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

18847

Distr.
LIMITED

ID/WG.508/6,
5 February 1991

United Nations Industrial Development Organization

ORIGINAL: ENGLISH

Regional Expert Group Meeting for
Latin America on the Capital Goods
Industry with Emphasis on Machine Tools

Santiago, Chile, 8-11 April 1991

GLOBAL DEVELOPMENTS IN THE MACHINE TOOLS INDUSTRY: IMPACTS ON USERS AND PRODUCERS IN DEVELOPING COUNTRIES*

Prepared by

the UNIDO Secretariat

* Mention of firm names and commercial products does not imply the endorsement of the United Nations Industrial Development Organization (UNIDO). This document has not been edited.

V.90-89982

TABLE OF CONTENTS

Page

TABLES

FIGURES

BOXES

I: INTRODUCTION TO THE MACHINE TOOL INDUSTRY

1 A STRATEGIC INDUSTRY

The machine tool industry is a small manufacturing sector with worldwide sales of US$42 billion in 1989. It is a rather slow growing sector: its turnover was fifteen per cent of electronics industry's in 1974 and nine per cent in 1989.

Table 1 World machine tool production in perspective
in US$ billions

	1974	1980	1986	1988	1989
Machine tool	13	26	29	38	42
Electronics	87	196	346	430	445

Sources: American Machinist
Yearbook of world electronics data

Despite its relatively small size, the machine tool industry is widely regarded as a strategic industry. Its main importance lies in its role in the learning process associated with industrialization: it is the supplier of continuously improving manufacturing technologies which, through machine systems and methods, play a major factor in the improvement of overall industrial productivity. This strategic role has often explained and justified the State involvement. However, apart from the case of centrally planned countries and of some developing countries, State enterprises are seldom to be found in this sector while industrial policies have focused on R&D promotion, procurement measures, restructuring efforts and modernization plan.

Because of its impact on user industries, the existence of a competitive national machine tool industry may offer some advantage to the local engineering industry however, in most cases, there is no clear relationship between the competitiveness of a country's machine tool industry and the competitiveness of its manufacturing industries. Increasingly, it appears[1] that the world machine tool industry acts as a transmitter of

---

[1] Jacobsonn S.: "Technological Change in the machine tool industry, implications for industrial policy in developing countries", in New Technologies and global industrialization PPD.141 November 1989, UNIDO

technology to the engineering industries.

2 MACHINE TOOLS

While machines are dedicated to the manufacturing of a specific product, machine-tools can be defined by their ability to perform a specific process. A large variety of machine tools has emerged over the years: there are some 3,000 different types which differ in the purpose for which they are designed, their size, weight, means of control, design of features and prices.

2.1 Metal cutting and metal forming machines

Metal cutting machines tools are used to cut away surplus material from a piece of metal in order to produce a part with the desired shape and size. Metal forming machine-tools shape the metal without the use of a cutting tool, by pressing, forging, bending shearing, etc.(Box 1)

The shares of cutting (75 per cent of total demand) and forming (25 per cent) machines have remained constant over time. however the structure within each of the subgroups has changed. Figure 1 shows the evolution in percent of world demand in value in 1980 and 1988[2]. Due to the development of multi-functions machines, demand has slightly decreased in the share of turning machines, boring and drilling machines. On the other hand the gains have been in machining centres and EDMs in specialized markets.

2.2 Conventional, automatic and Numerical Control machines

Conventional machine tools are controlled by a skilled machinist who studies a blueprint and manually directs the machine based on his knowledge of the machine tool and his interpretation of the drawing. New devices have relieved the machinist of certain manual tasks but he retained the control over the operation of the machine. Despite the diffusion of NC machines, conventional machines tools represent nine out of ten machines installed in the engineering industries of industrialized countries.

---

(2) WS Atkins Management Consultants: Strategic study on EC machine tool sector, May 1990 A Report submitted to the Commission of the European Communities

Box 1: Main Machine Tools

Metal cutting	Metal forming
Lathes	Presses
Milling Machines	Shearing, nibbling,
Drilling Machines	and notching machines
Boring Machines	Bending and forming
Grinding Machines	Forging and stamping
Machining Centres	
Gear Cutting	
Broaching	
Honning And Lapping	
Physico-chemical Cutting	

Table 2, presents the results of inventories carried out in the United States of America (1988), Japan (1987). The largest population of machine tools can be found in the United States of America with the mechanical engineering industries (which includes the machine-tool industry sub-sector) claiming 50 per cent of total installed capacity. In Japan 34.6 per cent of machine-tools are used by the transport equipment industries while the share of this sector is 16 per cent in the United Kingdom and the United States of America and 24 per cent in France.

Table 2 Stocks of machine-tools in Japan and United States of America

	United States 1988		Japan 1987	
	number	per cent	number	per cent
metal manufactures	320699	13.8	61207	7.7
mechanical engineering	1157009	49.7	247231	31.2
electrical,electronics	425208	18.3	133175	16.8
transport equipment	378993	16.3	274060	34.6
precision equipment	28682	1.2	42994	5.4
others	16190	.7	34308	4.3
total	2326781	100.0	792975	100.0

Automatic machine tools were developed after the introduction of new material for the tools in the early 20th century. Such machines tend to be built to carry out a specific sequence of operations making the maximum use of fixtures and tooling. However, mass production accounts for less than 20% of the total amount of production within the engineering industries and most of the products are manufactured in small batches(3). The challenge of automating machine tools was to render them self-acting while retaining their versatility.

Whereas in a conventional machine the information is transferred directly to the machine by the operator and then from the machine to the piece in an NC machine such information is translated into a written symbolic language of the microprocessor which will develop the detailed working programmes so that the piece is produced according to design specifications. By simply changing the instructions, the machine can be switched from the production of one part to another. The NC machine allows for automatic component-positioning (selection of speed, control of the movement of the tool). The choice of the level of automation is a function of the size of the average job and the degree of flexibility required, as can be seen in Figure 2. While mass production industries, which are characterized by large annual production per workpiece and low number of different work pieces, will choose special purpose machines (eg the transfer line), industries where many workpiece variants are produced in very small amounts, will find it more economical to choose stand alone NCMT.

3 MACHINE TOOL INDUSTRY CHARACTERISTICS

3.1 A mature industry

The machine tool industry's share of GDP is less than 1 per cent in most industrialized countries, while its share of manufacturing value added hovers in the 1-3 per cent range.

The machine tool industry shares some of the characteristics

---

(3) In the United States a survey showed that approximately 75 per cent of all machined parts were produced in batches of fewer than 50 units for which capacity utilization was very low.

Figure 1 : World demand by machine type in value term

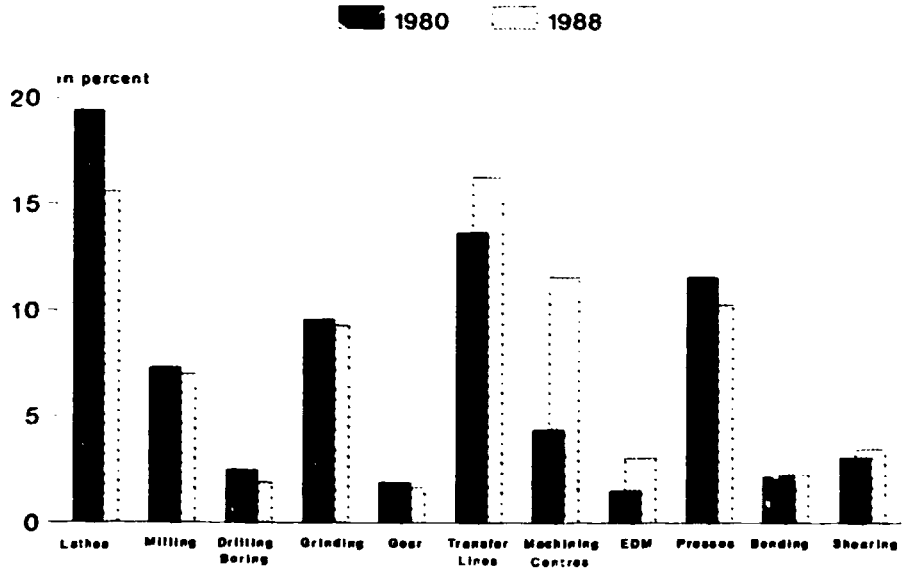
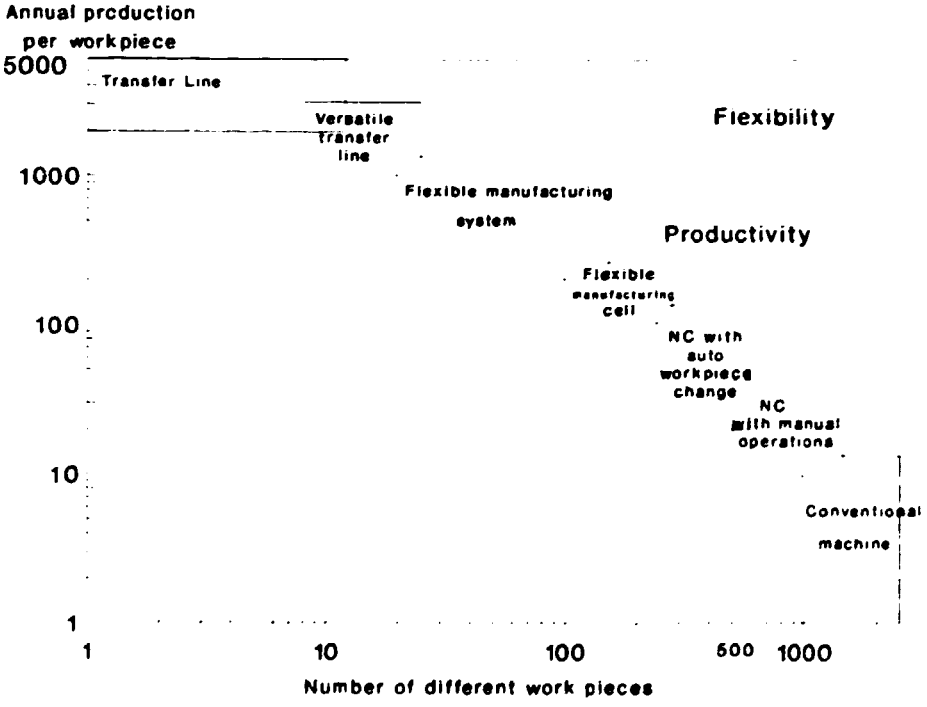


Figure 2 From conventional to automatic



of a mature industry: a slow growing output, a relatively low rate of product innovation and a growing international competition from developing countries. The industry is based on mature mechanical engineering technologies with a few exception (e.g. laser cutting) and technological advancement tends to be evolutionary rather than revolutionary. The level of investment in R&D represents on average 4 to 5 per cent of annual turnover .However, and in contrast to other mature industries the qualification of manpower is significantly higher .

The industry is known for its cycle which result from the multiplier effects of customers orders and cancellations in response to the cycles of their own markets. This characteristic deters many capable persons to join the industry because of the high probability of periodic layoffs.

Machine tool industry is also characterized by its high degree of openness. Trade ratio(4) can be as high as 300 per cent in countries such as Canada or Sweden, while in most industrialized countries this ratio is in the range of 75 to 100 per cent, Japan being an exception (50 per cent) because of its low level of imports

3.2 Market structure

The market for machine tools is highly segmented and different strategies may coexist within the industry. The mechanical technologies and design requirements differ for each type of products and this led to specialization in narrow product lines for particular markets.(Box 2)

3.3 Firms size

By industry standards, large machine tool producers are not large firms. Table 3 lists top companies by world-wide sales of machine tools and closely related equipment such as numerical controls.

Machine tool industry has been an ideal industry for entrepreneurial engineers who have typically founded small companies based on skill rather than financial strength. The presence of many small firms was made possible by production economies which were obtained from cumulative output of a single model:reputations were built around particular types of tools and the switching costs between different manufacturers products was

---

(4) The trade ratio is measured as : import+export/Production

Box 2: Market differentiation

There does not exist one machine tool market but several markets which can be categorized according to three specificities :

- degree of specialization of the machine: a conventional lathe has universal application, while some machines are tailored made for one application only
- its production volume : a machining center is well adapted for the production of small series of differentiated products; transfer machines are used in large volume productic
- its market potential : producers able to invest heavily will gain some hedge in large markets

The following table shows the main competitive factor for the three main segments, as well as the main suppliers and the forecast for the evolution of world demand for these markets.

	CONVENTIONAL MACHINES	NC MACHINES UNIVERSAL MACHINING CENTER	CONVENTIONAL NC SPECIALIZED
MAIN COMPETITIVE FACTOR	PRICE	PRICE/TECHNOLOGY	TECHNOLOGY
MAIN SUPPLIERS	- EAST ASIAN COUNTRIES - EASTERN EUROPE	JAPAN	F.R.G
SHARE OF WORLD MARKET	16%	36%	48%
MEDIUM TERM growth	slackening	growing	growing

Adapted from P.Fremeaux, R.Touboul: Machine outil 90, les enjeux BIPE Paris 1990

very high[5]. The dispersion of the industry structure is particularly pronounced in Italy

Due to diffusion of NC machine tools and FMS in the machine tool industry, the scale of production is increasing: Japanese firms have reached significant higher production volumes than most European and US firms.

3.4 Subcontracting

In industrialized countries machine-tool enterprises buy in some components and rely quite heavily on sub-contractors: the percentage for the value of bought in materials and subcontracting range from 40 per cent (Europe) to 60 per cent (Japan).The tendency is to increase subcontracting with the greater use of component specialist:items such as ball screws, tool holders and base frames are subcontracted.

The Japanese industry is inclined to subcontract and purchase component more than EC and US manufacturers. One of the consequences of this is that technical innovation initiated in the largest firms spreads quickly to the small and medium-sized firms.

In developing countries, fully integrated machine tool complexes are usual and production mix is often be quite large. When the enterprises were first established, they were confronted with a lack of reliable local sources for such inputs as forging and castings which they chose to integrate. If the capacity (as well as the capacity utilization) is sufficiently high, the cost associated with an integrated plant will not be too great; however if the capacity is low then the plant will not take advantage of the economies of scale in castings and will be unable to spread the cost of items such as testing equipment, over a sufficiently large output.

3.5 Technology intensive

Machine tool firms have design offices whose main task is to

---

(5) C.F. Pratten : "Economies of scale for machine tool production" in The journal of industrial economics Vol 19 1970-1971 pp 148-165

TABLE 3 Top Machine Tool Companies in the world

in US$ millions		Machine tool sales		Total Sales	employment
		1989	1988	1988	
YAMAZAKI MAZAK CORP	Japan	1183	796	796	3000
FANUC LTD	Japan	1079	928	1055	1770
LITTON IND INC	USA	730	600	4863	55000
AMADA CO	Japan	1153	891	1019	1509
CROSS AND TRECKER	USA	456	428		4100 *
COMAU SPA	Italie		380		3500
OKUMA MACHINERY WORKS	Japan	665	551	592	1753
CINCINATI MILACRON	USA	424	361	860	8400 *
MORI SEIKO CP	Japan	635	488		1570
TOYODA MACHINE WORK	Japan	466	418	1045	4367
DECKEL GROUP	FRG		350		
INGERSOLL MINING	USA	366	345	400	4500
GILDMEISTER	FRG		313		
KOMATSU MTD	Japan	474	398	5580	15801
MAKINO MILLING MACHINERY	Japan	318	270		951
AIDA ENGINEERING	Japan		247		684
AMADA SONOIKE MFG	Japan	390	307		537
TRUMPF GMBH	FRG	340	302		2122
HITACHI SEIKI	Japan	346	275		1237
FUJI MACHINE CO	Japan	392	241		717

* Including sales by foreign operations

Source: American Machinist August 1990, August 1989

solve their customer specific problems as they arise from day to day. Links with universities have been traditionally limited[6]. With the advent of CNC machine tools and computer-aid used for manufacture of the main components of machine tools, many of the traditional skill-dependent operations have been eliminated even to inspection and test. The machine tool operator, for example, tends to be someone with mathematical, and programming skills, while changing tools, material loading and unloading are tasks undertaken by semi-skilled operators.

---

[6]With the exception of the Federal Republic of Germany where about 20 of the university institutes and many of the Fraunhaufer Institutes conduct work pertaining to machine tools. The institute at Aachen is widely considered to be the best machine tool laboratory in the world while others in Berlin, Stuggart and Hannover are highly regarded.

II: WORLD MACHINE TOOL PRODUCTION AND TRADE

1 PRODUCTION

During the last two decades, world machine tool production[7] measured in current United States dollars has increased from US$8 billions in 1968 to US$19 billions in 1978 and US$42 billions in 1989 (Figure 3).

1.1 Leading producer countries

Table 4 presents machine tool production in the 35 main producing countries from 1977 to 1989. Machine tool production is heavily concentrated in a few industrialized countries. Japan has become the largest producer country, replacing the Federal Republic of Germany in 1982 while the Union of Soviet Socialist Republics remained the third producer; it is followed by the United States of America and Italy.

The shift (Figure 4)among leading countries is by and large explained by their attitude regarding NC technology. This innovation born in the United States in the 1950's was not widely adopted by the American engineering industries while Japan has been a forerunner in its application. The MIT Commission set up to identify the main causes of weaknesses in the US industrial performances, found[8] a pattern of interrelated factors, among which, two are specific to the machine tool industry: (i)Lack of export orientation: the small firms which had a regional view of the business, were reluctant to export and were not alert to developments in other countries (ii) Failure to capitalize on NC innovation. During the 1960's the diffusion of NC machine tools was slow and the United States of America lost progressively its leading position.

---

[7]World machine tool production is traditionally measured as the aggregated production of the thirty five-countries reported by the American Machinist review. This total is claimed to represent 95 per cent of world production. Production and exchange data refer to complete machine tools and exclude parts and attachments for most countries.

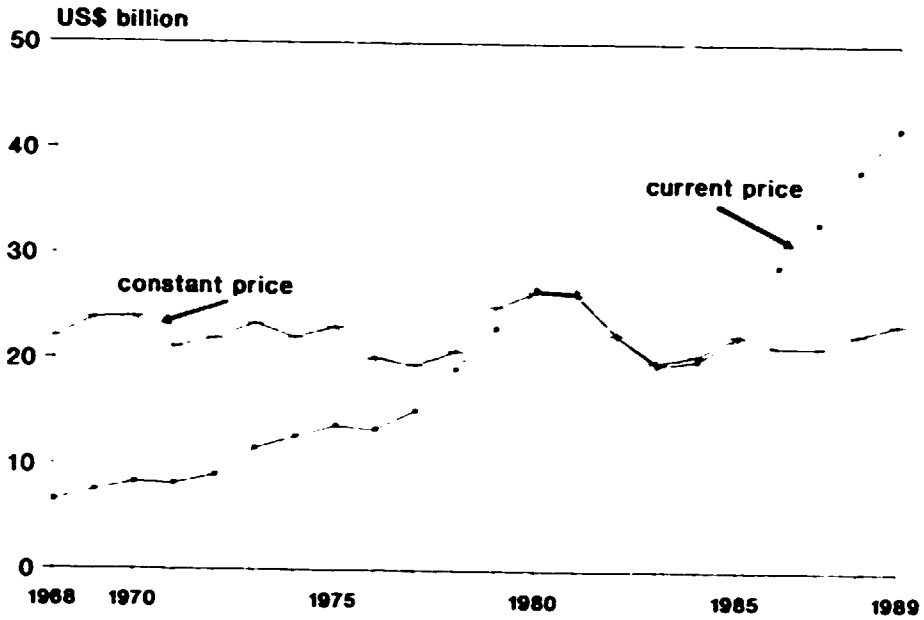
[8]M. Dertouzos, R.K. Lester, R.M. Solow and the MIT Commission on Industrial Productivity: Made in America. Regaining the productive edge, 1989 The MIT Press Cambridge, Massachusetts

Tab 4 Machine tool production (1977-1989) US$ millions

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	in percent 1989
Japan	1602	2350	2982	3826	4798	3796	3541	4473	5316	6872	6419	8722	9817	23.3%
FRG	2635	3396	4007	4707	3953	3505	3193	2803	3168	5185	6403	6572	6859	16.3%
Soviet Union	2202	2652	2902	3065	2932	2952	3077	2776	3035	3672	3976	4263	5000	11.9%
United States	2441	3004	4059	4812	5111	3748	2106	2423	2717	2748	2235	2519	3270	7.8%
Italy	878	1060	1354	1728	1513	1138	1037	996	1115	1623	2585	2639	3067	7.3%
Switzerland	580	768	930	994	846	816	766	759	955	1424	1652	1865	1797	4.3%
United Kingdom	588	821	1001	1395	933	781	573	675	783	916	1058	1501	1597	3.8%
GDR	641	699	806	891	828	821	829	789	730	1001	1512	1457	1445	3.4%
France	591	723	877	954	809	621	561	465	499	657	766	876	1081	2.6%
China (Taiwan)	58	126	198	245	294	186	205	244	278	367	578	782	1016	2.4%
PRC	355	405	420	420	440	470	475	482	341	364	632	750	832	2.0%
Spain	191	232	316	353	319	259	193	211	253	396	575	702	795	1.9%
Republic of Korea	57	95	163	130	178	158	119	143	175	333	531	632	760	1.8%
Rumania	120	294	459	590	625	615	439	353	324	306	618	663	708	1.7%
Yugoslavia	141	173	189	232	277	284	231	226	239	390	515	550	602	1.4%
Brazil	283	255	387	315	305	172	98	105	265	370	575	536	458	1.1%
Czechoslovakia	309	363	358	331	358	308	375	325	338	382	405	450	450	1.1%
Sweden	146	166	221	232	205	180	157	158	215	214	258	359	403	1.0%
Canada	71	85	159	194	269	264	290	199	199	209	244	344	383	.9%
Poland	583	679	420	405	310	151	105	121	148	154	323	320	320	.8%
Austria	96	112	101	166	108	160	128	121	120	156	155	247	302	.7%
India	89	112	127	165	209	187	217	264	245	270	278	290	262	.6%
Belgium	106	114	129	137	103	101	85	77	89	150	179	207	194	.5%
Bulgaria	30	30	41	43	201	221	182	192	132	143	140	195	175	.4%
Hungary	105	109	112	121	128	128	135	148	175	180	210	134	124	.3%
Denmark	43	45	50	52	42	50	46	48	58	72	77	78	73	.2%
Netherlands	69	66	83	65	60	48	120	120	43	65	47	78	72	.2%
Singapore	6	12	26	37	43	40	15	21	34	34	35	42	48	.1%
Finland							15	24	20	51	35	42	41	.1%
Argentina	60	60	62	50	35	35	28	23	0		35	48	38	.1%
Mexico	6	14	15	22	24	19	13	25	18	17	21	21	21	.0%
Portugal	10	10	14	16	16	16	13	15	11	13	19	19	17	.0%
Australia	18	19	18	18	69	44	66	66	36	40	45	12	16	.0%
Hong Kong		0	0	0	12	8	5	4	1	1	1	12	12	.0%
WORLD TOTAL	15124	19063	23001	26741	26460	22367	19526	19976	22199	28917	33079	38073	42064	

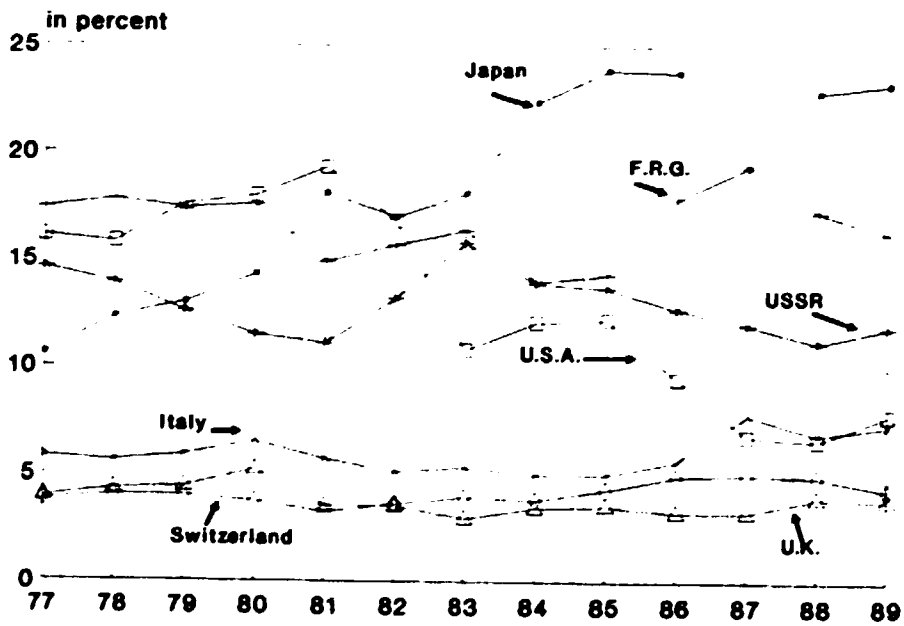
Source: compiled from American Machinist (different issues)

Figure 3: World production of machine- tools



Source: American Machinist and estimates

Figure 4: Leading producer countries Share of world production (1977-1989)



Source : American Machinist

In contrast, several institutional features have made Japan's industries especially well suited for the kind of flexibility required to use the new production technologies to full advantage.

(i) Work organization. Since the late fifties, in order to cope with the small and fragmented nature of their automotive market Japanese producers have made efforts to adopt a more flexible attitude towards production. Shop-floor re-organization created a most favorable environment for the conception and diffusion of numerically controlled machine tools.

ii) industrial policy. The first law for the promotion of Specified machinery industries was written by MITI in 1956 and since then the industry adopted the objectives of reducing costs, improving quality and raising productivity through centralization of manufacturing. The machine tool builders were encouraged to develop modular standard products suitable for a wide range of users and to concentrate on the needs of small users and to tap high volume markets. These plans were supported by a panoply of market protection measures coupled with various financial incentives. (9).

Europe remains the leading source of technology in machine tool and even with respect to control and robotic technology the number of European patents have been slighter higher than Japan (Table 5).

Within Europe, West Germany has taken the lead. The market niches dominated by German builders tend to be in high end equipment and each firm produces a limited range of sophisticated machine tools. The growth of Italian machine tools industry has been also dynamic. As in the case of Japan, the growing demand for flexible equipment from small and medium-sized firms led to a boom in production of NC equipment and Italy is the second largest producer of such equipment in Europe.

---

(9) As for examples lucrative sugar import licenses and latter hidden subsidies derived from State revenues coming from gambling on bicycles and motorbike races. See Clide V. Prestowitz, jr: Trading places, how we allowed Japan to take the lead Basic Books Inc, 1988 page 222-223

Table 5: Number of patents applications
1982-1988

	EEC	EFTA	Japan	USA
technology				
Mechanical	9253	2169	4371	5082
Controls	3852	552	3093	2746
Robotics	656	152	582	393
Laser Manufacturing	339	57	193	241
Laser sources	672	28	844	684
EDMs	112	92	241	50
Ceramics	1511	159	1631	1237
coatings	1453	179	1504	1537
Powder metallurgy	443	106	459	495

Source: Strategic study on EC machine industry Brussels 1990

1.2 Developing countries

The share of developing countries in world production of machine tools is 9 per cent in 1988, it is significantly less than the their share of world electronics output (14 per cent). Around twenty developing countries have entered into the industry[10] and developing countries' production is heavily concentrated in ten countries[11].

1.2.1. Engineering industries and machine tool demand

The existence of an engineering base is the first prerequisite to enter the machine tool industry for two reasons. On the demand side, engineering industries are by and large the main market of the machine tool sector while on the supply side the existence of supporting industries (i.e. castings, forging, high grade steels, electric motors, high tensile nuts and bolts, tools, jigs and fixtures, electronic control) are needed for the

(10) In several developing countries machine tool producers are seldom not recorded by industrial statistics, being either too small units or integrated within diversified metal working firms.

(11) That is: Brazil, China (PRC), China (Taiwan), Yugoslavia, Republic of Korea, Argentina, India, Mexico, Singapore and Hong Kong

Figure 6: ARGENTINA
Production,consumption and trade

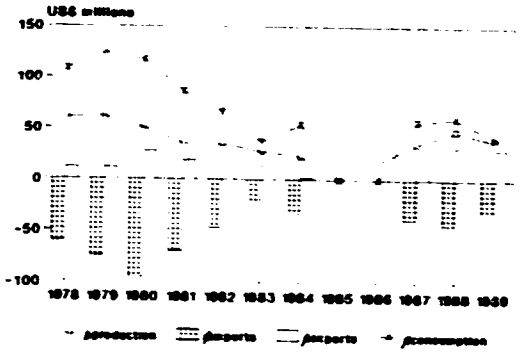


Figure 7: BRAZIL
Production,consumption and trade

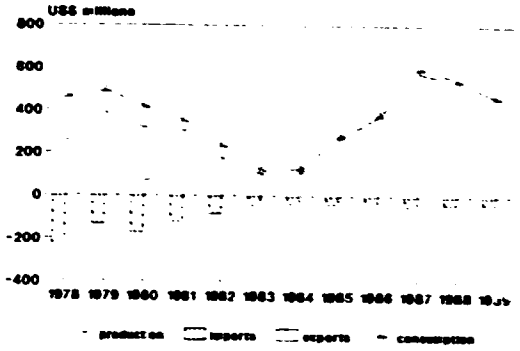
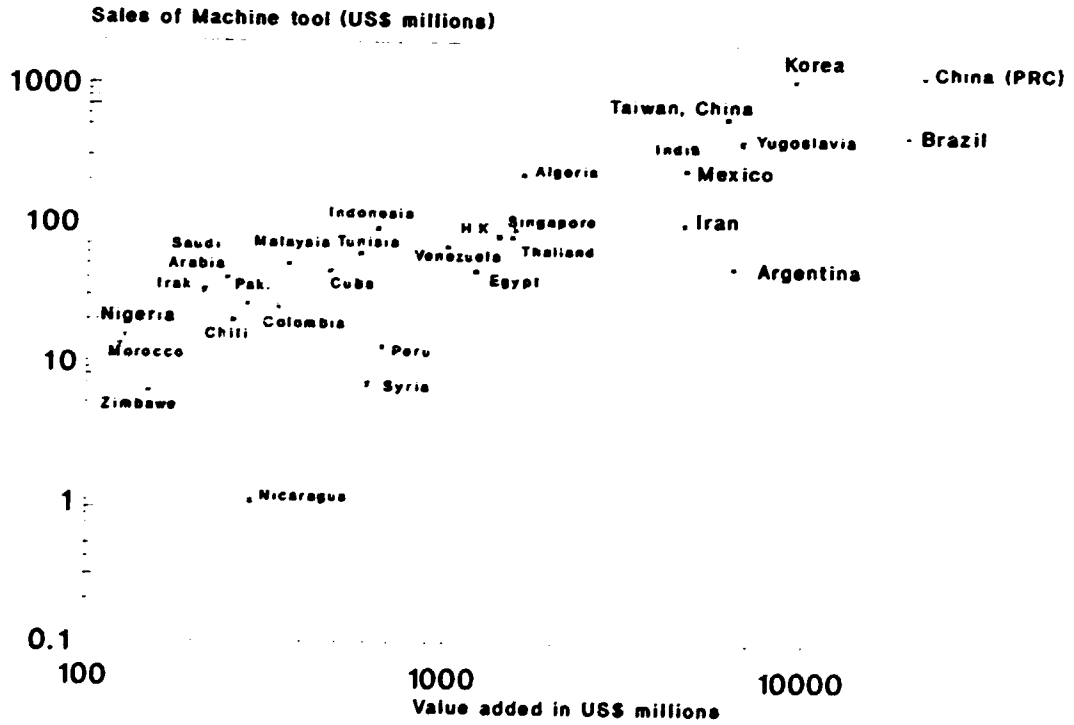


Figure 5 Machine-tools market and engineering industries development(1988)



Value added of engineering industries
(minus electrical ISIC 383)
from UNIDO data base

setting up of a machine tool industry. There appears to be a clear relationship between the machine tool apparent consumption in a given country and the level of development of its engineering industries (as measured by its value added[12]. Figure 5 illustrates this correlation in the case of twenty developing countries for which engineering value added ranged between US$200 millions to US$22 billions.

The viability of a machine tools industry in a developing country depends not only on the volume of production of the engineering industries but also on its composition:

In the low income developing countries, the engineering industries are embryonic and consist mainly of metal products manufacturers (production of metal containers, domestic appliances, furniture aggregated in ISIC division 381). The production of these items hardly requires any machining and can usually be achieved with the use of metal forming tools. Metal cutting machine tools are mainly used for maintenance and educational purposes.

In countries where the engineering industries output is more important, the share of simple metal products manufacture (ISIC 381) represents from 30 to 50 percent of the total engineering industries value-added. The firms engaged in production and maintenance of non- electrical machinery (ISIC 382) and transport equipment (ISIC 384) are the main users of machine tools. The growing needs of these two sectors offer a market for machine tools which may justify the setting up of a domestic industry.

Countries which have entered into machine tool production in a significant way are characterized by a value-added of engineering industries superior to a "benchmark" of US$ 1 billion (in 1987); some production can be recorded in countries where the value-added of engineering industries is between US$100 millions and US$1 billion.

1.2.2. Largest producer countries

---

(12) Excluding electrical machinery value added because of the bias introduced by the electronics industry which is highly developed in South East Asia and is not a large market for machine tools and as recorded by UNIDO in Industry and Development Global Report 1989/90

1.2.2.1.Argentina

Production began on a large scale in the sixties and the early 70's were considered as the "golden years" for the machine tool industry. The industry was strongly affected by the economic crisis and the sudden and drastic reduction of protection. Investment and domestic production dropped and many machine tool companies went bankrupt: by 1985 the output had fallen to represent one tenth of 1973 volume. After three years of deep crisis production rose to 10000 units and US$35 millions in 1987 and US$ 38 millions in 1988 while consumption was down to US$50 millions. (Figure 6)

1.2.2.2. Brazil

The Brazilian (Figure 7) machine tool industry is the largest in Latin America. In 1970 Brazil produced half its requirements and exported within the Latin American Free Trade Arrangement.

The economic crisis which led to a sharp reduction of the domestic market and, subsequently of the main export market (Mexico) led to a drastic reduction of output, and the industry underwent five years of deep recession (1981-1986). Due to the severe shortage in foreign currencies and the centralization of imports payments, machine tool builders were sometimes unable to purchase parts and materials from foreign suppliers.

1.2.2.3. China

In the People's Republic of China (Figure 8) machine tool production used to cover almost all its current needs; however parallel with the modernization programme launched in 1978, imports have dramatically increased to account for about fifty per cent of apparent consumption in 1988, as opposed to 14 per cent in 1978. The share of exports in production also rose from 5 per cent in 1978 to 15 per cent in 1988.

1.2.2.4. India

Indian machine tool production (Figure 9) was able to manufacture most of the general purpose machines required by the users in the late seventies. It was however slow in introducing CNC machine tools. When the government introduced liberalized measures in the early 1980's, large scale imports of special purpose machines and of CNC machine tools took place which explained the increasing share of imports into domestic consumption (40 percent of domestic consumption in 1988).

Figure 8: CHINA
Production,consumption and trade

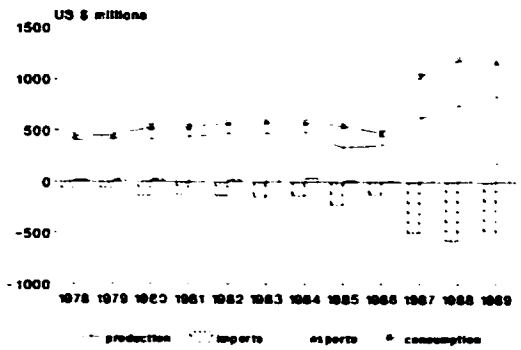


Figure 9: INDIA
Production,consumption and trade

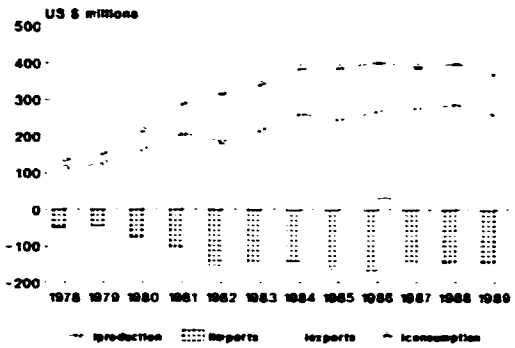


Figure 10: TAIWAN, CHINA
Production, import and export

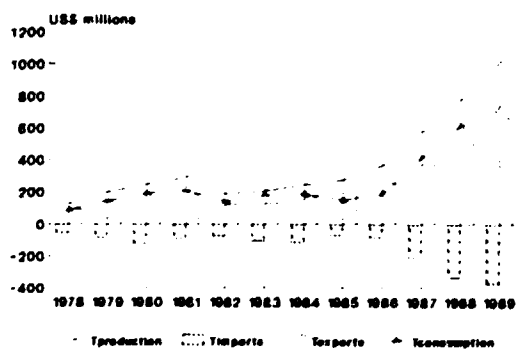
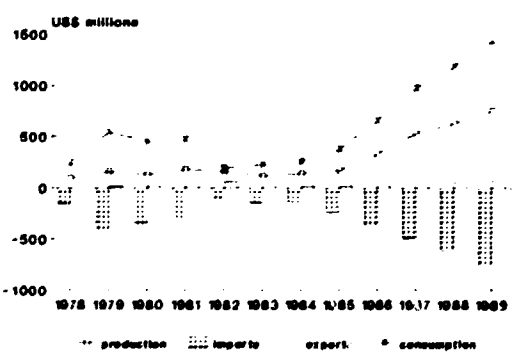


Figure 11: REPUBLIC OF KOREA
Production, import and export



1.2.2.5. Republic of Korea (Figure 10)

After the mid-1970's, the machine tool industry expanded rapidly aided by a Government long-term development plan. From 1986 to 1989, the Korean industry expanded dramatically and the increase of investment by engineering industries provoked a surge of machine tool consumption while the increase in wages led to an increased demand for factory automation. The domestic production was insufficient to keep up with the surge of demand and imports have represented 50 per cent of apparent consumption in 1988 (30 per cent in the late seventies).

1.2.2.6 Taiwan Province of China

Taiwan Province of China (Figure 11) is the world's eighth largest exporter. After five years of stagnation the appreciation of the Yen gave another impulse to Taiwanese exports which doubled between 1986 and 1988, while the increase in domestic investment led to a surge in the domestic consumption of machine tools. Taiwan Province of China is the only developing country running a trade surplus in machine tools.

1.2.3 **Developing countries' comparative advantage**(13)

The comparative advantage of developing countries machine tool industries can be assessed by using three criteria:

(i) the trade balance of the national industry: net exporter countries and net importer countries;

(ii) the percentage of production exported (X/P) which demonstrates international competitiveness even though the industry may be a net importer

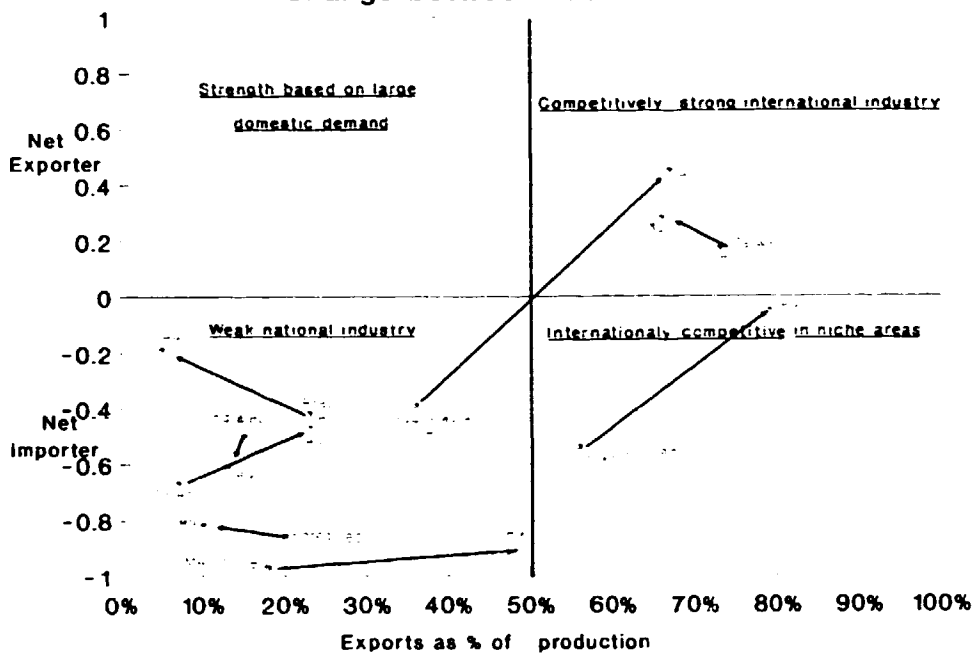
(iii) the domestic industry share of the domestic market (P/P+M-X) which shows the degree of self sufficiency when coupled with the first measure demonstrates whether this self sufficiency translates into international competitiveness.

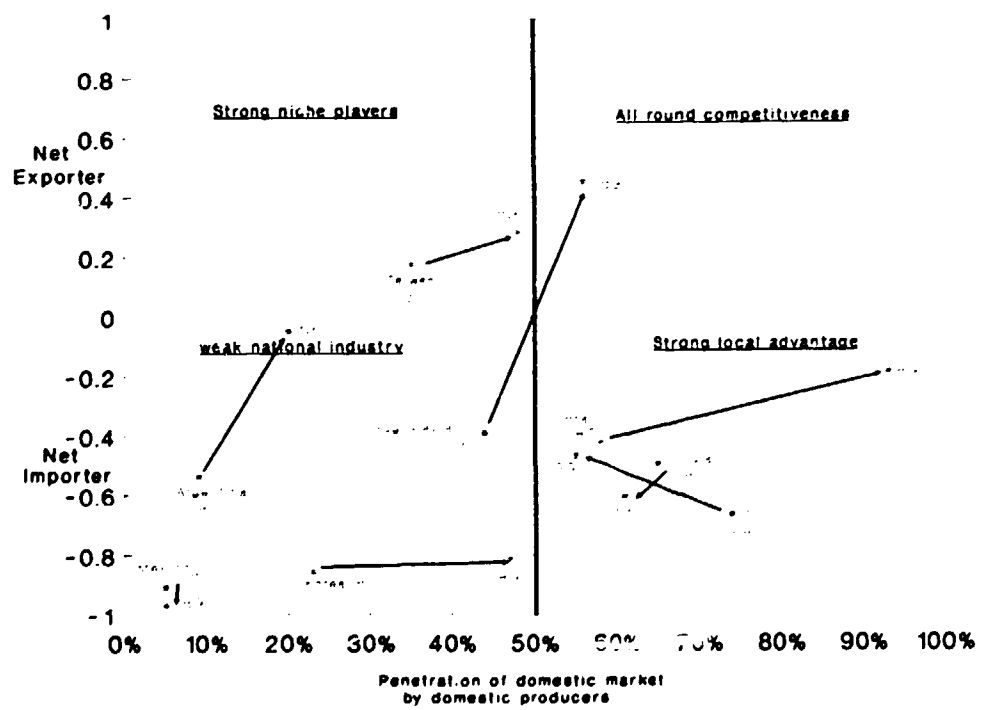
Figure 12 positions the main developing countries according to these three measures in 1980 and 1989. They can be classified in five categories of countries

---

(13) The methodology is adapted to the one elaborated by WS Atkins in Strategic study of the EC machine tool industry

Figure 12 Developing countries comparative advantage positions Change between 1980 and 1989





(1) Yugoslavia is a net exporter and its production has achieved a high penetration of the domestic market, is in 1989 the only country with all round competitiveness.
(2) Taiwan, China province is also a net exporter, however it is characterized by a lower (but growing from 1980 to 1989) domestic penetration: the growing domestic demand has encouraged imports but the local industry has focused on exports of volume and stalemate products and is a strong niche player (small and medium conventional grinding, machining centres, lathes and drilling machines).
(3)Brazil, India and the People's Republic of China are net importer and have a high domestic penetration: they appear to have strong local advantages which may be sometimes explained by high tariffs or artificial barriers.

Argentina, Korea and Mexico are net importer and have a low domestic penetration. They can further classified according to their export ratio:

(4) The export ratio of Argentina has grown significantly and this could suggest that this industry with a small market is competitive internationally in a few specialized products

(5) Mexico and the Republic of Korea are characterized by their low export ratio (and diminishing in Korea) and can be thus identified as weak national industries. However in Korea, the industry has been able to meet half of the local demand which has grown very rapidly and it appears to move into the category of countries with strong local advantages.

2 INTERNATIONAL TRADE IN MACHINE TOOLS

In 1968, one third of world machine tool production was traded, and in 1988 this ration rose to 48 per cent. Exporting has made the machine tool industry a global one, and success in this global business now requires effective exporting.

2.1 Largest importing and exporting countries

The ten largest importing and exporting countries (Table 6) have been ranked according to their average exports and imports performances over the last three years (1987-1988-1989):

- The Federal Republic of Germany is the leading exporter and Japan ranked second since in 1978. While the share of the United States in total exports declined, it was more severe in the case of European producers.
-The largest import market is the USA followed by the USSR and the Federal Republic of Germany. In contrast to other producer countries, Japanese imports remained low. The

FIGURE 13: Direction of Trade 1987

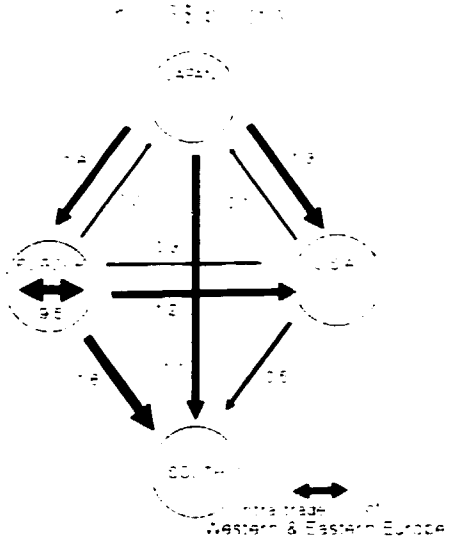
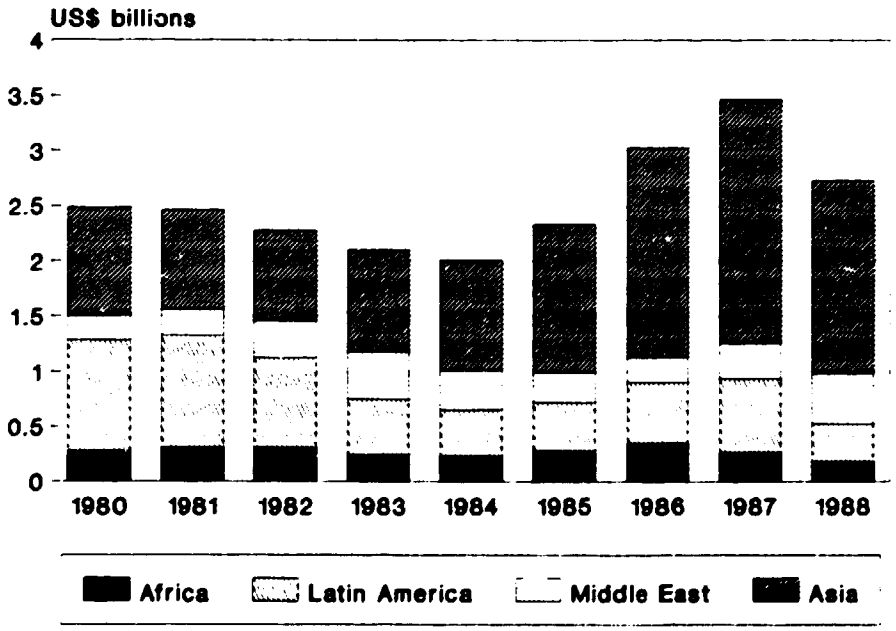


Figure 14: Imports of machine-tools (and parts) by developing countries



Source: compiled from E.C.E. statistics

Republic of Korea and the People Republic of China rank eighth and ninth among main importer countries.

Tab 6 The ten largest

Exporting countries		Importing countries	
US$ milllions, average (1987-1989)			
FRG	4019	United States	2157
Japan	3359	Soviet Union	1924
Switzerland	1553	FRG	1306
Italy	1298	France	935
GDR	1256	Italy	706
United States	766	United Kingdom	700
United Kingdom	605	Canada	646
Taiwan (China)	517	Republic of Korea	618
France	383	People Republic of China	531
Yugoslavia	370	Belgium	395

2.2 Developing countries imports

Industrialized countries represent by and large the largest import market for machine tools:in 1980 and in 1987 , 80 per cent of their exports were directed towards other industrialized countries (including Eastern countries) while 20 per cent were directed to developing countries[14].(Figure 13)

Exports to developing countries play a very significant role in the case of North America (34 per cent in 1980, 39 per cent in 1987) and increasingly in the case of Japan (from 29 per cent to 34.5 per cent). The proportion of Western Europe machine tool exports to developing countries has decreased from 18 per cent to 16 per cent, the same evolution has happened in the case of Eastern Europe (from 7.4 per cent to 7.0 per cent).

Machine-tools imports statistics of 73 developing countries

(14) Export data are compiled from the Economic Commission for Europe and, unlike American Machines export figures, they take into account exports of parts of machine tool (ISTC 736)

between 1980 and 1987 [15] show that the average value of imports of machine tools over the 1980-87 period has been

- less than US$ 1 million for 11 developing countries
- between US$1 million and US$ 10 millions for 32 developing countries
- between US$ 10 millions and US$ 100 millions for 24 developing countries
- Only seven developing countries[16] have imports (and consumption) superior to US$ 100 millions

For most of developing countries machine-tools imports represent less than 1 per cent of their total engineering products imports, and can hardly be considered as a constraint.

While the global share of developing countries in industrialized countries exports has remained constant in 1980 and 1987, there has been a significant change between regions(Figure 14).The share of Africa has declined from 2.4 per cent to 1.5 per cent and the imports of Latin American countries have been deeply affected: they represented 8 per cent of exports from industrialized countries in 1980 and 3.7 per cent in 1987. In contrast, the share of developing Asia has increased from 7.6 per cent to 12.3 per cent representing 60 per cent of developing countries imports in 1987. Western Europe remained the largest supplier of machine tool to developing countries[17], and Japan was second in 1987. While imports from developing Asian countries are relatively diversified, this is not usually the case for African and Middle Eastern countries which import mainly from Europe, or for Latin American countries which import from the United States and Europe.

---

(15) These data differ from American Machinist data: (i) UN statistics take into account import of spare parts (ii) they do not take into account developing countries imports of machine tools coming from other developing countries.

(16) including Taiwan Province of China which is not recorded in the United Nations Statistics

(17) ECE statistics do not take into account export of developing countries to other developing countries, however this South trade remains extremely limited in its amount.

3 FORECAST OF WORLD MACHINE TOOL MARKET

According to recent forecast[18], the world machine tool industry faces a continued period of expansion at an annual growth rate of 4 per cent in real term from 1988 to 1995. By the end of this period growth rates are expected to decline with no recession taking place.

The strongest growth (Table 8) in demand could occur in Japan and in the developing countries 7) while the prospects in the United States of America and in CMEA countries are poorer. High import increase will take place in Japan, EEC countries and developing countries (5.2 per cent).

The production forecast for the main world region present a bright outlook for the machine tool industry. The New Industrialized countries, Japan and EEC are leading the expansion.

---

(18) Strategic study for EC industry. Forecast were made before the Gulf crisis and did not take into consideration the likelihood of a recession in main industrialized countries

Table 7 : World machine tool forecast 1988-1995

World Domestic Demand

	Ecu billions* 1988	Annual growth rate in % 1980-88	1988-95
EEC	7.70	2.10	5.20
EFTA	1.57	5.10	4.90
CMEA	7.17	1.30	1.90
United States	2.79	-2.40	4.40
Japan	4.22	7.90	5.80
Developing countries	2.09	9.20	5.30

World Import

	Ecu billions 1988	Annual growth rate in % 1980-88	1988-95
EEC	1.82	6	6.70
EFTA	1.05	6.80	4.10
CMEA	1.39	-1.90	3.70
United States	1.46	6.80	6.10
Japan	.32	6.10	11.40
Developing countries	1.17	4.70	5.20

World Export

	Ecu billions 1988	Annual growth rate in % 1980-88	1988-95
EEC	3.51	-.60	4.30
EFTA	1.49	7.20	5.50
CMEA	.17	-3.40	6.10
United States	.63	-2.60	2.70
Japan	2.59	10.60	6.80
Newly Industrialized countries	.26	2.50	6.10
WORLD	8.65	3.50	4.90

World Production

	Ecu billions 1988	Annual growth rate in % 1980-88	1988-95
EEC	9.39	.50	4.50
EFTA	2.01	4	5.10
CMEA	5.95	1.80	1.60
United States	1.96	-6.40	2.50
Japan	6.49	9	5.30
Newly Industrialized countries	1.18	2.50	5.50
WORLD	26.98	2.50	4

* 1985 prices
Source: Strategic study on EC machine tool sector
Brussels June 1990

III: TECHNOLOGICAL CHANGES

1 FROM MASS PRODUCTION TO FLEXIBLE AUTOMATION

Among the new technologies, microelectronics is of central importance for the machine tool industry while the impact of new materials is only now beginning to be felt.

The introduction in the mid-seventies of the microprocessor, a complete programmable integrated circuit, to the factory floor has been the major technological breakthrough in the capital goods industry. It occurred after a long period of relative stability with regard to production technology[19]. The possibilities opened by electronic- based automation technologies have been considered *as a turning point in the history of mechanization*"[20] As compared to classical (electromechanical) automation, numerically controlled machine tools, flexible manufacturing systems and robots allow a much greater flexibility in terms of (i) accepted variance of throughputs (defined in number of cost effectively produced homogeneous items per unit of time (ii) acceptable variances in output varieties) and (iii) minimum scale of production[21] With the advent of flexible automation, plant size tends to become more independent of market size.

The trend towards more flexibility is also to be considered in the context of the changes which are affecting market demand in industrialized countries. The era of mass production of undifferenciated products has come to an end; the major challenge for producers will be to combine mass production and specificity. This demand pressure which was first felt in the consumer electronics market, has developed in the car industry[22]. It calls for new production technologies (such as modular manufacturing methods) borrowed from the electronics and aerospace industries[23]. Corporations which produce customized

---

[19] UNCTAD: The diffusion of electronics technology in the capital goods sector in the industrialized countries, Geneva, 1985

[20] Piore and Sabel: The second industrial divide: possibilities for prosperity, Basic Books, 1984

[21] It should be borne in minde that flexibility rests on organization: identical machines can be used in a rigid or flexible way

[22] Ted Kumpe, Piet T.Bolwijn: Manufacturing the new case for vertical integration Harvard Business Review, March-April 1988

[23] The Economist: "The arrival of haute carture", 29 July 1989

goods aimed at market niches, have to be flexible enough to increase rapidly their production in those segments in which demand proves the highest: they need equipment that can produce economically in small batches in order to reduce work in progress, minimize inventories and allow consumer demand to be met in days instead of months.

The consequences of these changes go beyond a retooling of manufacturing facilities: as can be seen from the Japanese example flexibility can be achieved through organizational innovation. In order to face up to these new challenges manufacturing companies are reorganizing their production processes under "just-in-time" (JIT) principles through such techniques as "set-up time reduction" or "Kan-Ban[24]" procedures. (Box 3) In Kan-Ban the objective is to produce goods which have been already sold:a tendency which illustrates the primacy of marketing imperatives on production. The essential elements of the Just In Time concept are that goods should be bought or produced in exactly the quantities which are needed and they should be delivered when they are needed.[25]

It is also important to stress that the diffusion of flexible automation equipment is taking place within a context of growing integration within the enterprise which is bringing together what were once discrete activities.[26]

This evolution started within each one of the "different spheres" of production through intra-activity automation in a stand-alone fashion: the diffusion of NCMT in the production sphere .A similar trend towards integration has taken place in the design sphere where the various stages of drawing preparations, converting ideas and modifications into a full set of engineering drawings are now contained within a computer-aided design system (CAD).

The second step of automation concerns the integration of

---

(24) named for the routine slip attached to each piece in transit

(25) U.Arnold, K. Bernard: Just in time: some marketing issues raised by a popular concept in production and distribution, Technovation, 9 (1989) page 401-431

(26) See Kaplinsky, Automation the technology and society, Longman, London 1984 and Bessant Integrated automation in batch manufacturing, OECD Directorate for Science, Technology and Industry, 1986, and John Bessant Integrated Manufacturing Technology trend series, number 8 Unido 1988

Box 3: Just in Time, Kan-Ban and Kan-Ban plus alpha effect

In manufacturing there is a conflict between two objectives: holding down setup time for the machines by making larger quantities and holding down carrying costs by frequent runs. The compromise quantity in known as the Economic Order Quantity. Japanese manufacturers have made efforts to reduce the set up time while in the mean time cutting the purchase order costs: and reducing the EOQ.

The basic idea of Just in Time (JIT) is simple: produce and deliver goods just in time to be sold, subassemblies just in time to be assembled into finished goods, fabricated parts just in time to go into subassemblies and purchased materials just in time to be transformed into fabricated parts. However when implemented, JIT is much more than inventory control: large lot size inventories obscure problems, when the lot size inventory is cut the causes of error are exposed.

Kanban is the name for a specific Japanese inventory replenishment system developed by Toyota. Literally translated, Kan ban means "visible record" "or visible plate" and it is taken to mean "plate". Most companies use a system employing order card which accompany work in progress;they do not constitute a kanban system because they are employed as a push system of parts ordering and parts control. The Toyota kanban system is a pull system; it provides parts when they are needed and therefore without excess inventory. Kanban will work well only in the context of a just in time system in general.

This system was designed at a time when all Toyota manufacturing system was done within a 50 kilometer radius. In the past years the company has opened plants in the United States, despite of this JIT has maintained and adapted: when ordering errors are made parts have to be flown from Japan; US suppliers make delivery to set up depots where Toyota make daily collections. This adaptation has forced the company to start Kan Ban plus alpha effect: high volume data communications links have been installed enabling the head office to monitor overall production. The objective is to turn JIT in real time: tomorrow' stocks will then be based on tomorrow's sales.

Extracted from Schonberger: Japanese manufacturing techniques, nine hidden lessons on simplicity London Free Press 1982 and "Toyota Motor:Delivering tomorrow orders made today", Financial Times September 10, 1990

individual activities in intra-sphere automation. In the production sphere, the flexible manufacturing system links several CNC tools and handling systems under direct numerical control supervised by a host computer.

Because microelectronics can be used in all information-based activities, the technology can be introduced from production management, administration, design and process specifications, and raw material processing, to packaging, testing and inspection of final products and manufacturing processes.[27] The pattern of integration within each sphere of activity, is now followed by a trend of integration between spheres, CAD/CAM systems linking design and production and FMS systems linking coordination and production.

2 AUTOMATION IN STAND-ALONE EQUIPMENT

Automation technologies have been first introduced on the basis of stand-alone equipment. Due to the retarding effect of the recession in the early eighties, the diffusion of automation has occurred more slowly and more unevenly than was expected. Since 1982, real capital spending has grown more than twice as fast as GDP in OECD countries and this increase has led to a rebound in machine tool sales which has been accompanied by a larger increase in NC machine tool sales. One of the factor contributing to the diffusion of NC has been the decline in relative price compared to conventional machine tool.

The combined production figures from the United States of America, the United Kingdom, the Federal Republic of Germany, Italy and Japan show that the share of NC machine tools in total machine tool shipments has increased from 21 per cent in 1976, to 41 per cent in 1982 and 57 per cent in 1988.

2.1 Diffusion of NCMT by type of machines

2.1.1. Lathes

Numerical Control lathes are the most widely used NC machine tools

---

(27) K. Hoffman: Technological advance and organizational innovation in the engineering industries, Industry and Energy Department working paper, Number 4, March 1989

Table 8 NC machine tool in percentage of production and consumption (measured in value) of metal cutting machine tool in selected countries in 1988

Production	France	FRG	USA	UK	Italy	Spain	Japan	Together
Drilling	.0%	32.2%	.0%	.0%	.0%	5.6%	69.0%	37.8%
Milling	89.2%	80.8%	47.2%	.0%	87.6%	60.5%	62.0%	71.4%
Shaping, slotting, sawing	.0%	57.3%	.0%	.0%	.0%	.0%	21.3%	25.3%
Lathes	91.8%	74.6%	84.0%	36.7%	70.4%	52.9%	89.5%	80.3%
Grinding and Polishing	6.7%	45.5%	.0%	.0%	.0%	29.5%	26.0%	26.0%
Boring		65.2%	.0%	89.3%	.0%	72.7%	50.0%	43.6%
EDM and ECM	33.3%	58.5%	.0%	.0%			95.3%	82.6%
Gear Cutting	.0%	63.5%	.0%	.0%	.0%	.0%	.0%	33.3%
Machining centres and transfer	92.7%	79.4%	54.9%	74.3%	49.8%	59.8%	100.0%	79.5%
Total Metal cutting	77.8%	63.0%	35.5%	62.6%	38.0%	48.6%	70.7%	60.5%
Total NC US$ millions	470	2972	584	478	757	253	4752	10266
Consumption								
Drilling	42.0%	27.0%	17.0%	100.0%	.0%	25.0%	67.0%	39.0%
Milling	80.0%	78.0%	43.0%	26.0%	97.0%	61.0%	61.0%	68.0%
Shaping, slotting, sawing	.0%		.0%	.0%	.0%	.0%		40.0%
Lathes	84.0%	68.0%	91.0%	57.0%	77.0%	62.0%	85.0%	80.0%
Grinding and Polishing	52.0%	53.0%	1.0%	.0%	7.0%	15.0%	21.0%	24.0%
Boring	94.0%	54.0%		100.0%	.0%	100.0%	40.0%	
EDM and ECM	88.0%	57.0%	46.0%	.0%	.0%	.0%	87.0%	72.0%
Gear Cutting	7.0%	73.0%	.0%	69.0%	9.0%	50.0%	.0%	21.0%
Machining centres and transfer	92.0%	92.0%	67.0%	76.0%	59.0%	65.0%	100.0%	81.0%
Total Metal cutting	74.0%	64.0%	47.0%	68.0%	46.0%	49.0%	64.0%	59.0%
NC metal cutting	825	1950	1284	503	790	248	2918	8518

shipment According to Table 8 89.5 per cent of lathes produced in Japan were NC (74 per cent in units). In the Federal Republic of Germany NC lathes represented 74.6 per cent of lathe production. The production of NC lathes is highly concentrated in Japan (around half of world production); other main producers are the Federal Republic of Germany and Italy

inventory: In the United Kingdom, while the number of non-NC turning machines declined by 25% to 147,329 between 1982 and 1987, the number of NC machines rose by 99% to 15273; NC machines represented 10% of non NC machines against 4% in 1982. In the United States a similar evolution has occurred.

The present technological trend is to have a single combination turret which can hold tools for both internal and external diameter turning. More sophistication is now built in order to machine a part in a single set-up;simple two axis lathes have given way to four-axis lathes. This ability to produce finished parts depends on being able to bring a variety of tools to machine the workpiece in one set up; turning centres are able to mill, drill, tap and bore as well as turn; they can also perform several similar operations simultaneously.

2.1.2. Boring, drilling and milling

Boring and drilling can be performed either by the use of lathes or by drilling, boring and occasionally milling machines.

Shipments: As can be seen from Table 8 NC drilling machines represented on average 37.8 per cent of total drilling machine tools in 1988 (69 per cent in Japan); in the case of milling machines the average ratio was 71.4 per cent and for boring machines it is 43.6 per cen Largest producers are the Federal Republic of Germany followed by Japan

Inventories In the United Kingdom, NC milling machines represented 21% of acquisition in new milling machines between 1981 and 1986, against 8 per cent between 1977 and 1981 while for NC boring machines the progression was from 15 to 21 per cent and for NC drilling machines from 2 to 6%.

NC milling, drilling and boring machines are themselves substituted by the machining centres which perform a combination of operations. While in 1976 machining centres accounted for only 38 per cent of the production of machines performing the milling function, the share rose to 65 per cent in 1986 in the major OECD machine tool producing countries. In the United

Kingdom, acquisition of machining centres increased very rapidly with three quarters of machining centres being acquired during 1982-86. Machining centres are second to turning machines in terms of stocks of NC machines.

Among other metal cutting machine tools, NC diffusion is rapidly increasing in the case of Electro Physical Machines and Electro-discharge machines (EDM). This equipment lends itself to automation because all parameters can be monitored continuously.

2.1.3. Metal forming machines

Metal forming machine tools, mechanical and hydraulic presses, punching and forming machines, and bending and forming machines traditionally represent 25 per cent of world production. Several indications suggest that these machines will represent a growing share of world demand, and will compete in some segment of activities with metal cutting machine tools. Their use allows reduction in machining sequences which are otherwise inevitable in metal cutting. Their success in this competition rests on three factors: the ease with which the manual content can be minimized, the degree to which they lend themselves to small batch production; and the reduction in tooling (dies and formers) costs which occurs with the increasing use of CAD/CAM and CNC

The progression of NC in metal forming machines has been somewhat slower than for metal cutting.

Shipments In the Federal Republic of Germany, NC machines represented 19 per cent of machine forming tools in 1988, 70 per cent in the case of shearing and punching machines, and 30 per cent in the case of press machines.

Inventories In the United Kingdom the proportion of NC to total machine forming grew from 1.2 per cent of installed capacity (in units) in 1981 to 2.4 per cent in 1986.

2.2 Diffusion of NCMT in industrialized countries

Inventory statistics measure the actual number of machines existing in manufacturing plants and they give an indication of the useful life of productive assets as well as the relative modernity of the engineering industries. Due to the longevity of machine tools, conventional machine tools represent the largest number of machine tools installed in the industrialized countries.

2.2.1. Inventories

In Japan, the number of NC machines rose very significantly from 1975 and their share in the total stock of machine tools increased from 3.6 per cent in 1981 to 10.7 per cent in 1987. In the last survey, figures for NC metal cutting tools limited to those less than three years rose to 33 per cent (compared to 12 per cent in the previous survey). In the United Kingdom the number of NC machine tools in use was 25800 in 1982 and 52400 (excluding robots) in 1987 out of a total of 768C00 installed machine; the ratio of NC in the total stock of machine tool increased from 0.2 per cent in 1970 to 7 per cent in 1986; the NC acquisition made during the past decade now accounts for half the NC inventory. In the United States of America, in 1988 the total number of NC machine tools had more than doubled since the inventory carried out in 1983.

The analysis of the diffusion of NC machine among industrial sectors in Japan, United Kingdom and France lead to similar findings. It appears that the engineering industries which are the less affected by automation are handtools, electrical apparatus, structural metal products which are among the most common engineering sectors in developing countries.

2.2.2 diffusion among small scale industries and subcontractors

One of the findings of the latest inventories has been the accelerated pace of acquisition of NC machines by small- and medium-scale enterprises. While large establishments were the first to experiment with NC machines, the advent of highly "user-friendly" manual data input NC and off-line programming systems have made NC a much more attractive prospect for smaller companies. This trend is clear in the case of subcontractors."*subcontractors have quickly realized that the machining centre is a highly flexible tool. In addition to jobbing work the subcontractor can tender for continuous batch work involving additional investment only in fixtures and programming*".(28)

This has not been so far the case in Italy(29) a survey was undertaken among 4000 firms which has shown that successful adoption of flexible automation involves a long learning

---

(28) Metalworking production, The sixth survey of Machine tool and production equipment in Britain.

(29) Presentation of Pr Camagni, Meeting of International Experts for a Programme of Industrial Automation of the Capital Goods Industry of Latin America, UNIDO, Vienna, December 1989

process, tiring reorganization procedures and strategy reallocation processes which are more easily possible for large firms or smaller enterprises operating in high technology sectors and accustomed to advanced electronics technology. The greatest difficulties seem to be of an organizational type, linked to the integrated and integrating nature of the new technologies; they require integrated production planning and design system, new professional figures.

2.2.3 forecast for the 1990's.

Table 9 provides an estimate of the population of NCMT in 1990: growth rates for NC machines in Europe has varied between 10 and 20 per cent per year.

The diffusion of NC as of any other technological innovation can be described by an S-shaped curve where the three distinctive parts are: initial expansion (rising curve), transition zone (inflection point) and saturation (falling curve). This pattern can be used in order to forecast the maximum performance of the technology and its saturation point measured as the percentage of total number of machine tools installed.

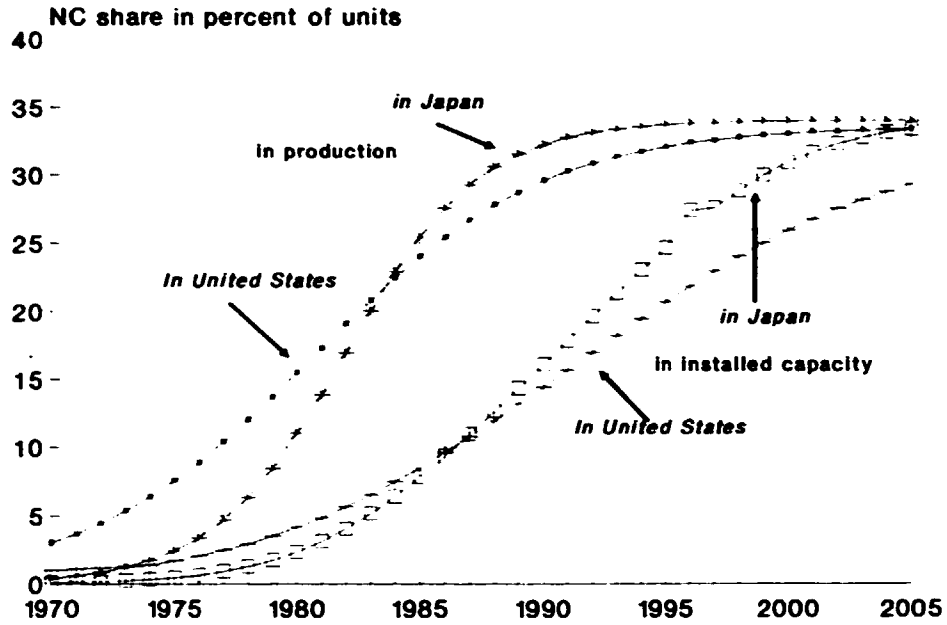
Table 9 Evolution of the stock of NC/CNC machine tools (000s)

	USA	USSR	JAPAN	ITALY	FRG	UK	FRANCE
around 1970	20	11	5	1	2	3	
around 1975	40		14	3			4
1980		21		11	25		10
1981			23				
1982						26	20
1983	103						
1985		65		55	65	45	35
1986							
1987			85			69	
1988	222						
estimate 1990	240	110	100	100	100	80	60

Forecasts based on consumption data in Japan from 1970 to 1988 have been utilized and it has been forecasted that the saturation level will be 34 per cent for metal cutting and NC

Figure 15 Forecast for NC share in production and installation

for metal cutting machine-tools



For Japan: IIASA; for USA computed

share in installation will approach saturation level after 2000 (Figure 15) with 34 per cent of machine tools installed being NC. In the case of the United States of America NC in installed capacity could reach 30 per cent in 2005

These forecast mean that the strongest diffusion of NC machine tool will happen during the next decade and it should have a significant impact in the coming years on the competitiveness in the engineering industrie

2.3 NCMT in developing countries

The diffusion of NCMT in developing countries has taken place in a significant way in those New Industrialized Countries of Asia and Latin America where production has begun , however some diffusion has begun in other developing countries.

2.3.1. Production :Evidence from the New Industrialized Countries

As documented in Table 10 the transition to NC machine tool manufacturing is underway in the New Industrialized countries. NCMT account for 25 per cent of production in value (30 per cent for metal cutting machine tools).Such ratios are sometimes strongly influenced by the high price of NCMT, this is specially the case in Brazil where NCMTs accounted for 3 per cent of production in volume (as compared to 30 per cent in industrialized countries).

Production of NCMT has concentrated on lathes and machining centres which represent 74 and 78 per cent of the total number of NC machine tools produced in Brazil and Argentina. In Taiwan Province of China there is a trend towards diversification to NC drilling and NC boring machines, Electro Discharge Machines and flexible manufacturing cells.(30)

2.3.2. Diffusion of NCMT in developing countries

Table 11 gives the available evidence on the diffusion of NCMT in developing countries.

2.3.2.1. in Asia

The number of NCMT has increased at a very fast pace in the Newly Industrialized countries of Asia where firms have invested

---

(30) In 1984 a Taiwanese company exported the first FMS American Machinist, February 1984

Table 10 Numerical Machine tool production in selected developing countries*

	1985		1987		1988		1989		Share of NC in production value of Machine Tool
	US$ mi.	units	US$ mi.	units	US$ mi.	unit	US$ mi.	units	
Argentina	1.20	16	10	100	12	96			20%
Brazil		413	223	1018	226	742		1052	43%
India		93		330	71	312			26%
PR China						1000*			
Republic of Korea	38		134	2039	155	2119	250		27%
Taiwan Prov.China	42	1118	114		166	3600		4900	24%

Sources : CECIMO
Brazil Bolletim Sobracon 1989
Electronics Koreq February 1990
* output of mechanical portion of CNC machine tools

Table 11 Stock of NCMT in selected developing countries

In Units	1981	1985	1987	1989
Republic of Korea		2680	5000	7500
Taiwan Prov.China		1220	2800	6250
Brazil	986	1995	4176	5800
Singapore	60	700		1800
Mexico				1300
Argentina	350	500		800
Columbia			61	
India			1182	

Argentina, Brazil: case study by F.Erber
Mexico case study
Republic of Korea, Taiwan: estimaa:
estimates from production and trade figures
Singapore: EDB, economic survey 1989

in order to maintain their export competitiveness. A tight labour market, the increase in salaries (100 per cent in dollar terms from 1986 to 1989) and the re-evaluation of the currencies have prompted the move towards automation.

-In 1985 the Republic of Korea had 2680 units installed;this number more than doubled in the subsequent three years to reach 6500 in 1988.

-In Taiwan Province of China the number of NC units was estimated at 6200 in 1988.

-In Singapore, automation is a priority[31] and a National Master Plan has been launched: there were 1800 NC machines in use and 380 robots [32] in 1989.

-In India, the census of machine tools of 1982 has shown that there were 1182 NCMT installed; three sectors accounted for over 70 per cent of the machines installed: machinery and parts, transportation and electrical machinery. For 1986 onwards documented data are not available, however a sample survey among twenty five large enterprises indicates that the percentage of flexible automation in the investment in machine tools has increased very significantly from 25 per cent in 1985 to 41.7 per cent in 1989.[33]

The number of machines per thousand employees is around 6.5 in the Republic of Korea, 15 in Taiwan, China and 27 in Singapore as compared to 20 per thousand employees in the US engineering industries:

2.3.2.2.in Latin America

The economic recession has slowed down the pace of industrial modernization in Latin America. -In Brazil the installed capacity of NC machines increased from 986 in 1981, 1995 in 1985 and 5970 in 1989; they are concentrated in a rather small number of companies:420 in 1987 which are both large corporations (above 500 employees) and subsidiaries to foreign companies. According to a study by the Research and Technology Institute of the University of Sao Paulo, although a few well-known machine tool makers produce advanced equipment, the average age of machinery

---

(31) Ministry of Trade and Industry: Economic Survey of Singapore 1989, page 25

(32) most of them are used for assembly operations and 57 per cent are employed in the electronics and electrical industries

(33) H.C. Gandhi: Regional study on machine tool industry in Asia, the case of India UNIDO 1990

is 15 years [34]

-In Argentina the stock of NCMT increased from 350 (1981) to 800 units (1989). The diffusion of NCMT has included small and medium enterprises from the outset, probably because both locally produced and imported models were simpler and less expensive[35].

-In Mexico, there were 409 NC machine tools in 1986 and more than half of machine tools imports are NC machines and the installed capacity has been estimated at around 1200 - 1400 in 1989; motor vehicle plants in the maquilladoras had around 50 NC machines installed.

The use of flexible automation is sometimes associated with a systematic effort to enter foreign market in Argentina [36] and Brazil[37], however in Columbia the companies presenting the largest volume of exports are not those using NCMTs[38].

The machine tool, automobile and aircraft industries concentrate the largest number of NCMT in Brazil: quality considerations and complexity of the parts produced and the strict margin of tolerance seem to represent the majors reasons for the introduction of NCMTs in Argentina and Brazil[39]

2.3.3. **Other developing countries**

Available statistics do not allow to conclude on the diffusion of NCMT in other developing countries.

Industrialiazed countries trade statistics show that 13

---

[34] "Market reserve policies provoke growing conflicts as Brazil's technology lags", Business Latin America April 3 1989

[35] F. Erber: The electronics complex and industrial automation: a comparison between Argentina and Brazil UNIDO 1989

[36] D. Chudnovski: The diffusion and Production of Numerically controlled machine tools with Special reference to Argentina, World Development vol 16 No 6 pp 723-732 1988

[37] A survey of autoparts manufacturers conducted in 1984 has shown that the manufacturers which used NCMT were those presenting the highest export ratio R.Tauile: Automacao e competitividade, uma avaliacao das tendencias no Brasil Instituto de Economias Industrial, Rio de Janeiro 1987

[38] Fedemetal: Las nuevas technologias de base microelectronica: analisis global e impactos de su incorporation al sector metalmecanico de Columbia, Bogota 1988

[39] R.Tauile, Erber: Machine tools in Latin America UNIDO 1990

developing countries, which cannot be considered as New Industrialized countries, have imported NC lathes in 1985, and 15 in 1987; however this scanty evidence does not show any trend of diffusion since a few countries purchased NC lathes either in 1985 or 1987.Exports of machining centres from Japan and the EEC were directed to 20 developing countries in 1987, with fourteen importing for more than US$1 million

2.3.4. **Prospects**

Available studies conclude on a rapid development of the NC machine tool market in middle income developing countries:

-In the Republic of Korea, the domestic demand for NCMT is expected to grow from 3700 units in 1990 to 7000 in 1995 and 14000 in 2000[40]: the motor vehicle industry will be the largest market, accounting for 55 per cent of the demand, followed by the machine tool industry.

-An AIDO study on machine tool industry in Arab countries has estimated that NC machine tool demand would grow at an average rate of 10 per cent between 1990 and 2000[41], while the demand for conventional machines would increase by 4 per cent annually. In the case of Arab countries it has been estimated that the demand for NC machine tool will increase at an average rate of ten per cent per year between 1990 and 2000, more than twice the expected rate (4 per cent) for conventional machine tool: however, by year 2000, it has been estimated that NC machine tool would represent 7.5 per cent of installed capacity[42].

-In PR China, it has been estimated that the demand for CNC systems will increase from 2000 units in 1989 to 5000 (1995) and 7000 (1987)[43]

-In the case of Peru it has been estimated that the demand for NC machine tools could in the near future represent close to 40 per cent of total machine tool demand

---

(40) Korea Institute for Economics and Technology: Mecatronics 1989 in Judet: L'industrie de la machine outil en Coree UNIDO 1990

(41) AIDO: The development of machine tool industry in Arab countries 1987

(42) From Arab Industrial Development Organization: The development of machine tool industry in Arab countries 1987 in : Le secteur de la machine outil en Algerie et Tunisie par A. Chelbi ONDUDI 1990

(43) data from UNIDO project DP/CPR/89/017/A/01/37

3 SYSTEM INTEGRATION

Whereas a NC machine tool is a substitution innovation, a flexible manufacturing system appears as a radical innovation, a way to do new things. The gains attainable through systemic integration of NC machines are considerably greater than those attained through the addition of stand-alone equipments and a FMS has been described as a miniature factory(44)

3.1 Flexible manufacturing systems

The total number of systems installed has increased from 80 (1980) to 1200 in 1989 and according to IIASA(45) projections it could reach 3000 in 2000.(Table 12) Most of the systems installed having at least two CNC machines, one can estimate that the total stock represent less than 1 per cent of CNC installations world wide. The two main users were Japan (167) and the United States of America (137); they are followed by the Federal Republic of Germany, the United Kingdom and France.

The diffusion of FMS has tended to be restricted to selected industries (Table 13) where they are used on a narrow range of operations for the production of particular components (e.g. engine manufacturing and transmission in the case of automobiles). About half of the systems installed are used in the transport equipment (car, tractor and aerospace), the second main user is non electrical machinery (mainly machine building) and the third electrical machinery. In the USSR, half of Soviet FMS's were used by the machine tool industry itself, 25 per cent in the automotive industry and 10 per cent in the electrical machinery.(46) The motor vehicle industry dominates forecast sales based on current proposals. Workpiece families manufactured are cylinder heads, brake drum housings and engine components.

When successfully implemented, FMS can dramatically reduce cost of production as a result of increased machine utilization, reduction in the setting up time and the lead time (machining time necessary to complete a cutting operation), savings in stocks, works in progress, capital employed and labour costs. a

---

(44) Bessant at the meeting of international experts on a programme for industrial automation of the capital goods sector in Latin America

(45) in ECE seminar on CIM, Sofia September 1989

(46) S. Sipos and H. Sitarska: "Technological and organizational change: a challenge to Eastern Europe", IDS Bulletin 1989, vol 20 number 4

Table 12 Distribution of fully integrated flexible manufacturing systems

estimates (units)

	1980	1983	1985	1987	1988	1989	2000 projection
Japan	28	135		254		167	
USA	6-14	15-31				137	
United Kingdom	3	4				93	
Federal Rep.Germany	10	13				74	
France	2	13				67	
USSR						56	
Italy		12			25	37	
Sweden						36	
German Democratic Rep.			11			28	
Czechoslovaquia						23	
Estimates world wide	80	>100				1200	3000

Sources:
1980-1983 : Bessant
Japan figures : 7th Inventory (1987)
Italy : Technovation,9 (1989) page 497
IIASA FMS world data Bank (1989)

Table 13 Sectoral distribution of FMS in Japan

general machinery	169	67%
electrical machinery	42	17%
transportation equipmen	39	16%
others	1	0%
	251	

in Europe	U.K.	S	FRG
machine building	26%	38%	69%
Motor vehicles and engi	30%	16%	4%
aerospace	12%		4%
electrical electronics	8%	8%	
subcontracting	24%	38%	6%
	100%	100%	83%

Source: Haywood and Bessant 1987
MITI 1987

study on 95 flexible manufacturing systems installed in the United States and Japan, [47] before and after the introduction of total flexible automation showed that average processing time per part decreases by a factor 3,floor space diminished by 2.5 and personnel requirements in three shifts decreased by two thirds.

However, investing in FMS is often a painful process and previous forecasts concerning their diffusion have proved to be over optimistic because they underestimated the following:

- technical problems in terms of interface software and network organization
-organizational problems : FMS cannot be considered as a technological fix to an inefficient plant. Large companies which had invested considerably in factory automation have had difficulties to make these systems cost effective and technically reliable. Due to all these difficulties, there has been a shift in the attitude of firms in favor of a step-by-step approach, starting with flexible manufacturing cells, the islands of automation which will be progressively linked with work transport and tool management to form FMS as part of an overall CIM operation.

3.2 Computer Integrated Manufacturing

Technological trends such as NCMT and FMS, were confined to the sphere of manufacturing, this stage of automation could be followed by another which will concern the integration between design, production and management. With CIM, networks connect every microprocessor, robot and programmable controller in a factory, feeding information from all stages of production into one computer[48]. In the design department, the diffusion of Computer Aided Design system, first used for drawing preparation, allows conversion of ideas and modifications into a full set of engineering drawings. These systems can generate the necessary data for computer controlled production equipment via various

---

[47] R Jaikumar: Post-industrial manufacturing Harvard Business Review November December 1986

[48] Nissan put together its own version of CIM for its new luxury car the Infiniti. Called IBAS, for intelligent body assembly system, it can spot trouble and issue instruction for repairs. The company plans to build similar systems in its plants abroad (Fortune: Japan capital's spending spree, April 9, 1990)

Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) post-processors. Similarly, the various activities in production management are now available as modules for integrated suites or management software which draw upon the same central database.

The unmaned factory was first described in the fifties was expected for the early 70. Forty years later, the worker-less factory is still within the realm of imagination[49].Managers who dreamed of replacing human workers with robots or CNC machines find that as machines become more sophisticated, the problems of finding good workers has not gone away. The idea that the machine shop trade is dying because of automation looks as a myth: "*automation is great if you have someone to operate it and to do the brainwork*"[50] It appears that the technocentric vision of the factory of the future is a dead end[51], flexible automation can only function if its manned by highly qualified technicians and the proper mixture of persons and machines may bring more value added.

---

(49) K H Ebel: L'usine automatise a besoin de la main de l'homme. Revue Internationale du Travail 5/1989 Geneva

(50) Special Report on training American Machinist June 1989

(51) Cohen, Zysman : "US competitiveness suffers: the emergence of a manufacturing gap, in Translatlantic perspectives Washington Autumn 1988

IV: POSSIBLE ISSUES FOR THE CONSULTATION

The evolution of the machine tool, from a noisy machine driven by men in blue overalls to an "island automation" operated by a technician and programmer has implications for developing countries which go far beyond the question of entry into the machine tool industry and keeping up with technological changes. It should be analyzed in the broader perspective of the changes affecting the rules of competition in engineering industries and beyond.

Thus, the preparatory meetings for the Fourth Consultation on Capital Goods with emphasis on Machine Tool Industry should address not only the problems which confront machine tool producers but also those faced by the metal working and engineering industries which are the main machine tools users.

In addition, the meetings should explore possibilities for regional and international co-operation and define the main elements for such a scheme. Thus the proposed issues for the Consultation are:

i) Conditions of entry and technological advancement of the machine tools industry;

ii) Considerations for the use of advanced machine tools technologies in metal working and engineering industries; and,

iii) Elements of regional and international co-operation in the production and use of machine tools.

The three proposed issues are elaborated further hereunder.

1 CONDITIONS OF ENTRY AND TECHNOLOGICAL ADVANCEMENT OF THE MACHINE TOOLS INDUSTRY

1.1 The entry into the machine tool industry

One of the most important decisions facing developing countries in the capital goods sector is the "make or buy decision"[52], taking into account the choice of a product mix and the acquisition of technology.

1.1.1 Constraints

The main constraint facing developing countries willing to enter the machine tool industry are both technologic and economic

technical constraints

The analysis of product complexity of a conventional machine tool through the ACT method developed by UNIDO[54] shows that in terms of technological requirement for their production, conventional machine tools have technological complexity eqiuvalent to that for radios, telephones or bicycles. While product complexity does not appear such an obstacle, the major technical constraints to entry are:

- scarcity of skilled personnel. The machine tool industry requires engineers and workers specialized and having

---

(52) M. Fransman: Machinery and Economic Development Mac Millan 1986

(54) See UNIDO: Industry and Development. Global Report 1989/1990 pages 122-131

acquired some experience in metal-working industries. Such highly qualified workers are not easily found and the cyclical nature of the industry make it difficult to retain qualified personnel. The advent of CNC tools and Computer-aided design helps to alleviate this skill constraint. However a sound knowledge of metal cutting technology is a prerequisite for deriving the maximum productivity from the use of CNC machining.

- inadequacy of supporting industries in terms of castings,forging gear cutting, heat treatment for raw materials. components and technical services. The setting up of an integrated unit is a costly way to circumvent this limit (1.1.3)

limited market

In indutrialized countries as well as in developing countries, major producers of machine tools have a strong engineering base.This is a requirement to enter the industry:decision to invest should not be based on argument such as the "strategic" nature of the machine tool industry.

The dimension of the market is directly related to the state of development of the engineering industries (see Figure 5). In most middle-income developing countries sales of machine tools are less than US$100 million a year, while in less developed countries they are often inferior to US$1 million. This constraint may restrain the entry to those countries which are characterized by a minimum value-added in engineering industries which can be estimated(53) at US$100 million (1986).

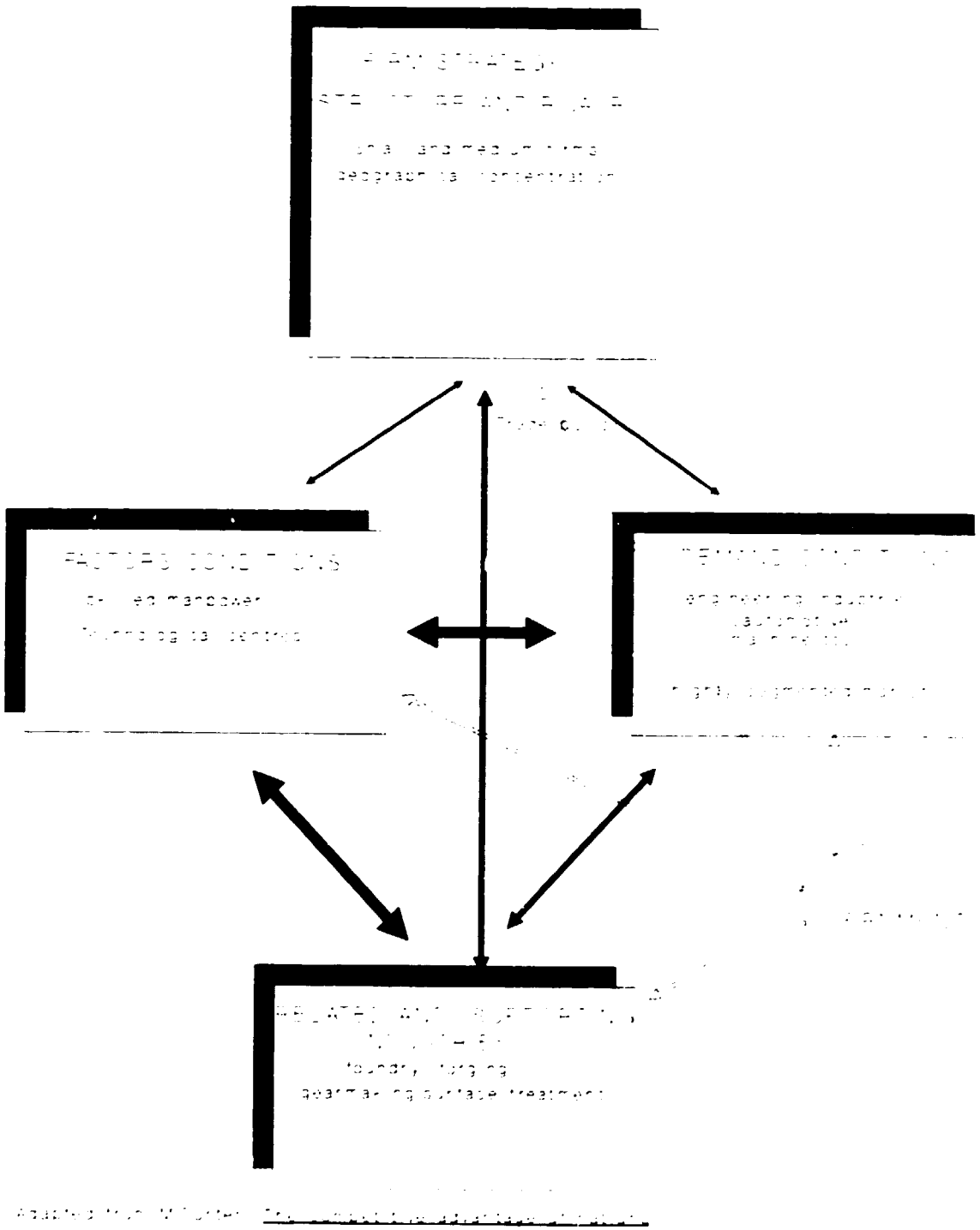
The market is also highly segmented and this should be thoroughly analyzed: while large engineering enterprises will often prefer to equip themselves with sophisticated machines for tolerance reasons, small enterprises and repair shops which do not have the same tolerance constraints will be more willing to buy simple machines and may thus represent the first market for a local producer.

However, by placing too much emphasis on the constraints of the domestic market, one fails to take into consideration the opportunities opened by regional and international markets:manufacturers in industrialized countries (where still nine out of ten machines are conventional), are shifting to NC machine tools and this evolution offers some market opportunities to developing countries.

---

(53) This limit should be understood as a very rough approximation derived from statistical evidences only.

Figure 16 : The machine-tool industry diamond



1.1.2 **Product mix**

In most developing countries conventional machine tools will remain the most widely demanded machine tools in the foreseeable future. Leapfrogging into NCMT production is unrealistic and the only technological route is through a step by step approach from assembly, to progressive integration into conventional machine tools manufacturing. Such entry approach is also the only feasible technological route towards the manufacture of more advanced equipment.

Reverse engineering, and South South cooperation can be advisable channels for the transfer of technology.

1.1.3. Integration

In order to cope with the unreliability of sub-contracting services, developing countries have often opted for a high level of integration .This experience has seldom being conclusive either in economical terms, since it has often resulted into a low level of plant utilization or in technological terms (there was no spill over to other firms)

The difficulty to reach a proper balance between integration and subcontracting stems from the fact that the machine tool industry demand in terms of foundry, forging, gear making is very small compared to similar demand from other engineering activities such as motor vehicle industry: it is thus not feasible to promote a subcontracting industry geared to the needs of the machine tool sector alone.

1.1.4 **Industrial policy: promoting national competitiveness**

The performances of State enterprises in machine tool production have often been disappointing. Government's industrial policies should aim at influencing each one of the determinants of competitive advantage in this industry in order to promote national competitiveness.

In an industry such as machine tool several competitive advantages combine to create self reinforcing conditions for competitiveness;these can be illustrated by a diamond as in Figure 16.(54)

i) factor conditions such as highly qualified skilled labour (in mechanics,and increasingly electronics and mechatronics) are the most important factors of competitiveness. In

---

(54)Adapted from M Porter: The competitive advantage of nations, New York, Free Press 1990

industrialized countries, technological centres and industry associations have been important knowledge resources. In developing countries government should provide adequate training facilities to assist the enterprises.

ii) demand conditions: Domestic demand should not be assessed in terms of volume of sales alone: attention should be given to qualitative aspects of the home demand which is more important for the industry: the machine tool industry's competitiveness is by and large defined by its ability to respond to the sophisticated demand from the local engineering industries: Government may intervene by shaping the local demand through its procurement policy, and by establishing standards and regulations. It plays also an important role in signaling new technology and advertising new market

iii) related and supporting industries: forging, casting, gearmaking, surface treatment facilities are the supporting industries which are needed by the machine tool industry and a close relationship between suppliers and machine tools firms will enhance the technological development of the industry. Instead of setting up integrated factories, government should endeavour to promote small and medium scale supporting industries . These supporting industries should be promoted as part of the engineering industry development programme in order to assure a high capacity utilization and alleviate the impact of the periodic shortfalls which is experienced by the machine tool industry.

iv) firm strategy, structure and rivalry. The machine tool industry is often made of medium scale enterprises which specialize on niche products. Efforts aimed at restructuring the sector in order to promote a handful of large groups have proved unsuccessful in industrialized countries(55), however while pooled production proved a disaster, operators have found it useful to collaborate on R&D and after sales services. Similar scheme could be devised in developing countries.

As any other infant industry, the newly established machine-tool industry is vulnerable and requires some form

---

(55) Financial Times:" Life yet in French machine tools", November 8, 1990. The large grouping set up in France (such MACHINES FRANCAISES LOURDES) and in the United Kingdom (ALFRED HERBERT) never worked out.

of protection during the learning period. Monopoly power on import together with the setting up of imports tariff and non tariff barriers, have too often outlived their purpose and adversely affected the competitiveness of the industry . It should been borne mind that one should not promote the machine tool industry (which is a small manufacturing sector) at the expense of the other engineering sectors: protection should be given for short period of time and be discussed with the users who have to be convinced that, in the long run, they may gain from the existence of a local machine tool industry.

It is important that the industry should become economically viable and competitive rapidly because prolonged protection which may lead to inefficiency within the industry, will be injurious to the successful development of the country's engineering industries as a whole.

1.2 The entry into NC machine tools

1.2.1. Difficulties

Conventional machine tools will remain for many years the most widely used machines, however the growth in demand for these machines will slacken while the market for NC will increase in industrialized countries as well as in some developing countries. The experience of those developing countries which have entered into the production of NC machine tools (NCMT) shows that this is extremely difficult which can be achieved by a limited number of countries.

- Technological difficulties in entering NC machine tool production are both of an electronic nature and of a mechanical nature: the challenge is to develop system integration capabilities in order to integrate the electronics into the mechanical equipment:i.e skills in mechatrnics
- Developing countries are constrained by the pervasive weakness in their basic mechanical engineering and machine design and building capacities. A survey made in the Republic of Korea (Box 4) has pointed out that the main difficulty for that country lies more in the mechanical parts (servo motor, measuring devices, cutting tools, spindle and hydraulic

Box 4 Identification of the main technical constraints encountered by Numerical Control Machine Tool manufacturers

		Lag with industrialized countries (in years)	Acquiring the Technology
Hardware	electronic equipment		
	Central Processing unit	3 to 5	local development
	Monitor and key board	3 to 5	import
	Programmable controller	1 to 3	local
	electrical and mechanical		
	transformer	5 to 10	local development
	servomotor	more than 10	import
	measuring device	more than 10	import
Software	for the tools		
	motor	1 to 3	local development
	multiple axes controler	1 to 3	local development
	for the peripherals		
	control of sequences	1 to 3	local development
	interface	3 to 5	local development
	specific software		
	graphics	1 to 3	local development
	numerical control	3 to 5	local development
Technical conception			
	main types of machines		
	machining centres	1 to 3	local development
	lathe	1 to 3	local development
	milling	3 to 5	local development
	EDM	5 to 10	import
	mechanical components		
	cutting tools	more than 10	local development
	spindle	more than 10	import
	transfert system	3 to 5	local development
	hydraulic components	more than 10	import
Manufacturing and assembly technology			
	main operations		
	die casting	5 to 10	import
	thermal treatment	5 to 10	import
	finishing	1 to 3	local development
	quality control	1 to 3	local development
	automation		
	conception and design	5 to 10	import
	production	1 to 3	local development

Source: Korea Institute for Economics and Technology 1988
in Judet P.: L'industrie de la Machine Outil en Coree
ONUDI 1990

Box 5: Choosing a technology transfer route to develop NC technology

There are three possible route which can be followed to transfer and/or develop CNC technologies:
(i) purchase the complete package through a turnkey operation from an internationally known owner supplier
(ii) to unpack the technology package and indigenously develop everything from scratch
(iii) to adopt a mixture of (i) and (ii). that is while sub contracting some parts of the technology package to foreign companies with experience in the respective areas. to develop the remainder indigenously.

The selection process of the appropriate route is a function among others of: availability of technology. costs involved. time required to assimilate the technology. manpower requirements. risks involved in reaching the set targets and depth of assimilation of technologies.

While state-of-the-art microprocessor based CNC systems are moving towards the 32-bit complexity: 16-bit CNC system technology is available: they are still being manufactured and marketed by all major companies. Turn key operation is the fastest method while indigenous development, which requires a large number of skills. takes the longest time. However when these two routes are compared in terms of deepness of assimilation of technology. the indigenous development looks preferable.

Parameters	Technology transfer route		
	Turn Key	Indigenous	Mixed
Difficulty of obtaining of technology	*	****	***
Costs involved	****	*	**
Manpower requirements	*	****	***
Chances of not reaching set targets	*	***	**
Time required to assimilate of technology	**	****	***
Chances of failing to assimilate technology	****	*	**

**** very high
*** high
** medium
* low

Adapted from CNC system development Project document DP/CPR/89/017/A/01/37

components than in the electronic or software field. This examples underlines that:" *the export aspirations of developing countries in the machinery sectors are constrained on the technical side not by their lack of information technology skills but because of the pervasive weakness in their basic mechanical engineering and machine design and building capacities.*(56)

Local production of the electronic control units has begun in Brazil and in the Republic of Korea where the domestic markets are respectively US$20 million and US$ 55 million.(57) In Brazil the production is segmented among three captive suppliers (machine tool producers) and four "merchant suppliers" which cater for different markets (80 per cent of the market). Competition is minimal although this monopoly has been challenged by an electronic firm which developed a simple model of NC. It appears that NCMT prices are about four times the price of Japanese comparable NC. Box 5 discusses a possible technological route from the manufacturing of conventional machine tool to the entry into Numerical control which gives the emphasis on software.

---

(56) K.Hoffman : "Technological advance and organizational innovation in the engineering industry", Industry and Energy Department working paper. Industry series paper No. 4 The World Bank, March 1989

(57) Electronics Korea September 1989

1.2.2. **Competitiveness**

While comparison of unit prices for similar machines (and average prices) between Japan, Korea and Taiwan Province of China shows a small differential, there is a large price differential between East Asian countries, India and Brazil where the average domestic price of a NC machine tool is five times the Korean average price. South Korean machining centres are also between a half an a third of the Argentinian price.(58)

The high price of these equipments is hampering the modernization of the industry in Latin America. During an unstable economic period decision makers are not inclined to take major risks, and this include investing in modernization: most car component firms in Brazil set a two-year pay-back period in their acquisition of new equipment(59) and this makes the acquisition of NC machines unfeasible

2 CONSIDERATIONS FOR THE USE OF ADVANCED MACHINE TOOLS TECHNOLOGIES IN METAL WORKING AND ENGINEERING INDUSTRIES

The changes which are transforming the machine tools have to be considered in the broader perspective of the changes of the major determinant of global industrial competition(60). Traditionally the differences in production factors (capital, labor and material) has been a major source of competitiveness. However, with the increasing process of globalisation, the differences related to factors of production have dwindled and a major source of competitiveness is shifting to technological capabilities to develop new products and processes in response to frequently market changing needs.

Competitivity has become the keyword and while low wages are no longer a decisive factor, flexibility of production, quality customization of products and total delivery time have become the

---

(58) Chudnowski and Groisman, 1987

(59) R.R. Lima: "Implementing the Just in Time production system in the Brazilian car component industry" IDS Bulletin 1989 vol 20 nx4 1989 page-14-18

(60) UNIDO: New technologies and global industrialization. prospects for developing countries, Regional and Country Studies Branch, Industrial Policy and perspectives division PPD.141 November 1989

most important competitive factors in industries such as electronics, motor vehicles, autocomponents and increasingly in other engineering industries where product renewal rates tends to be higher.

These changes in business environment have motivated engineering firms in industrialized countries to:

- equip themselves with flexible equipment (NCMT, FMC and FMS): as it has been shown the strongest diffusion of these equipment will happen during the next decade
- adopt new manufacturing practices, such as concurrent engineering (for a better collaboration between design and production), Just in time for avoidance of dead stocks.

These changes will have a significant impact on the engineering industries of developing countries. This will be specially the case in sectors such as aircraft, machine tool, transport equipment and of some auto components, general equipment such as pumps. This new competitive pressure which is being felt on export markets will increasingly concern domestic markets due to import liberalization measures(61).

Developing countries will have to keep up with this evolution which raise several issues. The impact on employment is a false issue: losses due to NC have not been significant while losses will be more important in those countries which fail to adjust.

In some areas where product quality is the overriding concern (precision tools, professional instruments), CNC machinery has become effectively an industrial standard; in the other the real issue for developing countries is to gain world competitiveness through better manufacturing practices.

2.1 Industrial automation in developing countries

The diffusion of flexible automation techniques represents a threat to developing countries, however investing in hardware should not be considered as the automatic answer. A large number of case studies in industrialized countries conclude that a decision to invest in flexible automation equipment is not likely to give the full benefit if it has not been preceded or accompanied by parallel change within the organization: "*all you get when you put a computer into a chaotic*

---

(61) Due to import liberalization measures taken in a growing number of countries, local engineering firms are now exposed to foreign competition

organization is computerized chaos".[62]

The first step towards industrial automation should be plant and company reorganization

2.2 Organizational changes

Advanced equipment is a solution if and only if some prerequisites are achieved that is the improvement in the management and organization of production: "*one does not acquire a Flexible Manufacturing System, one becomes a Flexible Manufacturing System*".[63] A sizable share of the gains from investment in flexible automation comes from organizational change and, as strongly emphasized by several authors,[64] this suggests that these organizational innovations are in fact a software separable from technical change and may eliminate the need for acquisition of hardware.

The strategy towards industrial automation should follow a step-by-step approach[65] starting with a reorganization aiming at productivity and flexibility improvements; changes will cover plant layout, development of skills, adoption of new working arrangements, planning and scheduling and production control. A possibility of progressively changing from traditional manufacturing method into advanced manufacture on plant level is the establishment of an Autonomous Manufacturing Island[66] (AMI) for a selected group of parts. For this selected group of parts, conventional machines and CN controlled machines can be combined to undertake the various machining operations while production planning and control, flows of materials and sequences of operations are optimized with the aid of computers. Included in this concept is also tool management and maintenance of

---

(62) In John Bessant and Howard Rush: Integrated manufacturing Technology Trends, Series No. 8 IPCT.70, UNIDO October 1988

(63) Bessant Integrated Manufacturing UNIDO 1987ç

(64) Final Report of the Meeting of International Experts on a Programme for Industrial Automation in the Capital Goods Industry of Latin America Vienna, 27-28 November 1989, UNIDO and also K.Hoffman: Technological advance and organizational innovation in the engineering industry, Industry and Energy Department Working Paper, Industries Series Paper Nx4, The World Bank

(65) As advocated by the participants to the Expert Group Meeting on Industrial Automation (UNIDO, November 1989)

(66) A concept which has been put forward by UNIDO/DIO/ENG in a on-going large machine tool project in China.

machinery and fixtures. The immediate investment for the establishment of an AMI is comparatively low and the AMI concept can easily be replicated for other groups of parts within the same/or other factories. Simultaneously changes from conventional machine tools to CNC machine tools can be effected as funds for investment and skilled labour and engineering forces become available.

Reorganization should extend beyond the firm level with the setting up of an appropriate subcontracting policy which can increase flexibility as shown in examples from Italy and Japan.(67)

2.3 Acquisition of hardware

Among the options for industrial automation which are open, there are NC machine, Flexible manufacturing cells and Flexible manufacturing systems. It should borne in mind that the investment per workplace in complex machines such as FMS or FMC can be easily in the range of US$500 000 per workplace(68). NCMTs appear to most experts as the most interesting techniques from the point of view of the developing countries, because they can be considered as mature technologies. Their skill-saving(69) nature is a strong argument in their favor. Available evidence suggests that if developing countries are already efficient users of conventional machine tools, they will face few insurmountable skill-related problems in using NC machine tools; though capital costs, scale requirements, available skills, protected markets and the availability of supplier may present constraints.

Investment in NC should be analyzed cautiously: acquiring an NC is expensive, three times the price of a conventional machine tool and the consequence of a breakdown may be devastating(70).

---

(67) In these two countries the existence of a large and flexible network of subcontracting firms appears to be correlated with the high level of diffusion of NCMT (see II)

(68) K.H. Ebel: Computer integrated manufacturing, the social dimension ILO 1990

(69) Which should be assessed in taking into account the greater skill content of the repair and maintenance staff

(70) in the case of a toolroom equipped with conventional machines the possibility of substitution between machines exist, while sometimes the new facility will be equipped by a NC machine only.

The choice of a NC machine should take into consideration economic factors: fixed cost of preparing the machine and the variable costs (labour and capital costs) and repair and maintenance but also product variety, batch size, the rate of utilization.

One of the main advantage of NC machine tool is flexibility. However flexibility does not come out automatically[71]. NC machines do offer economies of scope, but the experience of medium enterprises in industrialized countries show that in many cases flexible equipment is used to manufacture a group of similar components. A plant is organized to produce specific components, and in order to reap the benefits of the NC machine tool flexibility, one has to undertake a technological assessment of the plant and to implement organizational modifications which may be costly

Lack of preparation of the enterprise, publication of theoretical performances which have not been verified, lack of training and lack of technological mastering have led in many cases to bitter experiences in industrialized countries. In many cases the introduction of flexible automation equipment has not led to financial rewards.

Investment in NC machine tool should be analyzed very cautiously following proven guidelines and in order to advise engineering firms in developing countries, consulting services should be promoted through business associations or technical centers.

3 ELEMENTS OF REGIONAL AND INTERNATIONAL CO-OPERATION IN THE PRODUCTION AND USE OF MACHINE TOOLS

To circumvent the constraint of national markets, regional cooperation scheme could be promoted as in the case of the trade cooperation, between Argentina and Brazil. The opportunities offered by North South South schemes of cooperation should also be explored. It should aim at the production of parts of machine tools in different countries which would then be assembled in every country and partially exported back to industrialized countries. Experiences of such North-South-South cooperation already exist in the case of conventional machine

---

(71) P. Padilla: "Amelioration de la productivite d'exploitation des centres d'usinage et de tournage", CETIM informations Nx108 Decembre 1988

tools[72], and similar scheme is being assessed in the case of the motor vehicle industry[73].

International cooperation should focus on training[74], sharing of experiences on the problems posed by the diffusion of industrial automation. Another area of international cooperation concerns the lack of standards which represents a major constraint for developing countries buying NC machine tools. Efforts should maintained in order to achieve international (and open) standards for NC machine tools.

---

[72] A cooperation between Morocco, Tunisia and a french manufacturer, C3M, for the production of conventional machine tool (metal working and wood working)

[73] TOYOTA in the case of some ASEAN countries (Malaysia, Philippines and Thailand)

[74] In the context of the restructuration of training institutes, which will stress the use of numerical control machine tools, the Ministry of Education, together with the Ministry of Cooperation has set up a plan in order to transfer conventional machine tools to African training schools (Le Monde February 27 1990)