5 per cent. This could be partly due to the revaluation of the German mark vis-à-vis the United States dollar. Italy has succeeded in cutting into the country's share of exports because of distinct price advantage and other favourable terms given to customers. According to the estimate of the German Economic Institute, the labour costs during 1979 accounted for as much as 20.06 billion

DM per annum in the Federal Republic of Germany while it was 13.72 billion DM per annum in Italy for the corresponding year. It must also be noted that even in the developed countries, the labour-intensive character of machine tool manufacture, persists despite impressive advances in automation.

In spite of this handicap, the export share of the country's tool industry occupies the first rank and is far ahead of other countries, such as France, Italy, Japan, the Soviet Union and the United States. This is mainly due to the technological strength and quality-consciousness and high degree of aggressiveness of the country's tool exporters. The country is convinced that it can retain its world rank only by introducing new technology machines and by constantly upgrading the existing metalworking equipment. The industry continues to depend primarily on exports, which account for more than 60 per cent of the total output of machine tools in the country.

The country's machine tool industry has also come to rely on the home market for as much as 35 per cent of its production; the impetus to go in for higher technology machines will mainly

arise from home demand and from sophisticated export markets like the United States. During 1979 the increase in domestic demand was indicated by the higher investments in industrial development projects. Even in this swelling home market, only those who have gone ahead with product development have a chance of selling their latest designs of machine tools in view of the high productivity of modern equipment.

The country's imports of machine tools as a ratio to total consumption increased to 28.23 per cent in 1978 but went down to 24.80 per cent during 1979. As can be seen from Table 3, the imports of machine tools are somewhere in the region of about 25 to 30 per cent, as a percentage of total consumption. This again proves the fact that the biggest machine-tool-producing and exporting countries are themselves large importers of machine tools. The country's imports of machine tools are likely to rise because of the increasing cost of manufacture brought about by wage increases and lower working hours in the country's machine tool industry. Japan and Switzerland are expected to boost exports of their products to the Federal Republic of Germany

because of the almost steady cost of manufacture of machine tools in these two countries. Japan now ranks fourth in the list of countries from which the Federal Republic of Germany imports machine tools.

Technological Strength. The foremost position of the country's machine tool industry in the world is due to its technological strength in all spheres of machine tool manufacture. The research and development support to the machine tool industry is provided by continuous work done in the country at machine tool research institutes like the Technische Hochschule, Aachen and the Technische Universität, Berlin (West). It has been acknowledged by many that the research work conducted at these centres has been of such a far-reaching nature that the prosperity of the country's industry can be directly attributed to the visionary approach of the leaders who have been in charge of institutes and in establishing the closest liaison between them and the universities on the one hand and industry on the other. The country has pioneered some of the major advances not only in electronics but also

in many other fields including product reliability and safety. More than 25 per cent of NC machine tools exhibited at the Third European Machine Tool Organization (3 EMO) exhibition at Milan, Italy, were equipped with Siemens/Fanuc controls.

The country's technological strength is evident from the quality of their products, stretching from simple lathes to the most sophisticated manufacturing systems incorporating robots and computers.

Outstanding developments have been achieved by the country in the area of NC controls. In a joint venture with Fanuc of Japan, Siemens have almost relegated other control manufacturers like General Electric, Bendix and General Automation to lower ranking positions. Using Sinumeric Mate TG, a microprocessor-based CNC for lathes, the programmed workpiece contours and the machining sequence are shown on the graphic display in the same way as on an electronic drafting machine. The control system determines the necessary rough and finishing-cut sequences from infeed valves and it has the capability to display current cutting data.

Two major series of controls were recently introduced by Siemens/Fanuc, system 6 and 8.

Both use a new 16-bit microprocessor and offer the option of bubble memory with 256,000 character storage. The system 6 was developed by Fanuc to replace the system 5, 6T for lathes and 6M for milling machines. The system 8 was developed by Siemens to replace their old 7 and is available for lathes, for milling and for drilling with up to 10 axes for machining centres. The system includes an arrangement by which information can be presented on a display screen that provides some of the alarm and diagnostic functions.

Laser cutting has been added to NC and according to the President of Trumpf, the firm was the first to acquire a laser for this purpose and incorporate it in their punching machine. The machine floats on air supports when it is punching, but it is lowered to a rigid foundation when laser cutting.

Trumpf has been trying further to reduce noise in their punching machines by putting sound-absorbing casings round those components of the machine which produce most noise. The principal source of noise of course is the cutting tool. This has been reduced to about 10 dB through special geometry of the tool.

THE MACHINE TOOL INDUSTRY IN THE UNITED STATES OF AMERICA

The machine tool industry in the United States is located predominantly in the north-east and north-central parts of the country. In terms of numbers of employees, this branch of industry is relatively small and is characterised by many small and medium-sized firms, although the Western world's largest machine tool units are in the United States.

The current picture of the country's machine tool industry is bright for machine tool builders. New orders are pouring in at the rate of over $ 300 million a month and machine tool builders are adding shifts, planning expansions and otherwise moving to meet demands for more capable equipment. In spite of increased production, the industry is facing delivery delays and backlogs are climbing to a record high. In 1979, the total industry backlog was over $2.5 billion.

Most recently, however, the industry is facing some problems. With the operating rate of the metalworking industry estimated at 76 per cent and decreasing, there are ominous signs for the

machine tool industry. In metalworking, the problem is the automotive industry, which is operating at a little more than half of its capacity. But the industry accounts for only 20 per cent of the output of the metalworking industry. The machinery, electrical machinery and aircraft segments, which represent more than half of the total output of the metalworking industry, are still operating above 80 per cent. This fact should more than allay the pessimistic foreboding of United States machine tool manufacturers, so scared by the current recession in the country's economy. But to survive the recession the machine tool manufacturers need to undertake extensive product development which, as observed, is being done.

Production. The machine tool industry in the United States produced $3,004.3 million worth of machine tools in 1978 and in 1979 the production rose to $ 3,890 million. Production, consumption, exports and imports of machine tools together with percentages of export to production and imports to total consumption from 1975 to 1979 are shown in Table 4.

Table 4. THE MACHINE TOOL INDUSTRY IN THE UNITED STATES OF AMERICA: PRODUCTION, CONSUMPTION AND TRADE

(Value: in US $ million)

Year	Production	Consumption	TRADE			
			Export	Percentage to production	Import	Percentage to consumption
1975	2 451.7	2 201.7	576.6	23.15	317.6	14.42
1976	2 169.3	1 941.1	546.5	25.15	318.3	16.40
1977	2 440.7	2 389.5	452.1	18.52	400.9	16.78
1978	3 004.3	3 159.4	560.2	18.64	715.3	22.64
1979	3 890.0	4 290.0	648.8	16.97	1043.8	24.71

Source: American Machinist.

Exports and Imports. Machine tool exports represent an important factor in the U.S. trade balance but constitute a small proportion of the total amount of production, which is partly due to the fact that the U.S.A. itself needs to replace the old machine tools presently in operation in the metalworking industry. As a matter of fact, in 1979, the United States was the top consumer and importer of machine tools in the world and this appears perhaps natural if the age and quantity of machine tools installed in the country are considered.

According to recent statistics, based on the 12th American Machine Tool Inventory of Metalworking

Equipment, published in December 1978, the United States has the lowest percentage of machines under 10 years old (31 per cent) and the highest percentage of over 20 years old (34 per cent) of many industrialised countries like Canada, the Federal Republic of Germany, France, Italy, Japan and the United Kingdom. United States exports as a percentage of the total production are decreasing, as can be seen from Table 4. However, the U.S.A. perhaps is leading other countries like the Federal Republic of Germany and Japan in exporting high technology machines. The U.S. exports of metalcutting machine tools increased by 11 per cent over the 1978 level, with notable gains registered in exports of horizontal machining centres, vertical boring machines, horizontal boring-drilling-milling machines, electrical discharge machines, threading machines and multi-station transfer machines. Metalforming machine tool exports rose by 24 per cent in 1979 with increases in almost all product types.

Many of the machine tools imported by the United States come from Japan and the Federal Republic of Germany. During 1979 Japan supplied over one third of the total United States imports of machine tools followed by the Federal Republic of Germany representing 19 per cent.

United States machine tool imports

since many years figured lower than exports until recently and the deficits in the machine tool trade balance occurred for the first time in 1978 and continued in 1979 when imports were higher than exports.

Technological Strength. The machine tool industry of the United States now uses machines incorporating the latest technological features such as Numerical Control (NC), Computer Numerical Control (CNC), Direct Numerical Control (DNC) and the industry is shifting its emphasis from individual machines to complete manufacturing systems based on CAM (Computer-Aided manufacture). One noteworthy aspect is that NC machines accounted for 34 per cent of shipments in 1975 and this percentage is continuously on the increase and the United States produced as many as 5,688 NC machine units during 1978.

A new array of system-elements - matching centre, computer-aided operations, minicomputers, adaptive-controls, automated diagnostics and microprocessors - is at the service of the machine tool builders. In addition to accelerating change in modern manufacturing, as stated in the report of the Society of Manufacturing Engineers, United States of America,

published by the American Machinist, "they are also working a corresponding change in the configuration of industry and in the very nature of manufacturing engineering...". Clearly, the production of labour-intensive general purpose machine tools is on the wane and requirements for such machines are being met by imports from outside. In the coming years, the machine tool industry of the United States will emerge as the major supplier of integrated, flexible production plants to retain its lead in the world market. The secret behind the success of the country's machine tool industry lies in its ability to speedily convert technological innovations into production realities.

The industry is currently involved in rapid growth filled with swift transition in product design and application and undergoing revolutionary changes in both the nature of its products and the structure of the industry that produces them.

Even so, there are some deficiencies in the country's machine tool industry as pointed out by the Machine Tool Task Force Report on Machine Tool Technology

published in 1980. It states that co-operation between industry, academic and government sectors is not as strong in the United States as in some other countries, notably Japan and the Federal Republic of Germany. Lack of co-operation in the United States appears to have been due to a variety of reasons, such as anti-trust concerns, the diversity of user industries, the many small specialised and diverse companies of the industry, the individualism of various companies and the general adverse relationship that exists between the groups. Another salient observation of the Task Force is that the United States is the only major developed country that does not have a machine tool institute which in other countries often becomes the focal point for common technology interests. Yet another rather surprising observation is that many good ideas come out of research laboratories in the United States, but buyers are slow to adopt them because they are reluctant to risk using a new technology.

The outstanding technological breakthrough in production engineering pioneered by the machine tool industry in the United States has been in organizing the manufacturing process, through a computer-aided

system (CAM), called the flexible manufacturing system (FMS). This new method relies on three distinguishing characteristics: (i) potentially independent NC machines; (ii) a transport mechanism; and (iii) an overall method of control that co-ordinates the functions of both machine tools and the transport system so as to achieve flexibility. Within this broad scope, there are any number of individual approaches towards striking a balance between high output on the one hand and great flexibility with concomitant reduction in volume of output, on the other.

Yet another revolutionary change in computer-aided manufacturing (CAM) in the United States is the introduction of computer graphics, which can be defined as a human-oriented system that uses the capabilities of a computer to create, transform and display pictorial and symbolic data. Computer graphics are widely employed in the United States manufacturing industry for geometric modelling e.g., NC programming, preparation of drawings, calculations, assembly studies and work planning.

THE MACHINE TOOL INDUSTRY IN THE UNION OF SOVIET SOCIALIST REPUBLICS

The machine tool industry in the Soviet Union ranks third in the world. Yet the Soviet Union is a major importer of machine tools being one of the foremost consumers of machine tools. The machine tool industry in the Soviet Union was one of the very first to be put on a firm foundation after the Revolution for the industrial development of this vast nation. The machine tool industry was formerly concentrated in the areas around Moscow and Leningrad but now it has been, as a policy, deliberately well spread in the other areas except in the vast expanse of Siberia.

Production. The Soviet Union produced machine tools worth $ 1849.3 million in 1974 of which metalcutting machines accounted for $ 1354.7 and metalforming machines for $ 494.6 million. In 1975 the production of machine tools rose to $ 1984.4 million in which the share of metalcutting equipment was worth $ 1456.4 and metalforming machines worth $ 528 million. In 1975 the Soviet Union produced 232,000 machine tools consisting of 181,500 metalcutting machine tools and 50,500 metalforming

machines. Production of machine tools again registered an increase in 1976 to reach a total of 232,000 machines valued at $2,010 million, of which metalcutting machine tools accounted for $1,555 million and metalforming for $ 455 million. In 1977 the production of machine tools rose only marginally to reach 238,000 machines of which 6552 machines were programme controlled, probably including both NC and plug board types. The production in 1977 was valued at $2,201.9 million of which metalcutting machine tools were worth $ 1707.7 million. Even though the value of production rose to $2,652 million in 1978, the number of machine tools produced during that year was the same as in 1977. The increased value of production is attributed to the higher number of programme-controlled machines. The NC and plug board machines accounted for as many as 7,365 machines in 1978. The production of metal-forming machines touched 55,000 units valued at $ 596 million. The production in 1979 was estimated even less in number of units, viz., 230,000 at $ 2892 million of which metalcutting machines were estimated at $2234 million and metalforming machines at $ 658 million. The number of NC

machines was expected to rise to a record height of nearly 8,000 pieces. The Soviet Union has progressively increased its production of machine tools since 1974 and has consistently occupied the third rank in world production behind the Federal Republic of Germany and the United States. The production, consumption, export and import of machine tools together with percentages of export to production and of import to total consumption are shown in Table 5.

Table 5. THE MACHINE TOOL INDUSTRY IN THE UNION OF SOVIET SOCIALIST REPUBLICS: PRODUCTION, CONSUMPTION AND TRADE

Value: In U.S. $ millions.

Year	Production	Consumption	TRADE			
			Exports	Percentage to production	Imports	Percentage to consumption
1975	1 984.4	2 286.6	187.8	9.46	490.0	21.43
1976	2 010.0	2 489.0	235.0	11.69	714.0	28.69
1977	2 201.9	2 821.4	280.5	12.74	900.0	31.90
1978	2 652.0	3 123.0	332.0	12.52	803.0	25.71
1979	2 892.0	3 342.0	350.0	12.10	800.0	23.94

Source: American Machinist.

Exports and Imports. In 1978, the Soviet Union exported $ 332 million worth of machine tools. The exports in 1979 were estimated at $ 350 million. Most of the country's production of machine tools were exported to the leading CMEA countries. The top customers in order of significance were: Poland, Czechoslovakia, German Democratic Republic, Romania and Bulgaria. The Soviet Union also exported sizeable quantities of machine tools, largely as part of barter trade, to other Western countries.

However, the Soviet Union is an important importer of machine tools. In 1977, it imported machine tools worth $ 900 million. In 1978, however, imports decreased to $ 803 million and were estimated at $ 800 million in 1979. The Soviet Union imports most machine tools from the Federal Republic of Germany, France, the German Democratic Republic, Italy, Japan and Switzerland, and Japan. The Soviet Union made heavy purchases of machine tools for the Kama River Project and for its Togliatti automobile (Fiat) plant from the Federal Republic of Germany, France, Italy and the United States. Prospects of imports of machine tools from the West by the Soviet Union were not likely to improve during 1980 because of the country's shortage of hard currency.

Technological Strength. The Soviet Union has the widest research and development base, perhaps next only to the United States. The foremost research and development organisation, the Experimental Scientific Research Institute of Metalcutting Machine Tools (ENIMS), Moscow, and a large number of machine tool institutes at various universities in Moscow, Leningrad, Kiev and Yerevan are actively engaged in research on various aspects of machine tool technology. Some of the important research work in machine tools in the Soviet Union is in the area of precision machine tools. Extensive research and development work is being done in the static rigidity, dynamic stability and thermal stability of machine tools and their effects on working accuracies; and standards have been evolved in this regard. Instruments for measuring accuracy of spindle rotation over the whole range of working speeds have been developed and put into practical use.

Means of calibrating standards of length have been developed. Linear ruling machines, permitting a line reproduction accuracy of 0.3 micron and a ruling error of 1 micron over 1,000 mm are being produced. Line standards are calibrated with the aid of a comparator with a maximum measuring error of under 0.2 micron.

A laser interferometer has been developed for reproducing the standard of length. A very high order of measuring accuracy has been achieved by splitting the laser beam into two half beams, one of which is used to compensate for thermal distortion errors. Measurements are made possible with an accuracy of 0.02 micron. The laser interferometers are used in the manufacture of ultra-high precision measuring systems, line-standards calibration instruments and feedback transducers for high accuracy, closed-loop NC systems.

Research work is being conducted in the design and construction of basic machine tools. Among others, high precision machines for the generation of master helical bevel gears of ENIMS' own kinematic system, a machine for gear hobbing with direct motor drives for hob and the gear blank (without gear drives). are some of the examples.

One of the major areas of research and development undertaken at ENIMS in close collaboration with the industry is the automation of production processes, employing NC machine tools and industrial robots that constitute elements of complete automatic manufacturing systems.

New wide-range transistorised generators for Electron Discharge Machining (EDM) have been developed which have improved the machining accuracy by one to two classes; increased the productivity by two to three times and resulted in a reduction of electrode consumption by a factor of 10 to 15. EDM machines with table sizes up to 16,000 sq cm for processing large forgings and drawing dies have been developed. New methods of EDM with oscillatory rotary copying motion for the manufacture of large size moulds and dies and a method combining ultrasonic and Electrochemical Machining (ECM) for the machining of carbide heading dies and drawing dies have been developed.

Laser beam machines for processing diamond dies have been developed and produced. Research work is in progress for the application of laser beam machining for turning of hard-to-work metals.

Computer control is applied for production planning, scheduling, workpiece transport and location, machining, inspection, quality control, machine tool supervision, faultfinding, partial resetting and so on.

The Soviet Union is now engaged in designing new equipment to speed up the production of automatic machines using minicomputers. The emphasis on the production of NC and CNC machines is evident from the fact that the Soviet Union is a leading producer of NC machine tools as shown in Table 6, in which the production of the Soviet Union is compared with the NC machine tool production of other developed countries.

The research emphasis is to considerably increase the output of special tools and automated lines and also to increase the use of modular design of automated lines. The Soviet Union is currently engaged in the large-scale production of automated manipulators controlled by computers. The development of these robots obviously reflects the country's interest in establishing an impressive lead in space and nuclear research.

The Soviet Union is also developing superhard materials and alloys, in addition to natural and synthetic diamond tools for NC machines.

Table 6. Numerically controlled machine tools - world production - 1977

Sl No.	Country	NC Machines (Units)	Value $ Million	All Machine Tools (Units)	Value $ Million	NC Units All M/c Units %	NC Value All M/c Value %
1.	U.S.A.	4221	491	273,819	2350	1.55	21
2.	Japan	5436	300	147,731	1564	3.82	20
3.	Federal Republic of Germany	1885		256,911	2619	0.74	--
4.	U.S.S.R.	6300			2300	--	--
5.	France	576*	80	64,320	580	0.90	14
6.	Italy	710*			850	--	--
7.	U.K.	607*	47	65,552	701	0.93	7

* The figures correspond to 1976.
(For selected countries only)

Source: NMTBA Handbook 1978-79. American Machinist, February 1980
Metal working engineering and marketing. September 1979.

THE MACHINE TOOL INDUSTRY IN JAPAN

Even though Japan has been making machine tools for the last 100 years, it was neither a major producer nor a trend-setter till about the early 1960s. Massive Government assistance and dedicated R & D efforts, started after 1957, produced startling results by elevating Japan in 1972 to the fourth place in the world ranking of machine-tool-producing nations, surpassing leading nations like France, Italy and the United Kingdom.

Japan's machine tool industry presently is enjoying a complete recovery from the severe set-back it suffered in the 1973 oil crisis, with a salient increase scored in the new orders received during 1978. This recovery reflects the successful efforts of the industry to meet the needs of machine tool users that push modernisation and efficiency as the yen rapidly appreciates on international currency markets.

The production of NC machine tool received positive support from the Japanese Government and national research laboratories as early as 1958. The generous financial support from the Government and the dedicated

efforts of the manufacturers and R&D institutions produced impressive results. This factor, together with constant improvements in the product quality, earned for Japan the reputation of being a supplier of quality machine tools and also helped to erase from the minds of many the impression of Japan as a supplier of cheap products which were poor imitations of those made in the Western world. The Japanese machine tool industry has actively developed Numerically Controlled (NC) machine tools. This effort has not only met existing demand, but helped to create new demand from user industries. Even abroad, reasonably priced NC machine tools built in Japan have drawn increasing attention from user industries. Japanese NC machine tool builders are steadily strengthening their positions in machine tool markets both in Europe and the United States.

The technical level of the Japanese machine tool industry continues to rise too, with its current efforts to develop and build high precision machine tools for use by aerospace manufacturers. This challenge is stimulating some innovative development in the Japanese machine tool industry.

Production. Japan's machine tool industry's output was ¥ 45,169 million in 1960 and it touched a value of ¥ 100,892 million in 1962. From then onwards the industry's production rose except in the years between 1964 and 1966. But production soon picked up and established impressive gains up to 1970 during which year Japan produced ¥ 312,349 million worth of machine tools.

Japan's booming economy got the first jolt in 1971 when the dollar crisis hit the industrialised nations of the world. In 1971 machine tool production witnessed a 15.4 per cent decline over the values of 1970, and the production further receded by 22.4 per cent in 1972. Even though the production picked up in 1973 and 1974, there was another slump caused by the repercussions of the oil crisis in 1973. The production level stagnated in 1975 and 1976 and started rising in 1977. Since then, Japan has been establishing production records to dethrone several industrialised nations like France, Italy and the United Kingdom in the world ranking of nations producing machine tools.

Japan's output of machine tools touched a value of ¥ 312,844 million in 1977. If the

trends of production in 1977 are examined more closely on a type-to-type basis, the most outstanding feature is the big increase in the manufacture of special purpose machines. They totalled 3609 units worth ¥ 54,768 million and constituted 17.5 per cent of the total value of production of the Japanese machine tool industry. The second highest share of production was held by NC machines which accounted for 25.7 per cent of production by value. Japan produced a total of 5436 NC machines in 1977 valued at ¥ 80,548 million. The NC machines thus ousted the general purpose lathes which previously accounted for the highest value of production.

The production increased in 1978 by 17 per cent over that of 1977. The most noticeable fact of production in 1978 is that the output of NC machines further increased to touch a value of ¥ 108,476 and accounted for 35.8 per cent of the total production. This was 25.7 per cent more than in 1977. The production of NC lathes represented 4986 machines valued at ¥ 57,862. Furthermore, Japan's 1978 domestic demand considerably exceeded export demand. This demand reflects a

major trend. Various equipment manufacturers in Japan, operating under subcontracts from producers of export commodities, made strenuous attempts to cut costs. They installed newer and more efficient tools, particularly NC machine tools, as a key step. Orders placed for NC machine tools in 1978 rose by 32.9 per cent to 109.1 billion Yen and accounted for 36 per cent of the total value of the orders placed with machine tool makers in Japan. By replacing older equipment with new equipment, manufacturers continue to raise their efficiency and productivity. Thus they hope to offset unavoidable cost increases such as energy and labour. In turn, machine tool builders have stepped up development of newer and more efficient tools. NC tools with labour-saving features are being given special attention. According to the Japan Machine Tool Builders' Association (JMTBA), the production in 1979 was worth 436,361 million yen of which NC machine tools constituted 43.2 per cent valued at 188,631 million yen. The American Machinist reported the 1979 production at $ 2697.8 million. This represents a further increase of 9 per cent over the production of 1978. The production and

trade from 1975 to 1979 are shown in Table 7.

Table 7. THE MACHINE TOOL INDUSTRY IN JAPAN: PRODUCTION, CONSUMPTION ANI TRADE

(Value: in US $ million)

Year	Production	Consumption	TRADE			
			Export	Percentage to production	Import	Percentage to production
1975	1060.4	824.6	359.1	33.86	123.3	14.95
1976	1126.9	803.9	398.8	35.39	75.7	9.42
1977	1602.8	1074.2	616.4	38.46	87.8	8.17
1978	2350.3	1452.7	1017.5	43.29	119.9	8.25
1979	2697.8	1739.2	1113.8	41.28	155.2	8.92

Source: American Machinist.

Exports and Imports. In recent years the Japanese exports of machine tools have made impressive gains. When Japan was profiting from the high growth rates of its flourishing economy and the domestic demand was high, exports constituted only a small share of its total production. In 1969, the Japanese exports accounted for ¥ 21,742 million or 9.1 per cent of total production. The Japanese exports jumped in 1971 to 10.4 per cent over 1979 to reach a value of ¥ 28,044 million.

In 1973, Japan made a major breakthrough in exports by registering an export growth of 28.6 per cent over 1972, valued at ¥ 35,237 million. Exports further swelled to ¥ 57,664 million in 1974 and ¥ 61,611 million in 1975. This heady success in exports was maintained in 1976 (¥ 76,073 million) and in 1977 (¥ 115,493 million). In fact, in the year 1977, the Japanese exports soared by 51.8 per cent over 1976 and accounted for 38.46 per per cent of total production. In 1978 the Japanese exports of machine tools again rose by another 40 per cent over 1977 and were valued at ¥ 162,181 million.

An outstanding element in the export success is the NC equipment. NC machine tools exported in 1977 and onwards accounted for about 31 per cent of the total exports. With the active entry into NC fields by almost all the developed machine-tool-producing countries, competition among NC machine tool builders has been intensified consistently. Under these circumstances, price reduction is another important objective for Japanese builders of NC machine tools and other manufacturing eqquipment. Prices of NC machines are also much lower than a few years ago. Since the Machining Centre was put on

the market at a price under 20 million yen in 1978, a number of Japanese machine tool builders have begun marketing their Machining Centres at prices well below 20 million yen.

One important feature in this price trend is that prices of Numerical Controls have substantially declined in Japan and, to some extent, in other countries as well. When NC machine tools made their appearance, the controls accounted for roughly 50 per cent of the price of machine tools. Now they account for only one third and the trend is continuously decreasing prices for controls.

About a decade ago, almost half of Japan's exports of machine tools went to the United States. However, in recent years the unprecedented economic growth in the Far East has changed the pattern of overseas customers although the United States remains the largest market for Japanese machine tools. The Republic of Korea and other countries in the Far East accounted for 26.4 per cent of Japanese exports valued at Y 42,826 million in 1978. The second biggest customer in the same year was the United States. The East European countries accounted for 15.9 per cent and Western Europe for 12.6 per cent of exports in 1978. As the demand for NC machine tools is mainly created in

countries operating well-developed metalworking industries, Japanese builders give specia' attention to markets in the United States and the EEC countries.

The Japanese exports rose to 14 per cent in 1979 to reach a value of $ 113.8 million viz., over 40 per cent of the country's total production of machine tools, according to the American Machinist.

The imports accounted for a large share of the machine tools used by Japanese industry in the early post-war years. The imports accounted for 57.7 per cent of the domestic consumption of machine tools in 1955 and fell to 45.1 per cent in 1957. However, in tune with the progress achieved by Japanese technology, the share of imported machine tools gradually decreased over the years.

In 1966 Japan witnessed the first transformation when imports fell below exports plus domestic consumption of indigenously-made machine tools. The dependence on imports was drastically reduced by 1976 when Japanese imports of machine tools were barely 9.5 per cent of the total consumption. In value the imports accounted for $ 75.7

million. The imports dwindled again in 1977 to reach 3.17 per cent of the consumption valued at $ 87.8 million. More than 90 per cent of the domestic demand has been met by domestic production. According to American Machinist, the estimated imports of machine tools during 1979 would have reached hardly 9 per cent of the total consumption of the country during the year. Principal suppliers of machine tools to Japan are the United States and the Federal Republic of Germany.

Technological Developments. The technological level of Japanese machine tools in the 1960s was judged to be at least 10 years behind that of the Federal Republic of Germany, the United Kingdom and the United States. But the Japanese have very quickly bridged this gap by rapidly assimilating the modern technology designs of machine tools of almost all categories from simple lathes to sophisticated NC machining centres. The very fact that Japanese dependence on imports slid from 57 per cent of the total consumption in 1955 to barely 9.5 per cent in 1976 reveals the fact that Japan not only absorbed the technology from other countries but also accounted for impressive innovations coming from its own R&D institutions. It is an accepted fact that Japan has established a big

lead over other countries in electronics and machinery manufacture.

Japan's technological strength in the field of machine tools becomes evident from the fact that NC machines accounted for 30 per cent of the total production in 1979. The Japanese have made impressive progress not only in the manufacture of advanced machine tools but also in introducing many innovations in the realm of production engineering. Japan is the first country to evolve unmanned operations into working reality. This has been possible because of the outstanding work done by the Japanese in industrial robots which are equipped with very high levels of judgement faculty. Japan is leading the industrialised world in the use of robots. It is estimated that 10,000 robots are in use in Japan as against 3,000 in the United States and 850 in the Federal Republic of Germany, all three top leaders in robotic technology.

Every major Japanese machine tool builder emphasises in development and marketing efforts the Machining Centre (MC). The Ministry of International Trade and Industry (MITI) indicated that the production of machining centres totalled 1,377 units valued at 31.6 million yen in 1978. These figures represented a rise of 48.7 per cent over the previous year in volume and 36 per cent in value, both all-time highs.

Behind this active production of machining centres is a market-user trend. Japanese machinery manufacturers are now turning out a wider variety of types and models of equipment but small batch quantities of output for each individual type and model. Even in automobile manufacturing, which is noted for mass production, there is a movement towards producing a broader variety of cars to satisfy diversified consumer needs. NC machining centres appropriately fill this need. They are designed to meet various machining needs even in small quantities. Besides, unmanned operation is facilitated by most of the machining centre models, which results in substantially less dependence on hard-to-obtain skilled help. This is the development that the Japanese machine tool industry has pioneered successfully to its great advantage not only in the domestic market but in the export markets of the world.

THE MACHINE TOOL INDUSTRY IN ITALY

The Italian machine tool industry was born at the beginning of the century and developed during the years between the two Wars, until in 1938, it was producing 28,000 tons of machines. Although activity was resumed immediately after the Second World War, the return to pre-war production levels did not come up until about 1957.

At the end of the 1950s, the industry staged its first big comeback, which was linked with the development of the automobile and electrical domestic appliance industries. Thus, between 1958 and 1963, production was quadrupled, rising from 32,000 to 140,000 tons - in monetary terms to 180 billion lire - and while firms already operating in the sector were restructuring their production in accordance with the new technological requirements, many others launched newly into the production of machine tools.

After the crisis suffered by the whole Italian economy between 1964 and 1966, the year 1967 marked a second period of strong development for the

Italian machine tool industry - again associated with a marked recovery in investments in durable consumer goods. During this period, stimulated by the sharp rise in the cost of labour, there was a growing tendency on the part of many Italian firms to produce more sophisticated, automated and numerically controlled machinery. This expansion reached its peak in 1974, with a record billing of 500 billion lire for 185,000 tons of machinery.

According to a survey conducted by UCIMU, there were on 31 December 1975, 541,000 machine tools installed in Italy in mechanical engineering firms employing at least 20 persons. The total number of machines for the industry as a whole was 900,000.

Eighty per cent of the machines installed are Italian-made - a figure that has tended to rise in recent years, especially as regards more sophisticated machines.

Numerically controlled machines installed in Italy number about 3,400, which represents 0.7 per cent of the country's metalcutting machines and a

higher proportion than that recorded in France or in the Federal Republic of Germany.

The Italian machine tool industry has shown a steady growth from 1970 onwards. From 1970 to 1975, it generated an employment growth of 11 per cent while in all other branches of the Italian industry, there was in fact a reduction of personnel by 1 per cent. Among the mechanical industries in Italy, the machine tool industry has been most active followed by the electrical machine industry. The manufacturing industries in Italy have installed more new machine tools in the last 10 years than France or the United Kingdom.

The success of the Italian machine tool industry depends on the traditional structure of Italian companies. Firms with less than 500 employees account for 70 per cent of the production. These firms have increased their investments and are planning to meet the higher demands of the home and export markets.

Since United Kingdom and United States studies indicate a reactivisation of the boom for machine tools in 1979 and 1980, there is every likelihood of world

investments on plant and machinery reaching over 20 billion dollars as against 15 billion dollars in 1977. The Italian machine tool industry hopes to get a share of this bulk investment.

The Italian machine tool industry has adopted a novel method of capturing new markets by establishing training and trading centres in third world countries. A national agency called the Italian M3 T has been set up in Rome. The name M3 T denotes the Italian machine tools, training and trading establishment which combines training and trading functions. The basis for establishing this agency was a report prepared by the Data Bank of Italy which is responsible for analysis and documentation. In the report, the number and types of machines which were most likely to find a market in Latin America were worked out as well as the training facilities to popularize Italian machine tools. Since a person instinctively prefers the make of the machine on which he or she has been trained, the Italian machine tool industry pioneered the establishment of M3 T to attract new customers by establishing a training institute in Rio de

Janeiro at a cost of $ 4 million. The agreement was concluded with the Brazilian National Authority for Industrial Training (SENAI) for the delivery of programmable machines, NC machines and planning aids as well as for the training of Brazilian personnel in Italy and for deputing Italian instructors to Brazil. The financing for this project is provided by the financing wing of the Finanzaria Construttori Italiani Macchine Utensili (Italian Machine Tool Manufacturers Association). The training centre at Rio de Janeiro will demonstrate its capability in such a manner as to provide the most comprehensive training by using the best suited Italian equipment. This centre may prove to be a forerunner of many such centres in Latin America.

Another way in which Italy is trying to increase the sale of its machine tools is through the auspices of the Federazione Nazionale fra i consorti per l'Esportazione (Federexport), a national organization set up by the Italian Ministry of Industries, in which several thousand small companies and the Italian World Trade Centre are members.

Manufacturing in Italy is heavily concentrated in the northern triangle of cities formed by Genoa,

Turin and Milan. Milan is the centre of Italian Industry. In 1978, Italian machine tool builders moved up to fifth place among the exporting nations of the world (in dollar value of shipments). While export orders for their machine tools dropped in the first quarter of 1979 as against the last quarter of 1978, order levels were unusually heavy for that prior quarter and as a result the drop has had very little effect on machine tools producers in Italy who are running their factories to full capacity to meet the backlog of orders for their machine tools.

Production. The production of Italian machine tools touched a value of lire 900 billion in 1978 and 148,000 tons of machine tools according to the American Machinist. The total turnover in 1978 touched $ 1060.0 million. The Italian Machine Tool Manufacturers Association has reported that in 1978 the turnover per employee in the machine tool sector was lire 24.3 million. The domestic demand remained constant in 1978 and there are uncertainties regarding fresh investments by the Italian industry because of the 15 per cent inflation plaguing the country. Even though investment plans envisage fresh investments of the

order of lire 2,000 billion, UCIMU is sceptical of whether or not they will materialise. However, industrial circles expressed the hope that the much postponed industrial investment plans would come through in 1980. This should brighten the prospects for the Italian machine tool industry. Reportedly, the Third EMO held in Milan in 1979 generated business worth $ 800 million of which quite a big chunk might go to Italy.

The development of trade in machine tools has been helped by the establishment of a few specialised institutions. The Institute for External Trade (ICE) of Italy has been playing a major role. The Institute has been responsible for creating an awareness of the competition and the necessary dynamism to increase foreign trade by encouraging private initiative and providing support of financial institutions.

In Italy, the home demand decreased by 100 per cent in 1978 but improved in 1979 because there was a 48 per cent increase in the first four months of 1979. The production, consumption and trade from 1975 to 1979 are shown in Table 8.

Table 8. THE MACHINE TOOL INDUSTRY IN ITALY: PRODUCTION, CONSUMPTION AND TRADE

(Value: In US $ million)

Year	Production	Consumption	TRADE			
			Export	Percentage to production	Import	Percentage to production
1975	873.1	653.4	431.3	49.39	211.7	32.40
1976	750.9	541.8	365.3	48.65	156.2	28.83
1977	878.3	629.4	436.5	49.70	187.7	29.82
1978	1060.5	658.7	596.2	56.22	194.4	29.51
1979	1385.7	951.9	698.9	50.44	265.1	27.85

Source: American Machinist.

Inflation has been running continuously at 15 per cent which may have been responsible for the advance purchase of machine tools by the home market.

In the year 1975, the Italian Machine Tool Manufacturers Association conducted a detailed survey regarding the age of machine tools installed in Italian manufacturing industries. According to this survey, the average age of Italian machine tools in operation in Italy is 12.8 years which is higher than that only of Japan. This clearly indicates that the industry has been successful in selling a considerable

portion of its production at home despite the adverse conditions of fresh investments.

A major worry of the Italian machine tool industry is the labour problem.

Relentless demands by the labour force have not only increased the wages but correspondingly the weekly working hours have been reduced to 36 or 38 hours.

Exports and Imports. In 1977, Italian exports stood at $ 436.5 million. There was a substantial increase in Italian exports in 1978 valued at $ 596.2 million; Italian exports were estimated by the American Machinist at $698.9 million in 1979, which again points to the fact that Italy is entering the big league of exporters of machine tools. The continuous good export performance of Italy can be attributed to the organisational support provided by Federexport.

Italy has had a steady positive trade balance in respect of machine tools in the last ten years. In 1977 Italy imported machine tools worth $187.7 million and imports in 1978 stood at $ 194.4

million. The estimated import figure for 1979 was $ 265.1 million according to the American Machinist. The main countries from which Italy imports machine tools are the Federal Republic of Germany, Switzerland and Japan.

In an agreement signed between Federexport and the Italian World Trade Centre, it was decided to support the Italian foreign trade both structurally and qualitatively. The Italian World Trade Centre provides these companies with a large number of services. It gives national and international information services as well as help with financial support to improve their sales. This agreement helps small units which forego sales chances because of not recovering the full sale amount from the customer. This risk is particularly great in instalment plans. This problem has been considerably solved by offering these companies better insurance cover than that offered by commercial banks and insurance companies. The financial wing of the Italian Machine Tool Manufacturers Association(FINCIMA) is a signatory to such an agreement with Federexport.

Technological Strength. NC entered in a big way the Italian machine tool production in the 1970s. The growth of NC was also most dynamic because of the flexibility of CNC controls and miniaturization of their components. The microprocessors have added a further capability.

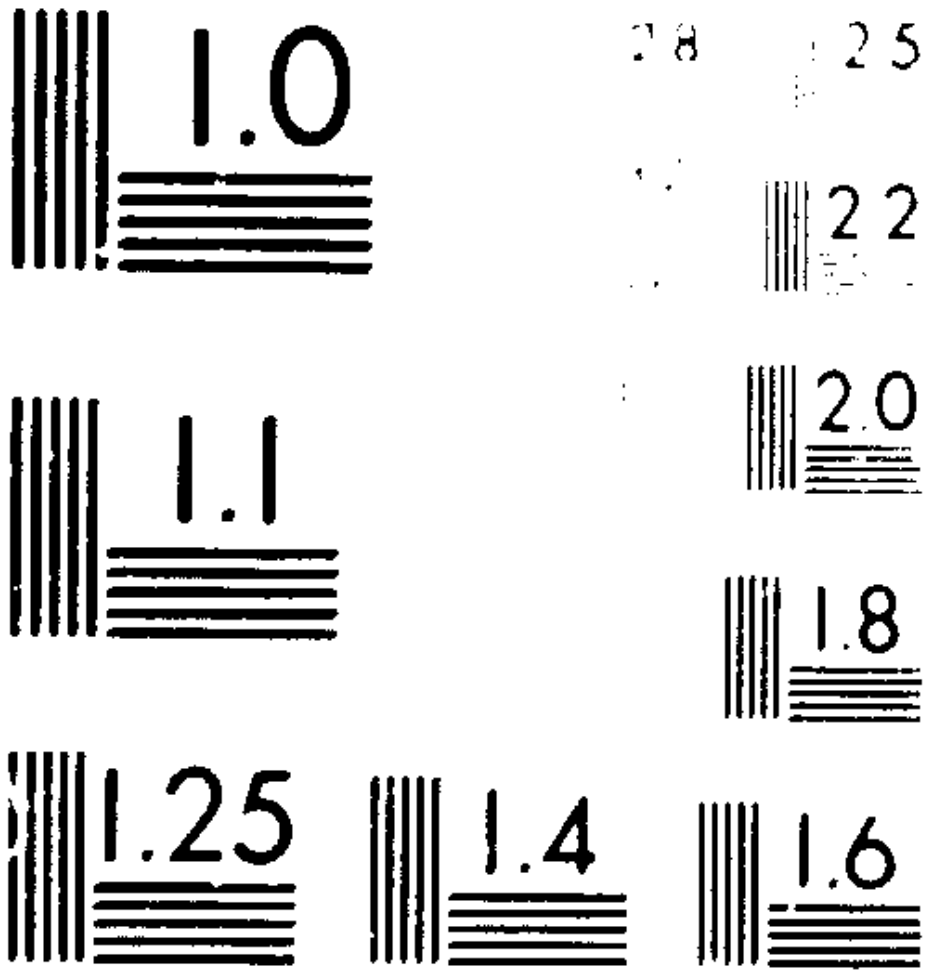
In the field of development, Italy has come forward with a number of praiseworthy products. In the modern DNC transfer lines, the individual NC machines are only links in a major system controlled by a central computer. These transfer lines are now employed in Italy for the production of various types of housings of heavy-duty vehicles, tractors, and agricultural machinery. On this flexible production system, gearbox housings and components of agricultural machinery are produced. This has revolutionised the concept of transfer lines. The other impressive machining systems are the Robogate and Polar 6000 automatic welding systems and L.A.M., an asynchronous assembly line for various types of motors.

In the field of controls, the Italian manufacturer, Olivetti, has come out with Vector 80 CNC, a special feature of which is the two-level machine-

operator dialogue set-up. During machining, communication of data takes place on a simplified level and advanced language is used only for programme editing. Fidia, Turin, have come out with a control unit that allows the machine tool to be employed as a motor driven measuring machine.

In the realm of three-dimensional co-ordinate measuring instruments, new designs and models have been brought out which are numerically controlled. These three-dimensional automatic measuring units function at high speed and accuracy. They are flexible and simple to programme and are meant for measuring mechanical construction elements. A system has been patented in which the motion along the axis is provided by a magnetic attachment. The stoppage in the measuring position is done pneumatically with the intention of improving the rigidity.

The Inspector line of co-ordinate measuring machines for Olivetti features SCAI (Software for Automatic Control by Tridimensional Inspector) programming language. The inspection cycle of a component can be programmed from an engineering drawing. Additionally, a complete inspection


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5

certificate can be printed out during and/or after inspection procedures; a display helps the worker learn inspection operations and the unit has the capability to statistically process inspection parameters as well as calculating and displaying the relative averages and mean-square deviations.

The Pragama assembling system, developed by Digital Electronic Automation Co., is a flexible programmable controller with 12 controllable axes which can be extended to 24. The positioning accuracy is ± 0.1 mm in all straight moved axes.

The fact that Italy has retained fifth place in the world ranking when traditional producers of machine tools like France, Switzerland and the United Kingdom have been relegated to lower levels is indicative of the technological strength of the Italian machine tool industry.

THE MACHINE TOOL INDUSTRY IN THE UNITED KINGDOM

The machine tool industry of the United Kingdom, after the post-war boom, started on a downhill course because of inflation and reduced investments in the engineering industries of the country. The industry's order books could keep the factories going for hardly six months in 1976, for seven months in 1977 and has hardly improved since. Consequently, there was large-scale retrenchment of labour and several companies went out of business.

The industry is surviving because of export business. The United Kingdom is among the ten leading nations of the world in the output of machine tools but it may slide down if the pound continues to be strong, and the domestic recession and the hectic competition in the world markets continue as well.

The United Kingdom is now trying out a qualitative change in its production instead of relying on a quantitative expansion of production. Some of the country's experts feel that if this is not done, then the élite work-force in the machine tool

industry may migrate to other sectors which would be certainly harmful to the economy because of the importance of the machine tool industry. The total number of employees fell from 70,500 in 1971 to just around 50,000 in 1979. The biggest problem in the country's manufacturing industry is the lack of ability to compete with overseas competitors. This applies both externally and also, unfortunately, internally.

Production. The United Kingdom produced tools worth $ 584.3 million in 1974, $ 728.3 million in 1975 and the production fell to $ 645.5 million in 1976 when recession hit the country's machine tool industry. The production further fell to $ 587.9 million in 1977 and again improved in 1978 to reach a value of $ 821.4 million. The American Machinist estimated the production of 1979 at $1106.4 million, representing an increase of 21 per cent over 1978. The increase in production is attributed to increased home demand which rose by 38 per cent. The production, consumption and trade of machine tools from 1975 to 1979 are shown in Table 9.

Table 9. THE MACHINE TOOL INDUSTRY IN THE UNITED KINGDOM: PRODUCTION, CONSUMPTION AND TRADE

Value: in U.S. $ millions

Year	Production	Consumption	TRADE			
			Exports	Percentage to production	Imports	Percentage to production
1975	728.3	618.5	363.0	49.84	253.3	40.95
1976	645.5	583.5	319.2	49.45	257.2	44.08
1977	587.9	525.8	300.4	51.10	238.3	45.32
1978	821.4	794.6	426.0	51.86	399.2	50.24
1979	1106.4	1212.8	468.1	42.31	574.5	47.37

Source: American Machinist.

Exports and Imports. United Kingdom exports of machine tools in 1975 were worth $363 million and in 1976 the exports fell to $ 319.2 million and were further reduced to $ 300 million in 1977. Exports started picking up to reach a value of $ 462.0 million during 1978 and exports for 1979 were estimated at around $468 million.

The United Kingdom imported machine tocls worth $253.3 million in 1975 and the import value of machine tools remained around this level up to 1977. The import of machine tools went up to $ 399.2 million

in 1978 and the estimated value of imports in 1979 may even have been higher, at $574.5 million. The major sources of imports are the Federal Republic of Germany, Italy, Japan and the United States.

It can be noticed from Table 9 that the country's machine tool imports as a percentage of domestic consumption is steadily increasing when compared to the Federal Republic of Germany, Japan and the United States.

Technological Strength. The country's machine tool industry has always shown a flair for innovations. The United Kingdom was the first country to establish a lead over others in NC machine tools because it was one of the first countries to incorporate NC technology into machine tools.

United Kingdom CNC machines have established a good reputation. The United Kingdom is perhaps the first country to incorporate the advances of space science into its machine tool controls. The Newall Machine Tool Company has incorporated Actrion microprocessing as the brain behind its numerical control system. The Actrion was

developed by McDonald Douglas of the United States to land man on the moon. The British are the first to use a modified version of the Actrion in NC systems fitted on a vertical spindle machining centre. The Actrion is made up of several microprocessors and possesses much higher diagnostic characteristics than the other known CNC systems. The country's industry is actively engaged in developing the hard-and software for programmable controllers and sophisticated industrial robots.

THE MACHINE TOOL INDUSTRY IN FRANCE

The French machine tool industry charted a dwindling course of production up to 1977 because of progressively decreasing investments in machine tools by the French metalworking industries. The fact that the French machine tool industry has not suffered a serious set-back should be attributed to the fact that the exports sustained the industry by virtue of high technology machine tools. Even in 1979, the metalworking industry of France did not provide hopeful indicators of higher investments.

The French machine tool industry is composed of small and medium-sized establishments. Consequently, even their competitiveness has been limited because they cannot muster the resources necessary to pierce the export market in a big way or to rejuvenate the home market by offering the customers the facility of payment by easy instalments.

The French industry is now striving very hard to consolidate its position in the home and

export markets by virtue of its nigh technology products.

Production. The French machine tool industry produced FFr 3263 million worth of machine tools in 1978 and an estimated FFr 3900 million in 1979.

The home consumption of machine tools in France witnessed a slight improvement in 1979 though it was 50 per cent less than in 1971, when it stood at 130,000 tons. A quick improvement cannot be expected because the production in 1979 was not expected to increase by more than 12 per cent over 1978. The decision to increase the competitive edge of the French machine tool industry is hampered by a variety of factors. In fact, France had to accept the sad truth that the majority of machine tools installed in the country's industrial establishments are comparatively old machines. It has been reported by the French Machine Tool Manufacturers Association (SCFMO) that in 1979 only about 32 per cent of the installed machine tools were less than 10 years old, while it was 37 per cent in the Federal Republic of Germany, 39 per cent in the United Kingdom and as much as 60 per cent in Japan. The

more disconcerting fact of the French machine tool industry is that while home consumption is creeping at a slow pace, the nations competing with France are progressively installing newer machines to sharpen their competitive edge in the world market. The production, consumption and trade statistics from 1975 to 1979 are shown in Table 10.

Table 10. THE MACHINE TOOL INDUSTRY IN FRANCE: PRODUCTION, CONSUMPTION AND TRADE

Value: in U.S. $ millions

Year	Production	Consumption	TRADE			
			Export	Percentage to production	Import	Percentage to production
1975	678.6	695.5	319.4	47.06	336.2	48.34
1976	657.2	732.7	272.2	41.42	347.7	47.45
1977	590.6	607.5	269.3	45.60	286.2	47.11
1978	723.0	630.2	382.7	52.93	289.6	45.95
1979	918.1	790.7	479.8	52.26	352.4	45.57

Source: American Machinist.

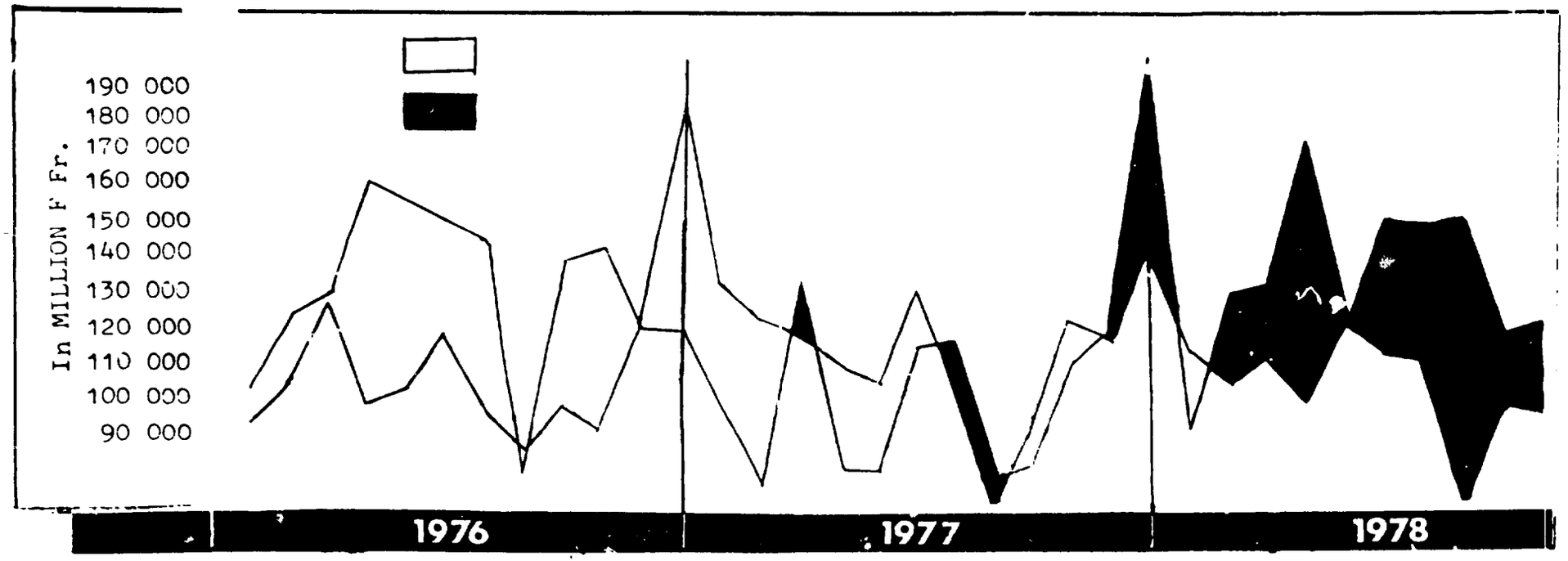
Exports and Imports. The French exports of machine tools in 1978 increased by 31 per cent in value

and 32 per cent in weight over 1977. More than 50 per cent of the 72,000 tons of machine tools produced in France were exported. During the same period, the French imports decreased 7 per cent in value (at 1979 value F.Fr) and 13 per cent in weight. The trend in exports and imports over the years 1976 to 1978 is given in Figure VI.

The export success was not limited to a particular region and geographically it showed a good distribution. The principal foreign customers of French machine tools in order of priority are: Romania, the Federal Republic of Germany, the Soviet Union, Italy and Algeria. Now efforts are in progress to penetrate more effectively markets in China, Mexico and Latin America.

French exports to the European Common Market countries improved considerably because of increased sales to the Federal Republic of Germany, Belgium, the Netherlands and the United Kingdom. By way of comparison, Italy increased its sales to France. Among the other countries, it is important to underline the penetration of French machine tools into Spain which is France's ninth customer in order of priority.

Figure VI. The evolution of exports and imports in France



Source: SCFMO, France.

Exports to the United States also registered an impressive growth and made the United States the seventh top customer of French machine tools. The French machine tool industry is also intensifying the efforts to sell its products to the Republic of Korea, Argentina and East European countries. Switzerland sells more machine tools than it imports from France.

It has been pointed out in the American Machinist that the industry is presently concerned with three major prerequisites to growth viz., investments, innovation and exports. Further, it is noted that exportation can last only if it is based upon a strong domestic market.

Results from the first few months of 1979 seem to indicate that French industry has begun increasing machine tool orders. Production in 1978 was up by 12 per cent and France recorded its first trade surplus in machine tools, $ 100 million, a position it maintained in 1979 as well.

France has been importing high technology and high production machine tools mainly from the Federal Republic of Germany and the United States. High precision machines

are being imported mainly from Switzerland. The country's metalworking industry has been importing machine tools at the rate of 45 to 50 per cent of its total consumption all through the last decade.

Technolcgical Strength. The French machine tool industry demonstrates high technological strength. The refinements on general purpose machine tools are identical to those seen on machines offered by France's competitors and France has not lagged behind in the field of NC and CNC controls.

The American Machinist has noted that the research and development activities carried out by the French private and national institutions are of such high calibre that they compare well with the best achieved elsewhere. The French machine tool industry has not lagged behind in developing the latest generation of machining centres which are now manufactured in answer to the requirements of the prestigious aerospace industry in France. The major machine tool companies like Ernault-Somua, S.A.G.E.M. and Cazeneuve have been exporting advanced machine

tools to several other countries in addition to the leading aircraft manufacturers like Sudaviation and Dassault. In 1979, there were 5,200 NC machines installed in the French metalworking industry of which as many as 1,600 were CNC machines. Renault is building a variety of industrial robots and special pallet loaders to assure a high degree of automation. The latest in this regard are those of Renault for painting and for welding. Renault has designed and built robots for applying lacquer, zinc paint, primer and mastic and for enamelling and metallizing. A seventh optional axis provides access to work areas inside autobodies. Ramo of France have come out with a machine in which parts can be held in a central headstock for simultaneously machining both sides. Blanks are automatically loaded, centred, clamped, machined and ejected without stopping the spindle. Citroën, who have been making honing machines for their own use, have started marketing an NC hone for engine sleeves, a 16-spindle progressive honing machine for hydraulic parts that maintains a tolerance of 2 microns and a high precision 16-spindle machine for fuel injection-

system parts, which provides hydraulic expansion of the hone to hold tolerance to half a micron at an output of 100 parts per hour.

It is regrettable, perhaps, that in spite of the impressive technical developments, several of these high technology products are not actually purchased by French customers because of the low level of investment in the country in modern machine tools. Some feel the stagnation of investments in France has forced many French machine tool manufacturers like Ernault-Somua to start manufacturing facilities abroad, notably in the in the United States of America.

THE MACHINE TOOL INDUSTRY IN THE GERMAN DEMOCRATIC REPUBLIC

The machine tool industry of the German Democratic Republic ranks eighth in the world league of machine tool producers and the country has gained fourth place as a machine-tool-exporting nation.

Even before the Second World War, traditionally Erfurt, Magdeburg, Leipzig and Chemnitz (Karl-Marx-Stadt) were important machine tool building centres. Since all these places are now part of the German Democratic Republic, the country naturally has become one of the leading producers of machine tools. The industry is concentrated in the south of the country, centred around the city of Karl-Marx-Stadt.

The German Democratic Republic produces quality machine tools suited for one-off, medium, large batch and mass production. It also produces custom-built machine tools f large manufacturing plants. Machine tool manufacture assumes an important position in the economy and about four times as many people are involved in the manufacture and marketing of machine tools than, for example, in the United Kingdom. At present, more than 80,000

people are employed in the machine tool industry. Its products cover both metalcutting and metal-forming machine tools. The country also produces NC and CNC machines.

The country's machine tool industry is centrally planned and controlled as in the case of other socialist countries e.g., Czechoslovakia and the Soviet Union. Over-all responsibility for sales and marketing policy is determined by the country's export-import agency, WMW, based in Berlin. The industry is divided into four manufacturing combines or kombinats each responsible for the manufacture of different groups of metalworking machine tools. The 7th October Kombinat manufactures machines for the production of circular components (e.g., lathes and grinders) whereas companies within the Fritz Heckert (previously Wanderer) Kombinat, manufacture machines for the production of prismatic or housing-shaped components (e.g., milling machines). The Herbert-Wraneke-Erfurt Kombinat concentrates on the manufacture of sheet metal, blanking and forming as well as machines and equipment for processing plastics. The fourth Kombinat is Schmalkalden which manufactures tools, jigs, fixtures and maintenance machines.

Production. In 1977, the country produced machine tools worth $ 641.4 million, of which metal-cutting machine tools accounted for $ 504.5 million and metalforming, $ 136.9 million. The production of machine tools improved in 1978 to reach a value of $ 698.6 million and the industry improved its performance still further in 1979. Production was estimated at $ 806.00 million worth of machine tools for 1979. The production, consumption and trade figures pertaining to the years 1975 to 1979 are given in Table 11.

Table 11. THE MACHINE TOOL INDUSTRY IN THE GERMAN DEMOCRATIC REPUBLIC: PRODUCTION, CONSUMPTION AND TRADE

(Value in US $ million)

Year	Production	Consumption	T R A D E			
			Export	Percentage to production	Import	Percentage to production
1975	582.2	268.8	507.8	86.77	191.4	71.20
1976	568.8	365.7	446.4	78.48	170.3	46.57
1977	641.4	218.7	596.6	93.00	173.9	79.52
1978	698.6	368.5	547.9	78.42	217.8	59.10
1979	805.8	388.0	661.6	82.10	243.8	62.84

Source: American Machinist.

Exports and Imports. Over 80 per cent of the country's production of machine tools is exported. The export range comprises a multitude of machine tools for turning, grinding, gear cutting, milling, drilling, boring, planing etc. The country now ranks fourth among the leading exporters of the world.

The country exported machine tools worth $596.6 million in 1977, $ 547.9 million in 1978 and it is estimated that it exported machine tools worth $ 661.6 million in 1979. The country imports only a fraction of what it exports. In 1977, machine tool imports stood at $ 173.9 million and in 1978 the imports rose to $ 217.8 million. In 1979, the country imported an estimated $243.8 million worth of machine tools.

In general, three quarters of the country's trade is with other CMEA countries, of which about half is with the Soviet Union. The country also imports machine tools from the Soviet Union and other socialist countries. Another important trading partner of the country's machine tool industry is the Federal Republic of Germany.

Technological Strength. Since the country is an important member of the CMEA, it has regu-

larly supplied high quality machine tools to the Soviet Union and other East European countries. The range of products stretch from general purpose machine tools to computer control machines. Most of the basic research and development work is conducted in the major universities of Jena, Dresden, Berlin, Leipzig and at the Machine Tool Design and Research Institute in Karl-Marx-Stadt.

At present the technological strength of the country's machine tool industry is evident from the fact that a lot of importance is attached to the production of custom-built machines and NC machine tools. Research work is also conducted in collaboration with socialist countries such as Czechoslovakia and the Soviet Union to continuously update the technical level of products produced by the country's machine tool industry.

The design excellence of machine tools produced in the German Democratic Republic can be attributed to the incorporation of modern components such as recirculating ball screws, DC drives and electronic linear position scales. The German Democratic Republic also produces linked production lines.

The German Democratic Republic is recognized as the leader in machine tool manufacture in the CMEA group of because of its

pioneering work in improving the machining environment, productivity and accuracy.

Yet the level of applied technology in machine manufacturing in the country falls somewhat short in certain areas in comparison to Western standards. The country does not build CNC controls at present although machines equipped with NC manufactured in the country can be supplied to customers. However, machines are supplied, for instance Niles lathes, which are built for CNC and fitted with Western CNC controls. It is understood that in 1980, the first CNC 600 to have been built in the country was to have been launched.

Computer techniques are employed in production, for instance, the tape preparation within the factory is done on a minicomputer. Also NC machines are linked to a central mainframe computer (the country makes its own minicomputers, e.g. ES10040 model), by machine terminals. In some of the country's factories, an automatic parts store is used in conjunction with the transport system and they are exploring the possibilities of issuing all necessary tooling and fixtures for a job along with the components and then transporting them together round the system to the work station. Such an advanced production management system on the shop-floor has become almost a necessity in view of the dire shortage of labour in the German Democratic Republic.

THE MACHINE TOOL INDUSTRY IN SWITZERLAND

The Swiss machine tool industry has established a world-wide reputation for its quality and precision products. Instead of manufacturing the whole range of machine tools, the Swiss have always concentrated on specific product lines like high precision lathes, precision grinding machines, gear grinding, sliding-head automatics, jig boring machines, electron discharge macnines with wire-cutting (EDM) and fine blanking presses. The Swiss machine tool industry has held the front rank in these product lines. The industry is comprised of a large number of small and medium shops, though there are a few which can be termed as large-scale units.

Production: About 90 per cent of the products of the Swiss machine tool industry are metalcutting machine tools and the other 10 per cent metalforming machine tools. In 1974, Switzerland produced $ 456.9 million worth of machine tools and the production went up in 1977 to $ 580.3 million. It was in this year that the Swiss

edged out France and the United Kingdom to occupy sixth place in the world ranking. However, Switzerland was again pushed back to ninth place in 1978 and 1979. The Swiss machine tool industry produced $ 768.2 million worth of machine tools in 1978 of which metalcutting machine tools accounted for $ 652.8 million. In 1979, the Swiss production was estimated at $ 797.1 million. The country's production, consumption and trade in machine tools from 1975 to 1979 are shown in the table below:

Table 12. THE MACHINE TOOL INDUSTRY IN SWITZERLAND: PRODUCTION, CONSUMPTION AND TRADE

(Value in US $ million)

Year	Production	Consumption	TRADE			
			Export	Percentage to production	Import	Percentage to production
1975	535.9	220.2	380.8	71.06	65.1	29.56
1976	535.6	134.4	455.5	85.04	54.3	40.40
1977	580.3	163.8	493.4	85.02	76.9	46.95
1978	768.2	239.3	652.8	84.98	124.3	51.94
1979	797.1	259.1	677.5	85.00	139.5	53.84

Source: American Machinist.

Exports and Imports. Switzerland has traditionally exported machine tools to all the industrialised countries of the world and recently it has stepped up its exports also to China. Its exports have registered significant growth since 1975 and stand at above 80 per cent of the total production.

Switzerland imported machine tools worth $124.3 million in 1978 and about $ 140 million worth of machine tools in 1979. The major imports are from the Federal Republic of Germany, France, Italy, Japan, the United Kingdom and the United States. Although imports range at about 50 per cent of consumption, compared with production they form less than 20 per cent.

Technological Strength. The Swiss machine tool industry is backed by many private and national institutions engaged in research and development of machine tools. The high technology machine tools like the CNC-controlled jig boring machines of Société Genevoise d'Instruments de Physique (SIP), Dixi and Hauser; CNC lathes and machining centres Sirius of Oerlikon; Dubied and Georg Fischer copying lathes; CNC wire cutting EDM machines of AGIE and Charmilles; precision grinders of Studer and a wide range of gear hobbing machines of Maag; gear grinding machines of Reishauer and Maag; and, for

watch and instrument industries, those produced by Mikron, Wahli, Strausack etc. are all products of world-famous Swiss producers of machine tools.

It is possible to assess the technological strength of the machine tool industry of a country by having a close look at the machine tools exhibited by it at the renowned world machine tool exhibitions like those of the EMO and others held in Chicago, London (at Olympia), Paris, Leipzig, Brno, Tokyo, Osaka, Hannover and Brussels. For example, at the 3 EMO at Milan, a wire-cut EDM machine was shown by AGIE which can automatically shift from one die opening to another. To do this without interrupting the operation of the machine, the wire is cut after one opening in the work is completed, the table shifts the work to the next opening, a tube is pushed through the new hole, the wire is pushed through the tube, the wire is tied to the other end of the wire, the tube is retracted, the wire-cut operation is resumed in the new opening of the work, all automatically.

A Reishauer gear grinding machine had electronic control to replace the change gears, both for a number of teeth and for helix angles.

Capacity is increased to 650 mm diam. on a new Maag gear grinding machine that provides an automatic cycle for spur and helical gears. The cycle is controlled by a combination of cams and pins. Even very slight wheel wear can be detected and compensated for by advance of the grinding wheel in increments of 1-2 microns.

An integrated fifth axis has been added to the Sirius HM3 machining centre of Oerlikon-Zürich, a division of Oerlikon-Bührle. This is provided by a horizontal axis of rotation atop the index table on which the work is mounted.

Switzerland being the home of the best organised horological industry in the world has also produced major innovations in precision machine tools needed by the horological industry. The sliding-head automatics developed in Switzerland have earned the name of Swiss Automatics because these machines were uniquely designed and produced in Switzerland. Now these are available in full CNC-controlled versions.

The Swiss machine tool industry now moving into the areas of highest precision by an

imaginative integration of the measuring function on its machine tools. This effort is backed up by impressive innovations from the fine mechanics and instruments manufacturing branches in Switzerland.

THE MACHINE TOOL INDUSTRY IN CZECHOSLOVAKIA

The machine tool industry in Czechoslovakia consists of 47 manufacturing firms producing metalcutting and metalforming machines. The Czechoslovakian industry dates back to 1905 and has a long tradition of building quality machine tools. There are two major groups of manufacturers: the Engineering Technique Group (TST), consisting of TOS, MAS, ZPS, ČKD, Smeral, ŽDAS, Narex and ŠKODA. The other group consists of national corporations in Plzeň, Blansko and Strakonice. Czechoslovakia is a leading producer of machine tools in the CMEA group, second only to the Soviet Union and the German Democratic Republic.

Besides general purpose machine tools, the country's machine tool industry is famous for its heavy machine tools and machine tools needed by the ordnance factory.

Production. Czechoslovakia produced machine tools worth $ 292.7 million in 1974, $ 305.4 million in 1975 and the production touched a value of $ 363.4 million in 1978. The estimated production in 1979 was worth $ 357.2 million. The

production, consumption and trade of machine tools from 1975 to 1979 are given in Table 13.

Table 13. THE MACHINE TOOL INDUSTRY IN CZECHOSLOVAKIA: PRODUCTION, CONSUMPTION AND TRADE

(Value in US $ millions)

Year	Production	Consumption	TRADE			
			Export	Percentage to production	Import	Percentage to production
1975	305.4	241.7	190.5	62.38	129.8	53.04
1976	337.9	260.7	190.2	56.29	113.0	43.34
1977	309.1	251.4	215.3	69.65	157.6	62.69
1978	363.4	287.4	246.2	67.75	170.2	59.22
1979	357.2	258.5	265.0	74.19	166.3	64.33

Source: American Machinist.

In 1978, the country's machine tool industry produced about 17,000 machine tools of which 5,500 were metalforming machines.

Exports and Imports. Czechoslovakia has traditionally traded with the East European countries. and the West European countries like the Federal Republic of Germany, France, Italy, the United Kingdom and the United States but recently

the volume of imports from the Soviet Union and the German Democratic Republic has increased. Czechoslovakia imported $97.7 million worth of machine tools in 1974 and the imports since have risen steadily to reach a value of $170.2 million by 1978. In 1979 the value of the machine tools imported by Czechoslovakia was estimated to be $166.3 million.

Czechslovakia exports more machine tools than it imports. In 1974, the country's exports of tools were valued at $ 152.3 million. The exports rose steadily to touch a value of $ 246.2 million in 1978. The estimated value of exports in 1979 was $ 265 million representing more than 70 per cent of the value of the national production of machine tools.

In the last 30 years, Czechoslovakia has exported more than 350,000 machine tools, thus testifying to the good reputation enjoyed by the country's products in the world market.

Technological Strength. The country's machine tool industry is greatly assisted by the research and development carried out at the Research Institute of Machine Tools and Machining (VUOSO), Prague, and the Institute for Metalforming Machine Tools at Brno.

The principal directions of research activity are in the development of Computer Numerical Control (CNC) for machine tools and modular manufacturing systems. Developments are in progress to come out with a fully flexible manufacturing system which would be completely automatic. This is to be achieved by a Direct Numerical Control (DNC) system with a three-tier hierarchy of computers: a central computer for systems control, including tool movements from a central magazine to tool sharpening, and intermediate computers (CNC) for control of the machining centres. A semi-automatic integrated manufacturing system consists of NC Machining Centres and Standard NC machines, like measuring machines (NC) and ultrasonic work devices and other supporting equipment. The system is controlled by DNC computers developed in Czechoslovakia. Some of the new developments undertaken by VUOSO are: an automatic system to sense the tool wear and breakage of tools in the automatic production system and tool magazines for CNC machining centres to store tools in a matrix formation with the scope to hold an unlimited number of tools. This is a step ahead of the limited number of tools in the tool changer equipment presently provided on machining centres.

THE MACHINE TOOL INDUSTRY IN POLAND

In Poland, there are about 25 factories producing machine tools. The Polish machine tool industry was completely rebuilt after the Second World War. It is now estimated that the actual investment in the machine tool industry of Poland is higher than that of France or Italy. In terms of money invested in the machine tool industry, Poland ranks only behind countries like the Federal Republic of Germany, Japan, the Soviet Union and the United States of America. Recently, Poland established both technological and economic contacts with the Federal Republic of Germany to produce high precision machine tools. Companies like Gildemeister in the Federal Republic of Germany have entered into collaboration agreements with the Polish machine tool industry. Formerly, much of the production equipment consisted of machines from Czechoslovakia, the German Democratic Republic and the Soviet Union, but lately Polish industry has installed modern equipment made in the Federal Republic of Germany, France, Italy and the United Kingdom.

Production. During 1979, Poland was among the eleven leading countries of the world in the production of machine tools. The production of the

Polish machine tool industry almost doubled in the years 1974 to 1979. In 1974, Poland produced machine tools worth $ 353.8 million and registered a 20 per cent increase in 1975 when the total production reached $ 422.8 million. The machine tool production again rose by 21 per cent over 1975 to reach a value of $ 510 million in 1976. A further increase of 24 per cent raised the production to $ 583.4 million in 1977. In 1978, the production reached $ 678.8 million which was 25 per cent more than the previous year. The estimated production in 1979 was $ 684.6 million. The production, consumption and trade of machine tools from 1975 to 1979 are shown in Table 14.

Table 14. THE MACHINE TOOL INDUSTRY IN POLAND: PRODUCTION, CONSUMPTION AND TRADE

(Value in US $ millions)

Year	Production	Consumption	TRADE			
			Export	Percentage to production	Import	Percentage to production
1975	422.8	698.4	125.8	29.75	401.4	57.47
1976	510.0	877.9	152.3	29.86	520.2	59.25
1977	583.4	968.8	151.4	25.95	536.8	55.41
1978	678.8	1111.2	163.4	24.07	595.8	53.62
1979	684.6	1012.0	190.9	27.88	518.3	51.22

Source: American Machinist.

OBSERVATIONS.

The preced 6 pages give the current position of the machine tool industry in the top eleven industrialised countries. There are indications that the machine tool industry in the industrialised countries is on the threshold of a greater advancement technologically. Sheer competition in the world market for capital goods, automobiles, aircraft and armaments and the more sophisticated requirements of industries like aerospace and communications, with energy restraints, skyrocketing costs of manufacture and massive efforts to increase productivity to keep costs under control will all call for a great technological breakthrough which could give birth to many new and non-conventional processes of material cutting and forming; and with that, the designs of machine tools and production technology in manufacturing and engineering industries will undergo perhaps further changes. Invariably in all areas, it is expected that micro-electronics will play a pivotal role and production organisation and management would have been further refined through the application of more sophisticated methods and robotics.

III. A BRIEF STUDY OF THE MACHINE TOOL INDUSTRY IN SOME OF THE LEADING DEVELOPING COUNTRIES

THE MACHINE TOOL INDUSTRY IN CHINA

Introduction. The Chinese machine tool industry has been expanding over the last decades. In 1949 when the new Government came to power, around 1,600 machine tools were produced and by 1978 the figure rose to 183,000 units. In the 1950s, with the assistance received from the Soviet Union, China built over 20 large-scale machine tool plants destroyed during the war including the reconstruction of industries in the north and north-east. Imports of machine tools from the Soviet Union jumped from 1,600 units in 1949 to 26,000 units in 1952. From 1958 to 1960, China went through the throes of its Great Leap Forward and further increased its imports. However, in 1960, when the Soviet Union withdrew its assistance, several large-scale machine tool plants were still incomplete. The focus of the reconstruction activities of the 1960s was therefore on the completion of these half-finished plants and

the dispersion of machine tool production centres. The flow of advanced machinery and machine tools from the Soviet Union stopped and China tried to produce these items domestically, relying on its own resources and on its insufficient technical know-how.

China currently has approximately 30 large-scale machine tool plants and several small and medium-size plants (more than 40) manufacturing almost all types of general purpose machine tools and some advanced designs as well. The industry employs about 500,000 workers. Efforts are being made to foster the machine tool industry all over the country, but production still tends to concentrate heavily in the east, north and north-east of China. Most of the larger plants are located around Beijing and Shanghai. Other centres of machine tool production are Shenyang, Harbin, Dalian, Qiqihar, Wuhan and Tianjin.

Production. China can produce almost all its current needs but it is necessary for the country to increase the variety and improve the designs and quality of its products, particularly high precision machines and instruments. Among the 269 new

machine tools planned for 1981 are the numerically controlled jig boring machines, universal and external grinding machines and different types of horizontal boring machines. This, it is learnt, is part of the modernisation programme, which the present leadership of China has initiated.

China began exporting machine tools in 1957 when 56 small lathes and planing machines were sent to Hong Kong, Pakistan, Thailand, Malaysia, Lebanon and Egypt. At present, it exports about 20,000 machine tools annually. China participated for the first time in the International Machine Tool Exhibition (3 EMO) at Milan in October 1979.

Machine tool production and trade from 1974 to 1979 are shown in Table 15.

Table 15. The production and trade in machine tools from 1974 to 1979 in China

(Value in U.S. $ millions)

Year	Production	Consumption	Trade	
			Export	Import
1974	140.0	172.0	3.0	35.0
1975	300.0	351.0	4.0	55.0
1976	315.0	360.0	5.0	50.0
1977	355.0	395.0	10.0	50.0
1978	405.0	450.0	20.0	65.0
1979	420.0	452.0	28.0	60.0

Source: American Machinist.

Technological Level. China's machine tool technology is behind that of the West in two main areas. Firstly, greater co-ordination of research and development activities has to be ensured in particular to improve the ability of the production plants to absorb what comes out of the experimental stages. Secondly, as regards production technology. China is close to 20 years behind the West; plants operate at inefficient levels and inventory control is almost nil. A major weakness is in organization and plant management. Many of the plants are vertical operations, with the majority of components made within the main factories. With such a system, it is difficult to boost efficiency through specialisation.

Notwithstanding these problems, China's machine tool industry is moving forward. Some of its basic universal models of general purpose machine tools are being exported to the West, armed with the unbeatable advantage of low price. The China Machine Tool Exhibition held in Hong Kong in 1977 displayed as exportable products gear shaping

machines, gear grinding machines, cylindrical grinders, optical profile grinding machines, lathes and other items.

China has built up a basic foundation in technology through its past experience. Its technical experience in the strict definition of mother machines, such as jig borers, horizontal borers, planomillers, and various gear cutting and finishing machines is, for example, superior to that of many other developing countries in East Asia.

On the other hand, when it comes to engine lathes, universal millers, radial drilling machines and other production machines, most of the designs are old and the production system inefficient. These general purpose machines should be strategic export products for the Chinese machine tool industry which has just started on a full-scale export drive and thus the lack of develorment in this field is particularly critical.

The country, it is understood, is making great efforts to improve and modernise its machine tool industry. It has sought the assistance of UNIDO in this regard. With a firm policy decision

of the Government backing the over-all modernisation programme, it is expected that the country's machine building and machine tool industries will undergo revolutionary changes.

THE MACHINE TOOL INDUSTRY IN BRAZIL

Introduction. The Brazilian machine tool industry is the biggest in Latin America. In 1979, it occupied fifteenth place in the world ranking of machine-tool-producing countries.

As in all other developing countries, the manufacture of machine tools was taken up in an organised manner only after the Second World War. During 1960, the Brazilian metalworking industry was estimated to have 205,654 machine tools installed. The inventory of machine tools in 1971 grew to 360,146 units. In 1974, there were 13 large enterprises which produced quality machine tools. The medium and small units numbering about 25 in 1974 produced simple general purpose machine tools. Most of the manufacturing units are concentrated in and around São Paulo but recently new units have been established in other regions.

The Brazilian machine tool industry took up the manufacture of NC machine tools in 1975. The projected development of the metalworking industry in Brazil from 1968 to 1980 is shown in Table 16.

Table 16

DEVELOPMENT OF THE METALWORKING INDUSTRY IN BRAZIL

Year	Production (Percentage)	Locally added value (Percentage)	Increase of added value (Percentage)	Machine tool park (thousand units)	Labour (thousands)
			Metal Products		
1968	100	100	100	-	-
1971	134	61	131.8	69.6	165.7
1975	198	60	188.5	91.6	218.1
1980	170	59	257.4	122.7	263.1
			Non-electrical machinery		
1968	100	100	100	-	-
1971	144	61	142.7	70.7	152.0
1975	212	59	202.1	92.3	198.5
1980	285	56	275.2	131.3	255.3
			Electrical machinery and equipment		
1968	100	100	100	-	-
1971	136	57	134.7	75.0	167.1
1975	192	56	185.7	96.5	208.0
1980	285	56	275.2	131.3	255.3
			Transport equipment		
1968	100	100	100	-	-
1971	137	47	137	90.9	227.3
1975	192	48	205	114.9	294.6
1980	285	48	302	147.2	368.0

Source: Institute for Economic & Social Planning (IPEA) Studies.

Production. The production of the machine tool industry in Brazil was valued at only $111.3 million in 1974 and by 1976 the production doubled to reach a value of $222.5 million. The output of the Brazilian machine tool industry further increased to $282.9 million in 1977, but there was a marginal decline in production during the years 1978 and 1979.

The production, consumption, export and import statistics of machine tools from 1974 to 1979 are shown in Table 17.

Table 17. The production and trade in machine tools from 1974 to 1979 in Brazil

(Value in U.S. $ millions)

Year	Production	Consumption	Trade	
			Export	Import
1974	113.3	175.8	6.0	70.5
1975	137.0	206.0	14.0	83.0
1976	222.5	386.8	10.7	175.0
1977	282.9	441.9	11.2	170.0
1978	255.3	461.3	20.1	226.2
1979	239.8	342.8	33.0	136.0

Source: American Machinist.

Technological Strength. The Brazilian machine tool industry launched a programme of restructuring in 1974. Under this programme, many of the machine tool manufacturing firms were expanded to produce a large number of machine tools and also to raise the quality of their products, to increase productivity and to enter the sophisticated field of NC machine tools. This restructuring was mainly done to enhance the technological strength of the industry. A special Research Institute of Technology was started in the University of São Paulo to provide the industry with the necessary know-how for designing and producing sophisticated NC machine tools. This Institute conducted in 1974 a survey to highlight the technical performance and standards of quality in manufacture. The Institute has been responsible for making recommendations to the metal-working industry on methods of solving specific manufacturing problems and in matters of selection of machine tools for specific purposes. The Research Institute is now engaged in designing and building machine tool prototypes either at the request of the manufacturers or on its own initiative.

The standards established by this Institute in the manufacture and testing of machine tools are on a par with international standards.

The Government of Brazil is providing a number of incentives for economically sound and technically advanced projects with a view to modernising the production methods of the Brazilian machine tool industry.

From the stage of collaboration with internationally well-known machine tool manufacturers of the world, the industry has graduated presently to designing almost all types of general purpose machine tools and a selected number of NC machine tools. The strength of the Brazilian machine tool industry is evident from the fact that it is sustaining the biggest automobile industry of Latin America.

Exports and Imports. The 13 major Brazilian machine tool producers account for 90 per cent of the exported machine tools. Traditionally, exports have accounted for a small share of the total production. In 1974, Brazil exported $6 million worth of machine

tools and exports have since grown gradually to $33 million in 1979. Exports of Brazil in 1979 accounted for just 15 per cent of the total production. Brazil exports mostly simple machine tools like lathes, milling machines, grinding machines and a few power presses.

Import of machine tools into Brazil has always been more than 50 per cent of the indigenous production. In 1974 Brazil imported $70.5 million worth of machine tools, representing about 62 per cent of the value of the indigenous production.

Even in 1979, imports accounted for $136 million as against indigenous production of $239.8 million. The high cost of imports can be directly attributed to the purchase of advanced technology machines, gear grinders, special transfer lines etc. needed by the Brazilian engineering industries. The reliance on imports of such sophisticated machines is likely to decrease as the indigenous machine tool industry starts producing the advanced technology machines.

THE MACHINE TOOL INDUSTRY IN THE REPUBLIC OF KOREA

Introduction. In 1979 there were 199 machine tool building firms in the Republic of Korea, the most important of which were: Dong Yang Machine Corp., Haw Cheon Machinery Works Co., Nam Sum Ki Kong Sa, Hyundai International Inc., Dae Woo Heavy Ind. Ltd., Chung Kong S. Co. Ltd., Kia Machine Tool Co. Ltd. and Yeong Chin Machinery Ind. Co. Ltd.

The country's machine tool production in 1975 did not even merit its inclusion in the world ranking of machine-tool-producing countries. But in two years time, i.e. in 1977, the country was listed 24th. In 1978, it jumped to the 20th place ahead of India. The estimated production of the Republic of Korea 1979 was $150 million. The phenomenal growth of the country's machine tool industry can be attributed to the national plan drawn up by the Government in 1973 to make the machine tool industry really strong. The Changwon Industrial Complex was built by the Government and many foreign investors were welcomed. The country's machine tool industry is now in a position to manufacture not only the full range of general purpose machine tools but also sophisticated

items like CNC lathes, machining centres, NC boring and milling units etc.

The country's machine tool industry is fostered with care by the Government.

The promotional features of the Government for the machine building industry include the following:

(a) People's Investment Funds, centring around people's saving to promote the construction of heavy industries;

(b) machinery industry funds (Governmental funds) to support promotion of the machinery industry;

(c) foreign currency fund to promote the domestic production of machines;

(d) medium and small company funds to support medium and small-scale companies;

(e) export support funds.

The Government also gives the following tax concessions :

(a) reduction of or exemption from tax for important machinery industries;

(b) preferential tax on funds for technical developments;

(c) exemption from customs duty on machines and facilities which cannot be produced domestically;

(d) exemption from tax on funds for improvements of facilities of medium and small companies.

To promote foreign investments in joint ventures the Government offers the following facilities:

(a) permission for investment with equipment;

(b) guarantee of remittance of dividends and principal;

(c) exemption from import approval laws;

(d) guarantee of remittance of royalties on licence contracts.

Production. The country's machine tool industry accounted for a production value of $10 million in 1976. The production of machine tools increased dramatically in 1977 to reach $57 million. The increase in production during 1978 was about 8 per cent over 1977. The value of production in 1978 was $95 million which was again

completely overshadowed by the production value of $150 million in 1979. These production values clearly indicate the meteoric rise of the industry and its promise to grow still further in future. The production, consumption, export and import of machine tools from 1974 to 1979 are shown in Table 18.

Table 18. The production and trade in machine tools from 1974 to 1979 in the Republic of Korea

(Value in U.S. $ millions)

Year	Production	Consumption	Trade	
			Export	Import
1974	-	-	-	-
1975	-	-	-	-
1976	10.0	100.0	-	90.0
1977	57.0	185.0	-	130.0
1978	95.0	246.0	5.0	156.0
1979	150.0	268.0	2.0	140.0

Source: METALWORKING - Engineering and Marketing, March 1980.

Technological Strength. Even though the country's machine tool industry owes its success to a large number of foreign collaborations and joint ventures etc., with firms in Japan and the United States heading the list, the industry is spending heavily on R & D.

The country now manufactures a very wide range of metalcutting and metalforming machine tools.

Sophisticated NC machine tools are built by many manufacturers. Hyundai International Inc. are making horizontal machining centres and NC lathes with technology obtained from Osaka Kiko of Japan. Cincinnati Milacron of the United States are collaborating with Hyundai to make cylindrical grinding machines.

Dae Woo Heavy Ind. Ltd. have designed their own NC lathes. The lathe has been interfaced with an industrial robot of Fujitsu to enhance its automation and productivity.

Dae Woo also make ball screws and nuts for NC machines.

Kia Machine Tool Co. Ltd. have developed their own special purpose machines to machine cylinder blocks. Dong Yang have a technical collaboration with Okuma of Japan to make high precision engine lathes, and Chung Kong Sa work in collaboration with Howa Sangyo Co. of Japan on the advanced design of milling machines.

Many of the country's technical universities carry out R & D work for the machine tool industry. Private builders have also invested substantially in R & D to remain competitive.

Exports and Imports. The export of machine tools started in 1977 with a modest performance of $ 2 million. The value of exports rose to $5 million in 1978. There was a dramatic rise of exports in 1979 reaching $22 million. The country's exports of machine tools were expected to touch $40 million in 1980.

More than 20 Japanese machine tool companies have established licence production agreements with builders in the country. Some of the machines built in the country are exported to Japan. Korea Heavy Machinery Ind. Co. Ltd. have entered into an agreement with Yamazaki of Japan to build Mazak lathes for export to Japan. More than 600 locally-built Mazak lathes were exported to Japan in 1979.

The country imported $90 million worth of machine tools in 1976, accounting for 90 per cent of the machine tool requirements of the country during that year. However, the remarkable growth of the indigenous industry has gradually brought down the dependence on imports. The Republic of Korea imported machine tools worth $140 million in 1979 which was about 50 per cent of the domestic consumption of machine tools.

THE MACHINE TOOL INDUSTRY IN ARGENTINA

Introduction. The Argentine machine tool industry came into existence immediately after the Second World War. The industry was set up to produce machine tools locally because imports were cut off. From a very modest production value of $11.9 million in 1966, the production value rose to $22.2 million in 1971. There were 94 establishments in 1971, accounting for a total production of 13,000 tons of machine tools.

In Argentina there are three main groups of machine tool manufacturers; the first group consists of large companies with more than 100 workers. The second category has between 50 and 100 workers and the third consists of small-scale units employing less than 40 workers.

Argentina now produces many types of general purpose machine tools and a few NC machine tools. In addition to 12 manufacturers in the large and medium sectors, there are a number of ancillary units feeding the parent units with a variety of mechanical, electrical, hydraulic and pneumatic components.

Most of the machine-tool-producing units are located in the two major cities, namely Buenos Aires and Cordoba.

Because of rampant inflation in 1978 and 1979, there was practically no investment in the machine tool industry. Capital investment in other sectors was also paralysed. In 1978 the rate of inflation was 127 per cent and in 1979 it was 150 per cent.

This is a pointer to the poor rate of growth of the machine tool industry in Argentina from 1977 to 1980.

Production. The Argentine machine tool industry produced $11.9 million worth of machine tools in 1966. The industry gradually improved its performance to reach $22.2 million in 1971. The production again rose in 1974 to $40 million. After attaining an output of $60 million in 1977, the industry has languished at this level without any appreciable growth because of high inflation.

Technological Level. The machine tool industry now produces a wide range of general purpose machine tools as well as a few NC machines. The large manufacturers possess adequate technology and modern equipment including NC machines and produce modern machine tools from copying to automatic lathes, milling and grinding machines, heavy duty presses and a variety of other machines for production and maintenance.

Table 19 gives the statistics regarding production, consumption, exports and imports of machine tools from 1974 to 1979.

Table 19. The production and trade in machine tools from 1974 to 1979 in Argentina

(Value in U. S. $ millions)

Year	Production	Consumption	Trade	
			Export	Import
1974	40.0	53.5	7.0	20.5
1975	42.0	70.9	9.7	38.6
1976	50.5	79.0	10.0	39.0
1977	60.0	102.0	15.0	57.0
1978	60.0	108.0	12.0	60.0
1979	62.0	125.0	12.0	75.0

Source: American Machinist.

Exports and Imports. Though Argentina exported machine tools worth $7 million in 1974, the share of exports to indigenous production has hardly exceeded 20 per cent. Argentina exported $15 million worth of machine tools in 1977 and has not improved appreciably since then. Argentina mostly exported machine tools to the other Latin American countries under the LAFTA arrangement, whereby the country enjoys customs-free exports.

Argentina has traditionally imported more than 50 per cent of its requirements of machine tools. In 1970, Argentina imported $33.1 million worth of machine tools and imports jumped to $75 million in 1979 when, for the first time, imports exceeded indigenous production as can be seen in the table above.

It was predicted that imports would increase further to 30 per cent in 1980.

THE MACHINE TOOL INDUSTRY IN MEXICO

Introduction. The manufacture of machine tools in Mexico began in 1959 in a small stamping press factory. Today there are many enterprises engaged in the production of metalworking machine tools in Mexico. Soon new plants started production of engine lathes and milling machines of different specifications. Even the other lines of machine tools such as turret and automatic lathes, surface and cylindrical grinders and drilling machines are under production.

The major types of machine tools produced in Mexico are divided into three categories, viz.

Metalcuttung	Metalforming	Woodworking
Engine lathes	Presses	Planers
Automatic lathes	Drop forges	Saws
Drilling machines	Shearing machines (guillotines)	Edgers
Grinders	Bending and rolling machines	Lathes
Saws		Shapers
		Tenoners
		Drilling machines

The industry receives strong Goverment support in the form of fiscal incentives and technical assistance. The industry has joint ventures involving firms from Czechoslovakia, the Federal Republic of Germany, Italy, Switzerland and the United Kingdom.

Machine tools produced in the country are mainly imported designs and apart from the products of joint ventures, machine tools produced in the other factories in Mexico near Puebla, San Luis Potosí, Queretaro and Monterrey are under licence from abroad, viz. France, Switzerland, the United Kingdom, the United States and Yugoslavia. The boost given to the Mexican economy by the petroleum industry to grow more rapidly in the years to come will impel the indigenous machine tool industry to rapidly expand.

Projections for machine tools, according to products, are given in Table 20.

Production. The Mexican machine tool industry produced hardly $2 million worth of products in 1974. The production reached a value of $15.5 million in 1979. The indigenous production is so meagre that most of the requirements of machine tools are met by imports. China and Romania have entered the Mexican market in a big way.

The indigenous production covers mostly general purpose machine tools like lathes, drilling machines, knee-type milling machines, turret and capstan lathes and a variety or shears, presses and

Table 20

THE MACHINE TOOL PARK IN MEXICO, 1960, 1970 & ESTIMATES FOR 1980

	1960		1970		1980	
	Less than 5 years old (units)	Share (%)	Less than 15 years old (units)	Share (%)	Less than 25 years old (units	Share (%)
Metalworking	13,677	87.3	73,148	84.7	174,283	24.7
Lathes	2,820	18.0	17,011	19.7	38,711	18.8
Milling machines	531	3.4	4,066	4.7	9,384	4.6
Drilling machines	980	6.3	9,000	10.4	30,246	14.7
Grinding machines	830	5.3	7,317	8.5	17,485	8.5
Presses	1,206	7.7	7,106	8.2	18,606	9.0
Other	7,310	46.6	28,648	33.2	59,851	29.1
Woodworking	2,000	12.7	13,062	15.3	31,390	15.3
Total	15,677	100.0	86,210	100.0	205,673	100.0

Source: Institute for Economic & Social Planning (IPEA) Studies.

forging machines. The production, consumption, export and import figures for the years 1974 to 1979 are given in Table 21.

Table 21. The production and trade in machine tools from 1974 to 1979 in Mexico

(Value in U.S. $ millions)

Year	Production	Consumption	Trade	
			Export	Import
1974	2.0	224.0	-	222.0
1975	4.5	249.0	-	244.5
1976	5.0	195.0	-	190.0
1977	6.0	86.0	0.3	80.0
1978	13.6	87.3	1.3	75.0
1979	15.5	99.0	1.5	85.0

Source: American Machinist.

Technological Level. Manufacture continues to develop with strong Government support in the form of fiscal incentives and technical assistance. There are many joint ventures involving firms from Czechoslovakia, the Federal Republic of Germany, Italy, Switzerland and the United Kingdom. NAFINSA, the Industrial and Finance Company of the Mexican Government, is spearheading the development of the manufacturing industry including the machine tool industry in the country.

Exports and Imports. Mexican exports of machine tools were nil up to 1976. Starting from a nominal export performance of $0.3 million in 1977, the exports touched $1.5 million in 1979. The products were mostly exported to the Latin American countries, under the LAFTA arrangements.

Mexico imported $222 million worth of machine tools in 1974 whereas local industry produced barely $2 million worth of machines during that year. While production of machine tools grew by about 15 per cent in 1978, imports increased by 25 per cent. However, the imports gradually declined and touched down to $85 million in 1979. Mexico imports mostly sophisticated machine tools from the Federal Republic of Germany, Japan, the United Kingdom and the United States.

VI. A CASE STUDY OF THE MACHINE TOOL INDUSTRY IN INDIA

A case study of one of the developing countries which has strived hard in establishing its own machine tool industry over the decades may serve as a useful example for those developing countries who are similarly trying to set up and/or develop their own machine tool production. The study may reveal some salient aspects such as the experience in building machine tools, infrastructural needs, direction of growth, initial hurdles to be overcome and above all the vital importance of the deliberate decisions and support of the national government for establishing this vital industry. Other details like structure, technological needs, development of indigenous designs and production engineering for the sustained growth of the industry which are embodied in the study could serve as guidelines. It is therefore hoped that the following in-depth study of the Indian machine tool industry will meet, inter alia, the above objectives.

Industrial Base Of India. If we take the historical development of industry as a whole since the beginning of the Industrial Revolution in the United Kingdom over 200 years ago, we can see a distinct pattern of development. Whether in the United Kingdom or in any other industrialized country of the world, the general pattern seemed to have been to lay greater emphasis on the consumer goods industry. It is only after considerable development of the consumer goods and the consumer durables industries that a country usually develops a sufficiently large market for capital goods and then in the second stage, the development of the capital goods industry is a natural consequence. In the United Kingdom, about seven to eight decades had to elapse between the Industrial Revolution of the textile industry and the emergence of the engineering industry as a major component of the capital goods industrial sector. It was only around 1840 that the United Kingdom emerged as the 'Workshop of the World'.

The case of developing countries, however, appears to be somewhat different in the present context of their low industrial development. Can they leave their engineering and capital goods industry to market forces

alone and develop them after a sufficiently large demand has been generated by their domestic consumer goods industry? Furthermore, could they afford to leave their capital goods industry to grow in a natural and in an unplanned manner, or will they have to plan the capital goods industry systematically, providing for its growth, the essential inputs and infrastructure - both physical and fiscal? The answers to these questions obviously depend upon the natural resources, endowments, availability of infrastructure and more important a country's political policy decisions. However, by quoting examples of some of the developing countries who have already established a strong base of their own capital goods industries, including a machine tool industry, it could be justified that a deliberate policy decision should be made by a country's government to establish and develop in a planned manner an indigenous capital goods industry in general and a machine tool industry in particular as a top priority in its over-all planning for industrialization. Take the case of India, for instance.

Relying on the historical experience of the advanced countries, immediately after India's independence in 1947 many economists in the country and others from abroad suggested that India should concentrate

first of all on consumer goods industries and wait a few decades before launching upon the setting up of capital goods industries including the machine tool industry. The answer given to such advisers was that they had ignored the most vital aspect of the over-all development viz., the neglect of the basic and capital goods industrial sectors would only create a situation in which the desired increase of the volume of consumer goods including consumer durables, could not take place for lack of the steel, machine tools and other capital goods needed to produce them. Furthermore, it would have meant delaying the development of a capital goods industry by several decades. The country and its political leaders therefore decided during the 1950s to launch a major effort to develop basic metal industries including steel, machine tools and other capital goods industries at the beginning of the process of India's industrialization.

The country's industrial situation in 1947 had four basic features: (i) there was no capital goods industry worth the name; there were a few engineering shops primarily designed to supply the needs of the Indian railways and there were also two steel mills

producing roughly 1½ million tons per annum; (ii) the entire infrastructure needed for acceleration of the industrial development in terms of power, water, transport, off-site facilities etc. was lacking; (iii) the level of Indian agriculture was depressed, unit output low and the labour-land ratio, adverse. Neither was there any system of inputs in terms of which both the fertility and output could be raised apart from extensive use of the land resources, and (iv) there were no other avenues of gainful employment besides agriculture. This led to depressed levels of income, consumption and saving.

The independent Government of India took policy decisions therefore; (a) to develop the country's capital goods industry; (b) to improve agriculture; (c) to enlarge the manufacture of mass consumption goods and create employment opportunities in industry; and (d) to develop the infrastructure for rapid industrial development.

These being gigantic tasks, it was perhaps natural for the Government of India to take upon itself the lead. The result of this was that the State emerged as the principal instrument of social and economic

transformation and also the dispenser of resources. From this it followed that the development strategies in all economic spheres had to be determined by the State in order that the resource allocation to different sectors of economic development could be done in a manner so as to achieve the intersectoral balance in the developmental process compatible with the framework of socio-economic objectives. That is where the concept of India's Five Year Economic Plans became important and possibly inescapable in the economic situation in which India was placed then.

The concept of planning as India adopted is basically a national exercise towards identification of options, classification of options in terms of relative weight and finally, selecting the processes and sectors of development which are relatively more important in terms of national priorites. Planned development in an economic situation in which India was placed was therefore not a question of the imposition of a certain ideology but only a rational instrument of co-ordinated development planning.

One of the fundamental decisions which was taken by the Government of India at the initial stage of

development was that the Indian economy should be structured on the mixed economy pattern which meant that while there would necessarily have to be a massive and progressively dominant share of Government in the economic development, there would also be a legitimate, definite and significant place for private initiative. In what manner these two lines of activities could be synthesised at different points of time and at different stages of development has been the principal objective of the planning exercise in India.

The emergence of the public sector in India as the principal instrument of economic development has thus come about and in the industrial field it is playing an important role side by side with the private sector. It has geared itself to the task with all its might. As a result it can be said with a fair measure of confidence that in the capital goods industry a great deal of progress has been achieved and that steel plant equipment and heavy electricals - from a variety of machine tools and industrial machinery to process equipment of diversified character and high precision - are being manufactured in India. It is not as if development in this sector

has been exclusive to the public sector. In fact, a number of large, medium and small-scale private enterprises were encouraged by preferential finance, a network of fiscal relief and also infrastructural promotion to accelerate and promote this effort towards self-reliance and near self-sufficiency in the capital goods sector. As a result, except for a few items of industrial machinery of high precision and complexity which are either not economically viable to manufacture or so technologically intensive as to be extremely expensive to be built in India, the country has become practically self-reliant as far as the capital goods sector is concerned.

Among the core industries, by 1980 steel production in the integrated steel plants was expected to touch the 9 million tons annual mark. The non-ferrous metal industry has also made considerable headway. Production capacity of aluminium ingots increased from 68,000 tons a decade ago to the current level of 250,000 tons per annum. Similarly, production capacity of copper has gone up from 10,000tons in 1965-1966 to nearly 30,000 tons in 1977. Production of blister copper was

about 15,000 tons in 1974-1975 and this most likely reached 25,000 tons in 1980. It was expected that during 1980, with the improved position of electric power supplies, cement production would top 33 million tons from a mere 11 million tons during 1974. Among agricultural inputs, the capacity of fertilizers increased from 0.55 million tons to 2.6 million tons, in terms of nitrogen, and the production of fertilizers from 0.23 million tons to 1.5 million tons. Petroleum refining capacity in terms of crude output reached 31.5 million tons in 1978-1979.

A large investment was made in the engineering industries for diversifying production in the public and private sectors and for securing better utilisation of capacity. New machinery manufacturing capacity was created for various industries. Among the major capital goods industries, installed capacity in 1979 was Rs 1800 million worth of machine tools; Rs 200 million of forged and hand tools; Rs 1081.8 million of boilers; 22.7 MVA of power transformers; 6.65 million horsepower of electric motors; 126,500 tons of transmission towers; 80,000 agricultural

tractors; 176,500 tons of heavy structurals, 64,000 commercial vehicles and 33,870 railway wagons.

In petrochemicals, the main development was in the capacity and production of basic intermediates required for synthetic fibres, plastics, aromatics, dyestuff and related industries. There was a substantial investment in other industries like power and newsprint.

Indian industries now produce a wide range of textiles of different fibres (natural and man-made), leather and leather goods, rubber products, drugs and pharmaceuticals, construction materials, a large number of organic and inorganic chemicals and electrical and non-electrical goods.

India's industrial capacity today encompasses the entire spectrum of manufactured products. These range from simple engineering goods and consumer durables such as bicycles, automobiles, refrigerators, radios, air conditioners, television receivers to a comprehensive range of sophisticated machine tools, industrial plants and machinery,

transmission towers and power station equipment, industrial machinery of a highly specialized nature for cement plants, textile mills, sugar factories, refineries, fertiliser plants, petrochemical plants, steel mills, and also technology-intensive products like aircraft, ships, nuclear equipment and satellites. Production of all these critical and vital inputs that are of basic importance to the country's economic development has been an essential feature of the emerging industrial structure of India which makes India one of the 10 highly industrialised countries of the world.

Early Years. Although machine tools were manufactured in India as early as 1890 and this continued throughout the early years of the twentieth century, the number of machine tool manufacturers was extremely small and the products made by them were very poor in quality and standardisation.

At the turn of the century, some workshops in the undivided Punjab had taken up the manufacture of machine tools to meet their own requirements. The machine tools produced, viz., heavy duty deep gap cone pulley lathes and deep throat drilling machines, were not of acceptable quality. During the First World War, some engineering concerns in the north of India also took up manufacture of other types of machine tools like girder milling and drilling machines and shell turning lathes. But these also did not come up to the recognised standards.

During the decade 1930-1940, manufacture of reasonably good quality machine tools was undertaken by P.N. Dutt & Co., Calcutta, West Bengal; India Machinery Co. Ltd., Dasnagar, West Bengal; Cooper Engineering Ltd., Bombay State; and Kirloskar Ltd.,

Bombay State. They manufactured sliding, surfacing and screw cutting lathes up to $9\frac{1}{2}$ in. centre height of cone pulley headstock type, single pillar drills, shaping machines, hacksaws etc. These machines were able to find a ready market in those days. The total number of machine tools manufactured in India before the Second World War was estimated to be 100 per annum.

The outbreak of the Second World War forced the Indian manufacturers to produce armaments which increased the demand for machine tools, a major portion of which was imported from abroad primarily from the United Kingdom. In anticipation of the needs of the Allies for their various theatres of war in India and South-east Asia, the British Government in India passed the Machine Tool Control Order in 1941. The main object of this order was to take an inventory of machine tools obtainable in India, regulate and improve production in general and secure for the armed forces, ordnance factories and other war industries the best quality machine tools. This may be said to be the beginning of the Indian machine tool industry on more systematic lines.

When both Italy and Japan entered the Second World War, the Mediterranean and the Indian Ocean were closed for shipping. Imports thus being more or less cut off, the Indian machine tool industry was called upon to make greater efforts to supply the requirements of the Second World War. Plans were drawn up by the Machine Tool Controller to increase the manufacturing capacity of the leading machine tool producers who had the basic plant and equipment, a background of reasonably good technical supervision and manufacturing experience. They were supplied with new machine tools and equipment from abroad, mainly from the United States under the American Lend-Lease Scheme. Some firms in India. including Cooper Engineering Ltd., Kirloskar Ltd. and Investa Machine Tools Ltd., received balancing plant worth about Rs 2.2 million. In addition, some firms were assisted in outright purchase of machine tools from the U.K. and U.S.A. A team of seven machine tool experts from the United Kingdom was deputed to help the indigenous machine tool industry with technical advice and guidance. The function of engineering inspection was set up under the Director General of Inspection in the Supply Department which greatly helped to rationalise and control the quality and standard of indigenous

machine tools. As a result of all these and other concentrated war efforts, the industry seems to have made good progress. The total number of graded machine tools manufactured in India in 1942 was only 273 but in 1946, this number increased to 4,121 valued at Rs 11.3 million. During the six years of the Second World War, about 20,000 machine tools valued roughly at Rs 60 million were produced.

The Industry in the Post-War Years. Although the Indian machine tool industry made this remarkable progress when compared to the short period of less than 10 years, it almost collapsed immediately after the Second World War. This was mainly because the structure and organisation of the industry were not strong and specialised enough to undertake the production of machine tools and compete against foreign machine tools which were allowed to be imported freely. Firms which were originally engaged in the manufacture of other engineering items had been encouraged to take over the production of machine tools, apart from The Mysore Kirloskar Ltd., which was specially set up for the production of machine tools during

1940-1941, and which was yet to make its significant contribution. Most of them either did not possess adequate equipment for producing high quality parts or the requisite knowledge of the technique of building precision machine tools. As a result, after the termination of the Second World War, the industry faced a grave crisis. In 1949, sales of indigenous machine tools fell and large stocks of unsold machine tools accumulated, leading to the reduction of output of machine tools in 1950 to barely Rs 3 million, as can be seen in Table 22. There was a general prejudice among the consumers against indigenous machine tools as the standards, designs, quality, precision and performance of Indian machine tools were far inferior to those of imported machine tools. In the struggle for survival during the post-war period of the Second World War, many machine tool manufacturers disappeared. The wartime number of 24 graded and 100 ungraded machine tool firms in the organised sector was reduced to 15 graded and barely 30 ungraded machine tool builders after the independence and the partition of the country. The dawn of independence thus led to the collapse of the indigenous machine tool industry mainly because of the post-war structural weakness of the industry and the partition of the country.

TABLE 22

THE PRODUCTION OF MACHINE TOOLS IN INDIA, 1941-1950

A	B	C	D	E
YEAR	Annual imports Value (Rs million)	Annual production in India of graded machine tools		Percentage a/
		Quantity	Value (Rs million)	
1941	6.8	-	-	-
1942	5.7	273	0.6	10.7
1943	5.4	1,713	6.4	118.5
1944	15.3	2,170	7.8	51.0
1945	18.2	3,699	11.2	61.4
1946	18.3	2,820	9.1	49.8
1947	36.8	1,400	4.6	12.5
1948	41.4	1,691	5.5	13.2
1949	42.0	2,240	4.7	11.3
1950	24.9	1,130	2.9	11.5

Source: Indian Machine Tools Manufacturers Association (IMTMA)

a/ Percentage of domestic value compared to import value ($\frac{D}{B}$ x 100).

Decade 1950-1960. At this critical juncture, the Government of India decided to help the machine tool industry to establish itself on a strong footing. As a first step, the Government planned in 1949 to set up a modern machine tool factory and entered into a collaboration agreement with Werkzeugmaschinenfabrik Oerlikon-Bührle AG (Oerlikon-Bührle Machine Tool Works), Zürich, Switzerland. This heralded the birth of Hindustan Machine Tools Ltd., Bangalore, which commenced production during 1954-1955. In later years, the company came to be nationally and internationally recognised as HMT Limited, a leading machine tool concern in the public sector over the past three decades. Furthermore, the Government of India gave much financial and fiscal assistance to the private sector machine tool companies and allowed them the freedom to acquire modern designs and technical know-how from reputed machine tool manufacturers abroad. The industry received special technical assistance and guidance from the Director General of Technical Development (DGTD), Wing of the Ministry of Industry at the Centre, who also monitored closely the growth of the industry. In addition, one of the important incentives that the Indian machine tool industry received from the Government was that imports of machine tools were

restricted and imports of such types as were being produced indigenously were totally banned.

Due to these and several other measures which are described in the next section, the indigenous machine tool industry increased its output and imports started decreasing. During the first Five Year Plan commencing in 1950, the total value of machine tools consumed by India was worth Rs 200 million of which indigenous industry produced only Rs 30 million worth and imports accounted for the balance. But the indigenous production of machine tools steadily rose from 1957 to 1960. The annual production of the industry in 1956 was Rs 10.8 million and it rose to Rs 58.6 million in 1960. This marked the initial growth stage of the industry when it consolidated the production of a number of general purpose machine tools, many of them manufactured under licence from abroad. The product range covered various types of geared-head centre and capstan lathes, milling machines, drilling machines, radial drills, grinding machines etc. of modern design.

Besides the two major production units in the State-owned public sector, 15 large and medium-scale

firms in the private sector produced a variety of general purpose machine tools. What is significant, however, is the growth of small-scale units manufacturing machine tools which during 1958 numbered 344 of which the Punjab alone accounted for 264 units which were concentrated in Batala, Ludhiana, Amritsar and Jullundur. The remaining small-scale machine tool units were located in other states like Gujarat, West Bengal, Maharashtra, Madhya Pradesh, Tamil Nadu, Andhra Pradesh and Karnataka. The statistics of production, import and percentage of production of imports of machine tools from 1950 to 1960 are shown in Table 23.

Decade 1960-1970. In the decade from 1960 to 1970, the Indian machine tool industry passed through a phase of rapid growth. The annual production which stood at Rs 58.6 million in 1960, jumped to Rs 372.3 million in 1970. The performance of the industry would have been even better had the recession not intervened from 1966 to 1969, which forced the industry to cut back on production. The industry recovered from the traumatic experience of the recession mainly due to its imaginative approach to diversify the product range to include

TABLE 23

THE PRODUCTION OF MACHINE TOOLS IN INDIA, 1951-1960

A	B	C	D	E
YEAR	Annual imports Value (Rs million)	Annual production in India of engraved machine tools		Percentage[a/]
		Quantity	Value (Rs million)	
1951	25.0	2,834	4.7	18.9
1952	22.1	4,488	4.4	20.1
1953	31.3	2,961	4.4	14.1
1954	38.6	1,544	4.7	12.2
1955	52.9	3,064	6.8	12.8
1956	83.7	3,016	10.8	12.9
1957	146.4	4,033	23.5	16.0
1958	144.2	5,469	34.1	23.6
1959	163.3	4,434	41.6	25.5
1960	209.4	5,980	58.6	28.0

Source: Indian Machine Tool Manufacturers Association

a/ Percentage of domestic value compared to import value $(\frac{D}{B} \times 100)$.

more advanced designs of machine tools which were hitherto imported.

It was largely during this period that the machine-tool-producing units in the public and private sectors entered into numerous collaboration agreements with renowned manufacturers of machine tools in Europe, Japan, the United Kingdom and the United States to widen the base of production and to add a number of new products. New designs like combination turret lathes, single spindle automatics, multispindle automatics, vertical turret lathes, gear shapers, gear hobbers, precision copying lathes, multi-tool automatic lathes, drum turrets, horizontal boring machines, broaching machines (vertical and horizontal types), front chucking machines, single and special purpose machines, transfer lines, heavy duty hydraulic and mechanical presses were taken up for production to meet the growing needs of the metalworking industries. It was during this period that the Indian machine tool industry laid the foundation for the manufacture of almost all types of general purpose machine tools. In addition to general purpose machine tools, the production of special purpose machine tools under licence from a well-known firm

abroad was also started to cater to the needs of the automobile, tractor and armament industries in particular and others like diesel engines and electric motors. The programme of diversification within and outside the field of machine tools was primarily aimed at building the necessary resilience into the industry so that it could face any spells of recession without getting paralysed.

The Indian machine tool industry achieved the distinction of reaching a high percentage of production to total consumption in 1970. From a mere 23 per cent in 1961, the indigenous production as a percentage of total consumption of machine tools rose to 71 per cent during 1970.

In 1966-1969, there were 66 firms in the organised sector which accounted for 90 per cent of the total output of machine tools. The three public sector units (mainly HMT Limited) held the foremost leading position and accounted for more than 50 per cent of the total production of machine tools in the country and this ranking has been consistently retained by the public sector units even today. It was in 1970 that the Indian machine tool industry established its credentials by participating in

in prestigious exhibitions abroad like the International Machine Tool Exhibition held in Hannover, Federal Republic of Germany. Furthermore, the industry was becoming conscious of the need to produce advanced technology machines and also to update the quality and versatility of indigenously manufactured machines. Statistics regarding production, imports, exports, consumption and share of production in consumption are given in Table 24.

Decade 1970-1980. The Indian machine tool industry further registered an increased rate of production in the decade 1970-1980. The output of the industry which stood at Rs 372.3 million in 1970 rose to Rs 502.2 million in 1971. After suffering a slight setback in 1972, when the production value dipped to Rs 494.6 million, the industry again raised its output to Rs 622.6 million in 1973. The increase in the output of the machine tool industry continued right through the decade to reach a value of Rs 1,544 million in 1979.

The growth percentage of the industry from 1974-1979 reveals a steadily growing trend. The value of production in 1974 over that of 1973 registered a growth percentage of 42 per cent. This sharp increase in production was due to the orders rushed through

TABLE 24

THE INDIGENOUS PRODUCTION, TRADE AND CONSUMPTION OF MACHINE TOOLS IN INDIA, 1961-1970

(Value in Rs million)

A YEAR	B PRODUCTION	C IMPORT	D EXPORT	E CONSUMPTION	F a/ SHARE OF PRODUCTION IN CONSUMPTION (percentage)
1961	73.3	242.2	-	315.5	23
1962	104.0	260.4	01.1	363.3	29
1963	167.8	315.0	01.0	481.8	35
1964	209.8	344.4	01.2	553.0	38
1965	254.8	349.3	01.4	602.7	42
1966	284.8	429.9	06.6	708.1	40
1967	254.7	394.0	06.7	642.0	40
1968	206.3	362.5	18.6	550.2	37
1969	266.8	189.9	29.5	427.2	62
1970	372.3	183.0	27.9	527.4	71

Source: Indian Machine Tool Manufacturers Association

a/ $\frac{B}{E} \times 100$.

by the user industries to obtain the benefit of the "development rebate" granted by the Government of India till the end of May 1974. However, after 1974, the growth percentage was 18 per cent in 1975, 12 per cent in 1976, 10 per cent in 1978, 12.8 per cent in 1979. There was a negative growth rate in 1977 mostly on account of the general slump in industrial production. The real rate of growth achieved by the industry during 1973 to 1979 can be put at 8 per cent after making the necessary correction for inflation. Statistics regarding production, imports, exports, consumption and the share of production are given in Table 25.

Technological Advancement. During this decade production steadily increased and consequently there was a comparative reduction in imports. Figure VII shows the growth in production and exports and gradual decline in imports of machine tools from 1945 to 1979. The percentage of indigenous production rose from 70 per cent to 86 per cent of consumption as can be seen from Figure VIII.

The increase in the value of production does not merely reflect a greater number of machine tools produced, but it is also due to the qualitative

TABLE 25

THE INDIGENOUS PRODUCTION, TRADE AND CONSUMPTION OF MACHINE TOOLS IN INDIA, 1971-1979

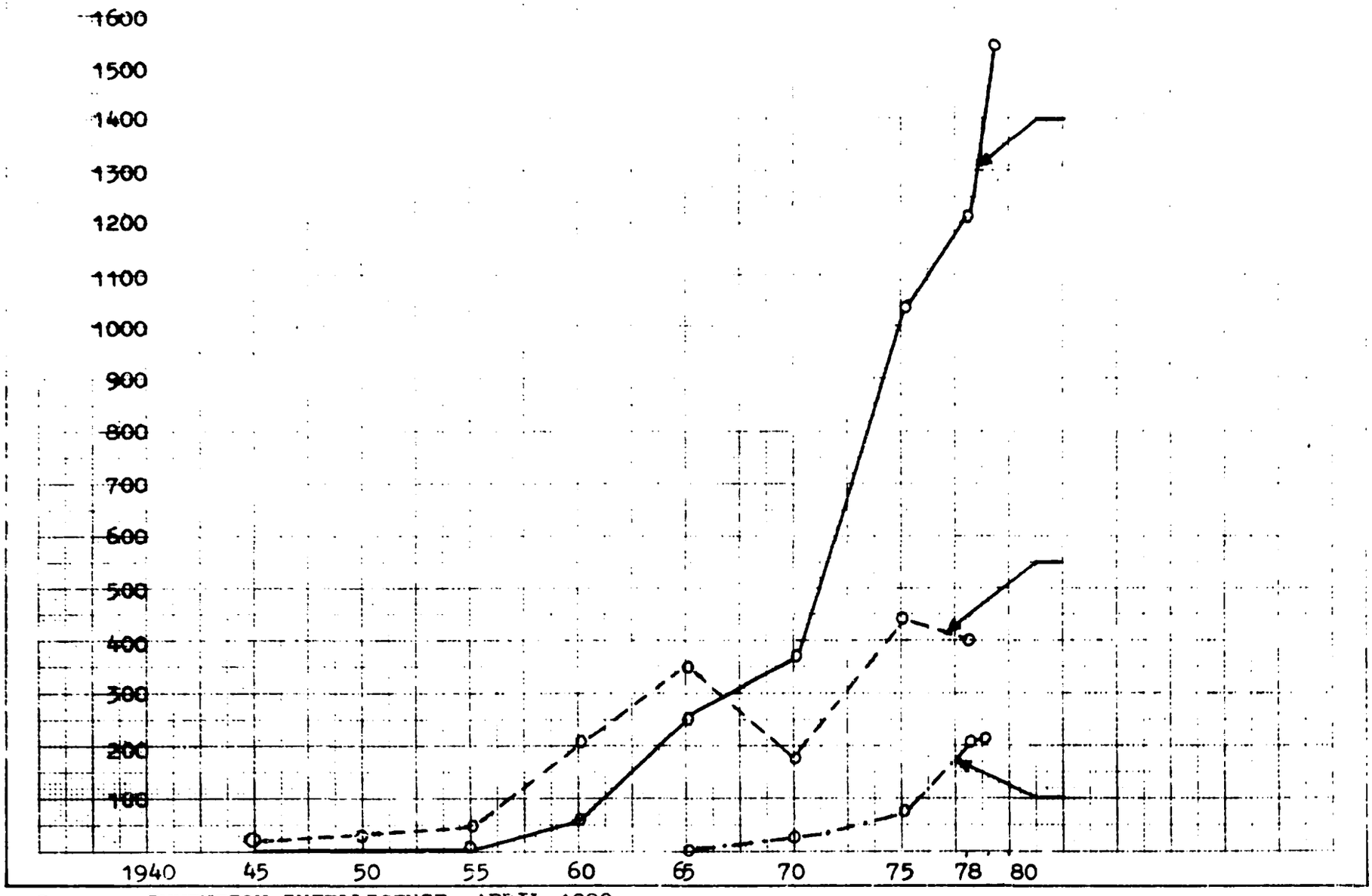
(Value in Rs million)

A YEAR	B PRODUCTION	C IMPORT	D EXPORT	E CONSUMPTION	F a/ SHARE OF PRODUCTION IN CONSUMPTION (percentage)
1971	502.5	217.0	30.5	689.0	73
1972	494.6	236.4	21.0	710.0	69
1973	622.6	286.7	36.9	872.4	71
1974	884.4	294.6	71.2	1107.8	80
1975	1040.3	440.5	81.8	1399.0	74
1976	1168.5	444.9	169.2	1444.2	81
1977	1095.7	357.2	136.6	1316.3	83
1978	1210.5	400.0	205.0	1405.5	86
1979	1544.3	-	210.0	-	-

Source: Indian Machine Tools Manufacturers Association

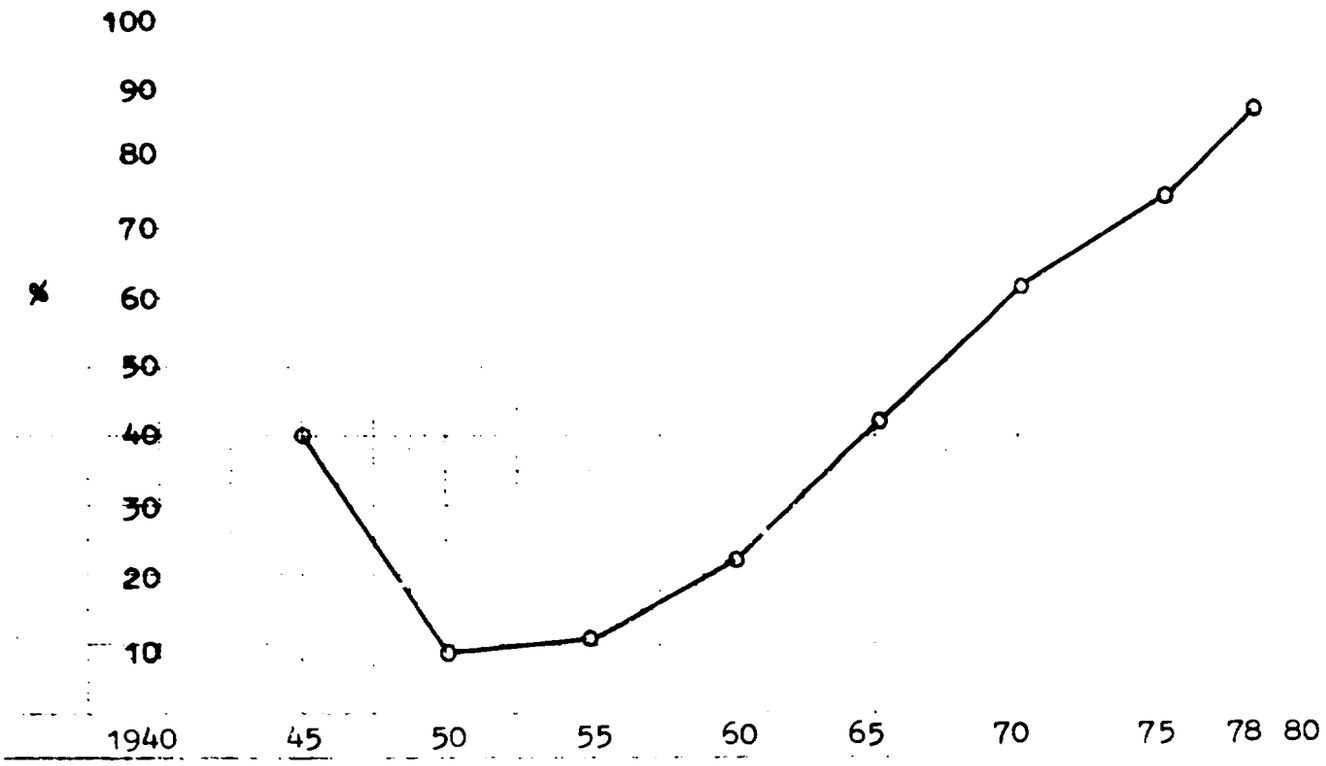
a/ $\frac{B}{E} \times 100$.

Figure VII. The growth in production, imports and exports of machine tools in India



Source: INVENTION INTELLIGENCE, APRIL 1980

Figure VIII. The percentage of indigenous production in consumption in India



Source: INVENTION INTELLIGENCE, APRIL 1980

improvement as well as expanded range of advanced technology machine tools like the hydraulically operated front chuckers, multispindle automatics, multi-tool automatic lathes, single and special purpose machines, multi-station transfer lines, inclined bed heavy duty hydraulic copying lathes, crankshaft turning lathes, crankshaft grinders, centreless grinders, angular wheel grinding machines, Swiss-type moving headstock automatics (Petermann), heavy duty hydraulic and mechanical presses ranging from simple single column eccentric presses of 40 to 100 ton capacity to highly complex double column heavy duty hydraulic/ mechanical presses of up to 5,000 ton capacity, heavy forge machines and fine blanking machines. The improvements in quality also include standard and special accessories, coated carbide cutting tools, hydraulic and electronic controls of machine tools.

Furthermore, the Indian machine tool industry entered the manufacture of modern NC machine tools during this decade. Even though the first Indian NC machine tool was exhibited at the International Machine Tool Exhibition in Hannover in 1970, it took the industry

five to six years before it could come up with production models of various types of NC machines and machining centres. The industry is now in a position to offer NC and CNC turning centres, CNC vertical machining centres with automatic tool changers and NC turret machining centres. The production of NC and CNC machine tools also created an awareness to produce the required software packages for the optimum utilisation of these machines. The number of NC machines installed in the country now is well over 150, 50 per cent of which are installed in the organised industry and the balance in jobbing and small industries, R&D establishments and educational institutes. The production of EDM machines was also established during this period. The industry has entered into the production of gun drilling and deep hole boring machines.

Structure of the Industry. Among the 125 large and medium-scale establishments manufacturing machine tools today, are: HMT Limited (public sector), Mysore Kirloskar Limited, Bharat Fritz Werner Limited (joint venture), Godrej & Boyce Mfg. Co. Pvt. Ltd., Cooper Engineering Limited, Heavy Machine Tool Plant, Ranchi (public sector),

Praga Tools Limited (public sector), Perfect Machine Tools Co. Pvt. Ltd., Batliboi & Co., Ltd., Beco Engineering Company Ltd., Madras Machine Tool Manufacturers Ltd., Amteep Machine Tools Pvt. Ltd., Simtools Limited, Kerry Jost Tools Limited, New Standard Engineering Co. Ltd., TELCO(Machine Tool Division), Alfred Herbert (India) Ltd. and Kulkarni-Black & Decker Limited.

In 1979, the installed capacity of the Indian machine tool industry was 17,500 machine tools per annum with a value of roughly Rs. 1800 million.

In addition to the organised sector engaged in the production of machine tools, the small-scale manufacture of machine tools, accessories and allied equipment has expanded rapidly. This is evident from the hundreds of small units located in the states of Punjab, Haryana and cities like Rajkot, Kolhapur, Jamnagar, Bangalore and Coimbatore. These small units produce knee-type milling machines, planing machines and some unsophisticated models of grinders. The name Batala lathe has almost acquired a special connotation in the Indian context. Batala in the Punjab is the home of hundreds of small units producing a variety of ungraded

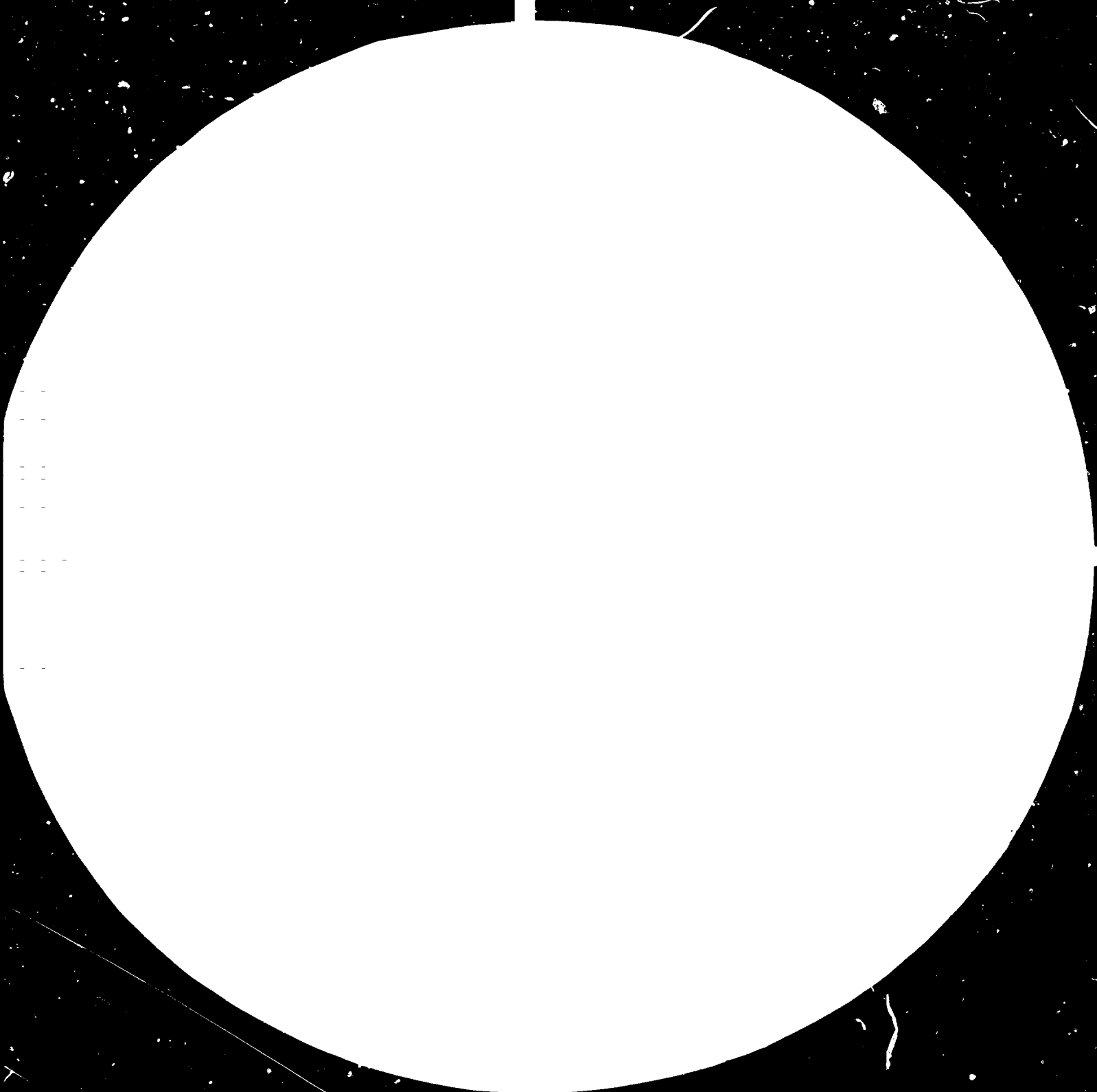
machine tools which sell for a fraction of the price of graded machine tools produced by the organised sector. The Batala phenomenon demonstrates that the production of machine tools need not be confined to capital-intensive large factories but could be spread over a large number of small units to produce the components and to assemble them at some central facility. The low wages and the reasonable overheads are responsible for the lower prices of the products. If modern designs, refined production technology and quality consciousness can be infused into the entrepreneurial fervour of this sector, then larger units can concentrate solely on the production of sophisticated machine tools and equipment and acquire the components from the small sector for producing modern designs of machine tools. This is what is presently happening in the Indian machine tool industry.

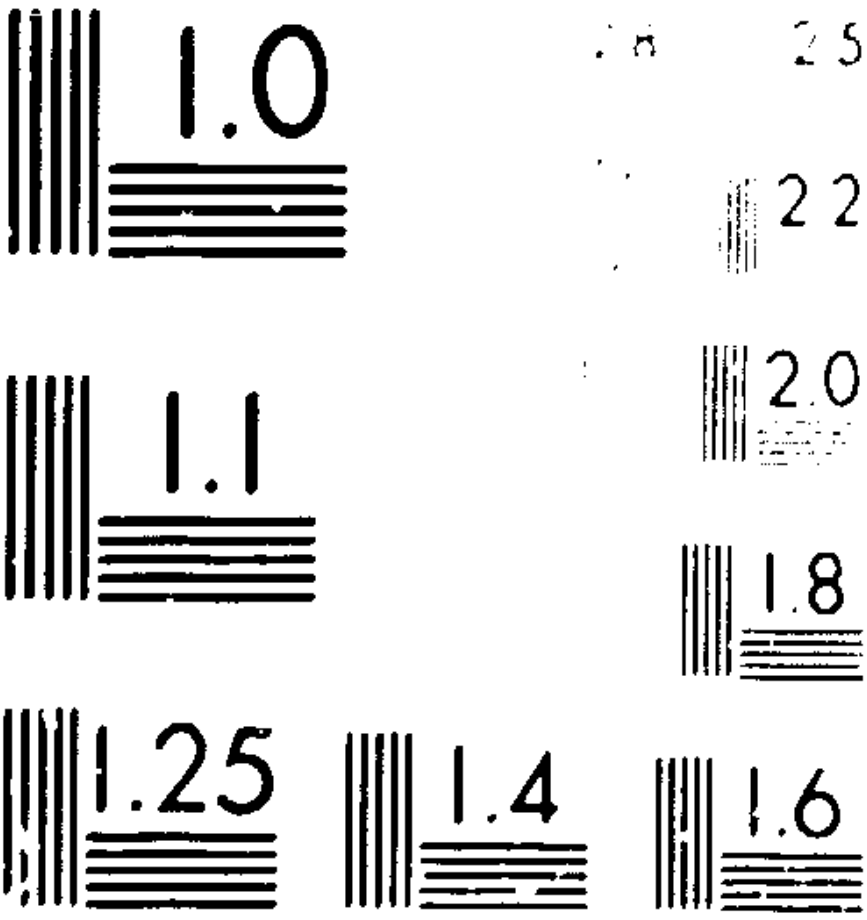
As a result of the large output of machine tools, the metalworking industry in India grew to include over 15,000 factories employing about 1.2 million workers, with a machine park of 315,000 machine tools, about half of which were made in India. The total industrial production in the country today is estimated at Rs 200 billion per

annum, with a little more than 50 per cent being the contribution of the public sector.

Ancillaries. The development of ancillaries to relieve the larger units from the responsibility of making all the components has become established in India. There are several industrial estates started either by the large-scale manufacturing houses or by the State and Central Governments providing the main infrastructure like building, power, water supply to innumerable entrepreneurs, some of them qualified technocrats.

The ancillary industries not only support the parent industry to meet the techno-economic necessities of the competitive market but also permit the diffusion of ownership and management. The importance of ancillary industries was first realised in India when the bicycle manufacturers of the Punjab made use of the products of ancillary units and succeeded in producing quality bicycles at a much lower cost than those made by large-scale units elsewhere in India.




1.0
2.5
2.2
1.1
2.0
1.8
1.25
1.4
1.6

The machine tool industry in India established ancillary units in the beginning of 1960 and the advantages accruing to the parent units were evident from the fact that subsequently more ancillary units were started all over the country. In 1979, there were 95 industrial estates in the country catering to the needs of larger manufacturing units. The current level of ancillarisation in the machine tool industry is about 25 per cent. This level will get progressively enhanced with the growing reliability and the technical ability of the units to produce complicated components with required accuracy. Already signs are evident that ancillarisation is bound to grow in future because of the unmistakable advantages of interdependent industrialisation which will not only serve the needs of the industry but also of the community in terms of larger employment potential, enhanced purchasing power and broad-based ownership conferred by a competitive economy.

Exports. The Indian machine tool industry started exporting its products from 1955 onwards. But till 1962, the export performance was almost negligible. In 1962, exports were worth just over

Rs 1 million. An organised export drive pushed the exports to Rs 6.6 million in 1966 and this again rose to Rs 30.5 million in 1971. The exports touched Rs 81.8 million in 1975 when Indian machine tools were exported to Europe, South-east Asia and the United States. The main products exported were centre lathes, turret and capstan lathes, radial drills, single column pillar drilling machines, knee-type milling machines, cylindrical grinders, surface grinders, tool sharpening machines and power presses.

There was an impressive increase in exports in 1976 when the value climbed to Rs 169.2 million representing a twofold increase over the export performance of 1975. After a minor set-back in 1977, when exports dropped to Rs 136.6 million, the industry again improved its export performance in 1978 when it sold Rs 205 million worth of products abroad. In 1979, machine tool exports rose to an estimated figure of Rs 210. million. The 10 largest importers of Indian machine tools in 1978 were Australia, the Federal Republic of Germany, Hungary, Iraq, Kenya, the Netherlands, the United Arab Emirates, the United Kingdom, the United Republic of Tanzania and the United States of America. Table 26 shows exports from 1962 to 1979 in relation to indigenous production and imports.

TABLE 26

THE INDIGENOUS PRODUCTION, TRADE AND CONSUMPTION OF MACHINE TOOLS IN INDIA, 1962-1979

(Value in Rs million)

A	B	C	D	E	F a/
YEAR	PRODUCTION	IMPORT	EXPORT	CONSUMPTION	SHARE OF PRODUCTION IN CONSUMPTION (percentage)
1962	104.0	260.4	01.1	363.3	29
1963	167.8	315.0	01.0	481.8	35
1964	209.8	344.4	01.2	553.0	38
1965	254.8	349.3	01.4	602.7	42
1966	284.8	429.9	06.6	708.1	40
1967	254.7	394.0	06.7	642.0	40
1968	206.3	362.5	18.6	550.2	37
1969	266.8	189.9	29.5	427.2	62
1970	372.3	183.0	27.9	527.4	71
1971	502.5	217.0	30.5	689.0	73
1972	494.6	236.4	21.0	710.0	69
1973	622.6	286.7	36.9	872.4	71
1974	844.4	294.6	71.2	1107.8	80
1975	1040.3	440.5	81.8	1399.0	74
1976	1168.5	444.9	169.2	1444.2	81
1977	1095.7	357.2	136.6	1316.3	83
1978	1210.5	400.0	205.0	1405.5	86
1979	1544.3	-	210.0	-	-

Source: Indian Machine Tool Manufacturers Association

a/ $\frac{B}{E} \times 100$.

In 1979, approximately 14 per cent of the production of the Indian machine tool industry was exported. The Indian machine tool industry has set itself an export target of Rs.750 million by the year 1984.

A significant feature of the export performance is that now even small-scale units are producing machine tools for export in addition to the manufacturers in the medium and large sector.

Indian machine tools are now exported not only to advanced countries like the Federal Republic of Germany, the United Kingdom and the United States but also to the developing countries of Africa and Asia. The machine tool industry has demonstrated its ability to sell in the highly competitive world markets. In the past the exports were channelled mainly through foreign agents and importers. But now more interest is being shown by reputed foreign manufacturers who are approaching the Indian machine tool builders to get machines built in India for export to overseas market. In addition, leading firms like HMT have their own network of world-wide export branch offices through which they import their machine tools and distribute them to the dealers in the respective countries. They maintain fully-fledged. factory-trained teams of service engineers and hire

mostly locals for carrying out the selling operation.

The Indian machine tool industry is constantly demonstrating its capabilities by participating in almost all important international exhibitions in the highly industrialised countries. In addition to the well-known foreign exhibitions like EMO and the International Machine Tool Show, Chicago, United States, the Indian Machine Tool Exhibition, IMTEX, regularly organised by the Indian Machine Tool Manufacturers Association (IMTMA), attracts a large number of foreign buyers.

Besides export of machine tool products, the Indian machine tool industry has started in a modest manner to export its engineering services and management consultancy. The leading machine tool manufacturers like HMT have undertaken to establish turnkey machine tool projects abroad mainly in the Asian and African countries. Their expertise is also being utilised by the countries abroad in setting up machine tool training centres as well as in-factory training of foreign manpower in skilled trades and in engineering disciplines like planning and shop

supervision of manufacturing processes.

It is expected that the invisible export of software expertise in machine tool technology could contribute substantially to the foreign exchange earnings of the Indian machine tool industry as a whole.

Research and Development. Although some leading machine tool manufacturing companies in India had their own design and development departments around 1960, organised design and development activities in the field of machine tools seem to have begun from 1965 onwards. It took a long time to establish production of the machine tools which were indigenously designed at the beginning of the 1960s. but slowly Indian R&D engineers and production technologists acquired the ability to design and put into production general purpose machine tools in comparatively less than over a decade. During 1960-1970, though, the production of indigenous designs of machine tools was slow, yet several designs of general purpose machine tools were evolved and, simultaneously, Indian designers were acquiring knowledge and ability to tackle designs of more complicated machine tools.

The collaboration agreements with foreign machine tool manufacturers were necessary in the beginning to speed the process of growth of the indigenous machine tool industry and as an essential component for the training and development of engineers, technicians, designers, planners, managers as well as skilled operators. But reliance on foreign collaboration for the technical know-how to produce machine tools has had its own limitations in regard to the production of more advanced and high productive automated machine tools. The country realised that there was a danger in perpetually depending upon foreign sources in this regard. The short-term gains of importing designs and technology to fill specific market requirements were responsible for concluding many collaboration agreements in the beginning. But importing technology on such a large scale in a vital field like machine tools could not continue indefinitely, apart from on a selective basis, because of the fear that foreign sources would not always respond positively when more modern and highly sophisticated and export-oriented designs and production technologies were concerned.

The Indian machine tool industry is conscious not only of the need to establish in-house R and D

activities but also of the useful role of institutionalised R&D, particularly for the benefit of small and medium units which do not have the benefit of the resources required to sustain advanced research and development work in an in-house manner. Hence the industry attached high importance to institutional R&D which could generate know-how by creating facilities to evolve, try out and establish modern concepts leading to designs, construction and testing of new models and prototypes of machine tools. The Indian machine tool industry directed the institutional R&D establishments to investigate and evolve technologies which could augment capabilities in product design, production processes and engineering systems.

The Government of India took the initiative in the matter of institutional R&D and set up the Central Machine Tool Institute at Bangalore (CMTI) in 1965 which was to act as a nucleus for institutional R&D. CMTI was established by the Government of India in collaboration with the Government of Czechoslovakia. In the last 15 years, CMTI has been able to develop several machine tools with indigenous technology and more importantly train hundreds of machine tool designers

and production technologists for the industry. As a result, a number of machine tool manufacturers particularly in the medium and small sectors have been taking advantage of the expert services rendered by the Institute.

The activities of CMTI have grown both in size and content. Besides undertaking designs and development assignments and conducting training courses for machine tool designers, technologists and production engineers for the machine tool entrepreneurs, it has widened its facilities to carry out research in the testing of machine tools, machining technology, metrology and numerical control systems.

An NC Centre is being established at CMTI by the Government of India under the United Nations Development Programme (UNDP) to provide assistance to the metalworking industry in all areas related to numerical control. Training of personnel from user industries, demonstrating the technology of manufacture using numerical control, advising on the selection of NC equipment, and undertaking development work in the

field are some of the items on the programme of work of the Centre. So far, over 300 industry-sponsored participants have attended these courses.

The Centre undertakes machining of parts on NC machines to demonstrate and prove quality consistency and economics of machining. For this purpose the Centre is equipped with a 5-axis machining centre, a 3-axis milling machine, a 2-axis cylindrical grinder, and two NC lathes. A minicomputer and a co-ordinate measuring machine have also been installed.

Personnel from industries can bring in their parts, programme them, edit the programme, plot it on a Co-ordinate Plotter, tool-up the machine, use the tape for actual machining and produce the parts in a limited quality to ascertain repetitive accuracies, manufacturing times, economics etc.

Companies intending to acquire NC machines can utilise the facilities in the Centre for trial machining and decide on the specifications of the machine they intend buying. Consultancy services

are also offered in the selection of NC machines, control systems, part programming languages, post processes, supporting and maintenance aids etc.

As regards development activities, a CNC system using a microprocessor-based computer is in its final stage of assembly and development. A microprocessor-based tape preparation system to punch and edit the tapes has just been introduced and the first few units are being supplied to a couple of users. The Centre is considering developing software for the static stimulation of machine tool economics, process planning, production scheduling etc. leading to the implementation of computer-aided manufacturing (CAM).

As far as in-house R and D is concerned, as is common elsewhere in the industrialised countries, large manufacturers of machine tools in India are continuously strengthening their in-house R and D in machine tool design and production technology. For instance, HMT are putting up a separate and expensive building to locate their entire research and development activities. The Centre is expected

to evolve conceptual designs, latest peripherals, controls, in-process gauging systems and building and testing of prototypes exhaustively, before the commencement of serial production.

A systematic modernisation of their existing designs of machine tools, to update them to the latest international standards, is one of the main activities of this Centre.

Recently, the Government of India has instituted certain measures.

A new enactment dictates that no new imports of designs and technology by an individual manufacturing concern will be permitted until and unless the enterprise proves to the satisfaction of the Government that it has its own strong R&D base, whereby not only will the company absorb and adapt the imported technology, but it will continuously strive hard to depend upon its own R&D efforts for future innovations and improvements in design and technology. Many fiscal incentives were granted in India's Annual Central Budget for 1980 for the growth of R&D activities in the manufacturing industries.

In spite of the impressive strides made by the indigenous machine tool industry, an ever-widening technology gap is separating India from the industrially advanced countries producing machine tools. In fact, the Indian machine tool industry is presently at a crossroads; with one route leading to highly productive, automated machine tools and advanced computer-aided manufacturing systems, and the other route leading to a labour-intensive approach which, according to one view, could mean stagnation for the entire industry. One way of putting the Indian machine tool industry on a more modern footing could be through the technologically advanced thrust of the metalworking and capital goods industries - particularly transportation, communications, power generation and armaments - which are on the threshold of a great technological breakthrough and need highly advanced types of machine tools and very sophisticated production technology.