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DIFFUSION OF NUMERICALLY CONTROLLED MACHINE TOOLS IN FINNISH ENGINEERING INDUSTRY

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ABSTRACT: The paper describes developments in the machine tool market and in the use of numerically controlled machine tools (NCMT's) in the engineering industry in Finland. These developments are also compared with the situation in major industrialized countries. According to the results, Finland seems to have a time lag in use and manufacture of NC technology, and complete diffusion will not occur before the year 2000 approximately.

KEY WORDS: Diffusion, Numerically controlled machine tools, Finland

DIFFUSION OF NC MACHINE TOOLS IN FINNISH ENGINEERING INDUSTRY

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DIFFUSION OF NUMERICALLY CONTROLLED MACHINE TOOLS IN THE FINNISH ENGINEERING INDUSTRY

Introduction

Machine tool (MT) making is a 200-year-old industry. It started with the making of spinning looms, steam engines and weapons out of cast or wrought iron. As in the beginning, it - or at least the advanced part of it - is still a high-tech industry which supplies sophisticated powered tools to cut and form metal parts used in aircraft, land vehicles, ships or industrial machinery, or in the engineering industry in general (Sciberras 1985). About the early history of the MT industry we have several accounts (e.g. Carlsson 1984).

Old MT factories and firms in the industry had been founded by individual craftsmen who started in one of the 30 broad categories of tools. Typical of the industry is the small average size of the factories: only some 120 men in Europe and some 200 in the USA or Japan (Panorama 1990). Thus thousands of firms supply their products to the USD 46.6 billion world market (American Machinist 1991). For example, the biggest MT producing country today, Japan, supplied in 1990 a total of about 200.000 metal-cutting units MT's

and maybe some 70.000 metal-forming units (Metalworking 1991). Thus we could estimate that the world market today consists of more than 1.2 million MT units.

MT production is a stategic industry and has been very international right from the start. The local market in a medium or small-sized country is too small for a highly specialized factory. But just this wide international trade has made it possible for a small country, like Switzerland, to become a major producer - the sixth largest producer of MT's. The other side of the dependence on international trade includes embargoes and export controls on the advanced high precision MT's, which hinder the transfer of manufacturing technology between adversary countries for military reasons. To make supersonic aircraft, strategic missiles, silent submarines or even small arms at a reasonable price a good knowledge in engineering and machining is needed.

The MT industry has undergone two major changes in the last 30 years. First, the industry as a whole has lost its dynamic character in industrial countries. Second, the technical innovations in numerical controlled steering systems has influenced the products and has segmented the industry into winners and losers.

Market characteristics

Although the volume of production and investments in the engineering industry has increased, MT production and sales volume is much the same as 20 years ago. In developed industrial countries sales are decreasing and only in developing countries are sales still increasing. Working of metal is less necessary than before due to new, thinner and harder metal materials and plastic substitutes. New machining technologies are more effective and economical than before, the tools and machinery last longer than before thus reducing the number of MT's necessary. The biggest impact on MT industry would seem to come from the customers' side. While the various branches of the electronic industry has taken the lead in the engineering industry growth, the MT industry has "lost" many customers of the past.

Total world production, deflated by the US producer price index for MT's, grew by an average of 2.9 % per year during the period of 1955-80. The winners where Asian and ex-Comecon countries. MT production in Japan increased 17 % per year, but the figure in the US actually fell. The unit shipments of metal cutting MT`s in the US, in the past the biggest producer, were barely larger at the end of the 70's than it was at the war-time peak in 1942 (Carlsson 1983). Between 1972 and 1984 the MT industry output in the US fell again -3.5 % yearly (U.S. Outlook 1987). The EC is the largest producer and consumer of MT's but also it lost markets. In 1988 EC

production reached the 1980 level, but about 100 companies had shut down production and 1400 continued in business (Panorama 1990). A big part of production demand in the OECD countries comes from MT exports to ex-Comecon and developing countries, which are net importers.

Classification of machine tools

The other major change in the MT industry came from the innovation of numerical control (NC) in 1949 by MIT in the United States. NC development was further sponsored by the US Air Force during the Korean War in order to improve the airplane production methods.[1] The first commercial NCMT application came to market in 1956. Soon after this in 1958 the first NC machining centre (MC) was also designed and built in the U.S.

MC was the first totally redesigned machine tool to take full advantage of numerical control. The machine performed a variety of operations - milling, drilling, tapping and boring - on an 18-inch cubic workpiece (Sciberras 1985). From the standpoint of automation it is nesessary to stress the increasing importance of MC's, since they constitute one of the basic components of flexible manufacturing cells (FMC) and systems (FMS) (EC Commission 1985).

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[1]. The term NC is used in the broad sense in order also to include more sophisticated types of control, such as CNC (computer numerical control).

To clarify the MT's and their use we refere to the figure 1. Here MT's are classificated according to four basic principles:

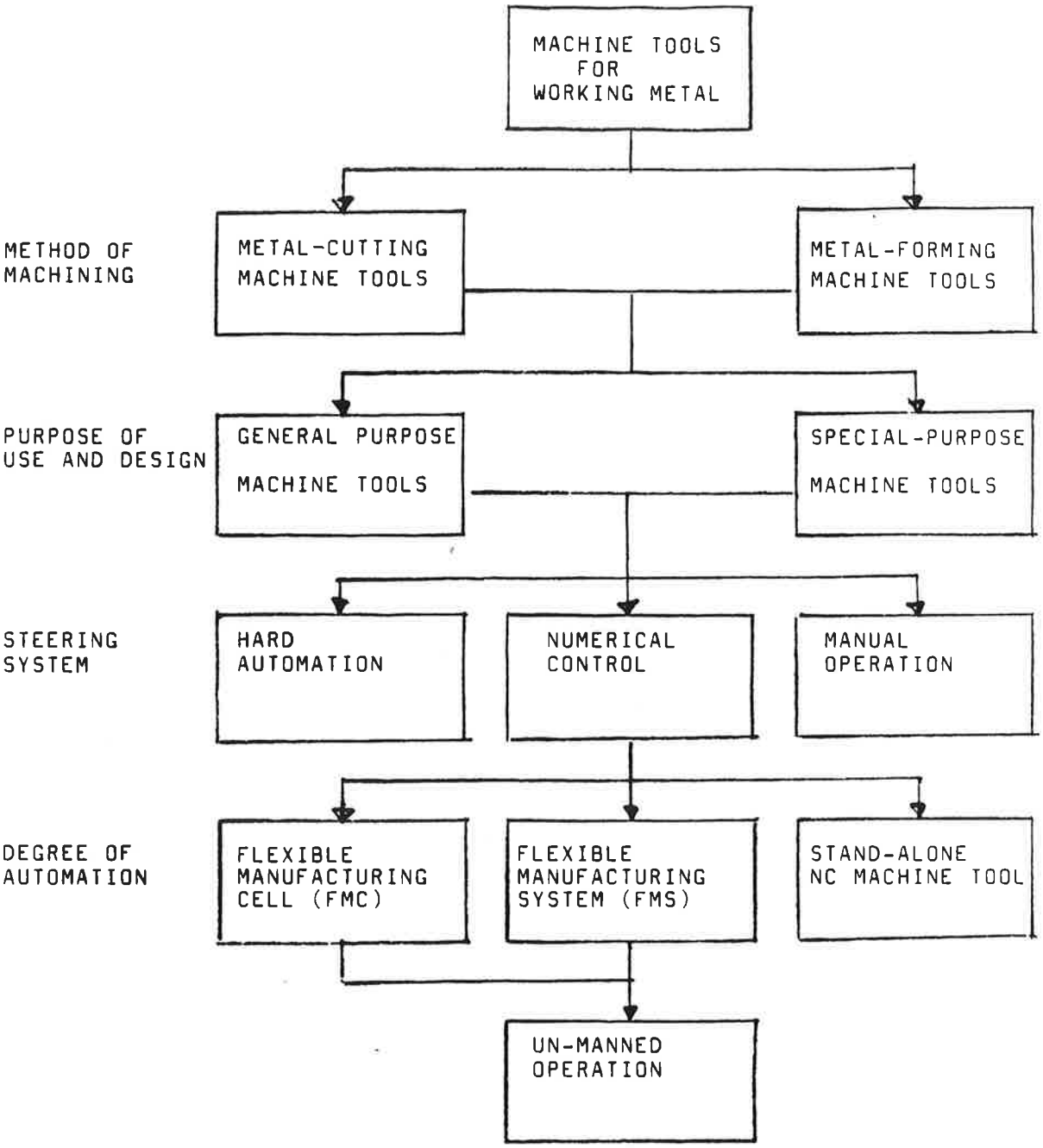
- Method of machining metal
- Purpose of use
- Steering system
- Degree of automation.

The first way to classify the MT's is how they work metal. The grouping into metal-cutting and metal-forming MT's is widely used. Of the world production cutting MT's have a 76 % share and the forming 24 %.

Depending on the use of MT's we can find general-purpose and special-purpose machines. General-purpose MT's are designed to machine a wide variety of products in short runs. Special-purpose (custom built) MT's are used mainly to machine the same kind of parts in a planned way.

The latest innovations in MT's have come from the development of the steering systems. Manual operation is the conventional way of operating a MT and this method requires one operator for each MT. Over the years different mechanical methods were developed for un-manned operation, namely hard automation to reproduce identical parts. Automation is incorporated within machinery or added later

Figure 1:
CLASSIFICATION OF MACHINE TOOLS



Source: Luukkanen (1985)

and connected to a fixed transfer line. If the product runs are long enough and the parts simple, hard automation is still on economic way of machining parts like nuts and bolts (Luukkanen 1985).

Innovations in early hard-wired (electro-mechanical) numerical control gave the possibility to program a NCMT for sophisticated operations where many axles are moving. In the 60's minicomputers were used in computer numerical control (CNC). And from the mid 70's a micro-computer was controlling the NCMT's operations. This innovation gave the NCMT's a big advantage and boost. The size of the control unit was soon similar to a TV-set, programming and operation were easier thanks to the screen and memory where programs could be stored for the next use or next operation. The price of the CNC control was decreasing. While in the 60's the NC unit cost 40-50 % of a NCMT, in the late 70's it cost only 10 % of the NCMT. Now CNC units are sold for some FIM 30.000 and a compact size of CN units make them economical and practical in small MT's.

As we can see in figure 1, the degree of automation varies in production where NCMT`s are in use. The simplest way is a stand-alone NCMT, where one man can operate up to three units. The second level of automation is attainded with a flexible manufacturing cell (FMC), where one or more NCMC's with a tool-changer are used and in which a robot loads and un-loads the work-pieces. The widest automation can be achieved in a fexible manufacturing system (FMS),

where flexible transfer lines connect different machining units.

While techically one NCMT can replace three manual MT units and thus need less costly operators, in the long run the sales of NCMT's has affected the total MT market: less MT's are needed than before. In the engineering industry penetration of NCMT's has increased productivity. Furthermore a FMC is 40 % more effective than one stand-alone NCMT, and a FMS increases this efficiency further (EC Commission 1985). From this standpoint many authors see NCMT's in the engineering industry as forerunners of electronics technology and forerunners in modern industrial automation in batch production (Mieskonen 1989).

Diffusion of NCMT's in major OECD countries

All major MT producers in all major industrial countries soon applied NC concept. But a real boom in NCMT trade did not come until the mid 70's. First the US firms took the lead in the whole MT business as well as in NCMT's. But in the early 80's US had lost is place as the biggest producer to Japan and West Germany. In this competition NCMT's played a key role since the market grew rapidly and the trade in manual operated MT's stagnated. From 1980 on Japan geared itself fastest toward NCMT production, concentrating on general purpose machines where economies of scale were important.

Expanding its export to the US and Europe, Japan gained a dominant market share in cutting MT's in general and in NC lathes especially.

As seen in figure 2, trends in consumption favored NCMT's in all big OECD countries. In value terms half of the MT's sold in 1983 in the OECD countries had a NC unit (Carlsson 1989). Still the stock of NCMT's was small as well as their share of total MTs in use. While the world stock of NCMT's was about 431,000 units in 1983 and around 500,000 units in 1984 (Luukkanen 1985), their share of the total MT stock in units was only about 4 to 5 % (EC Commission 1985).

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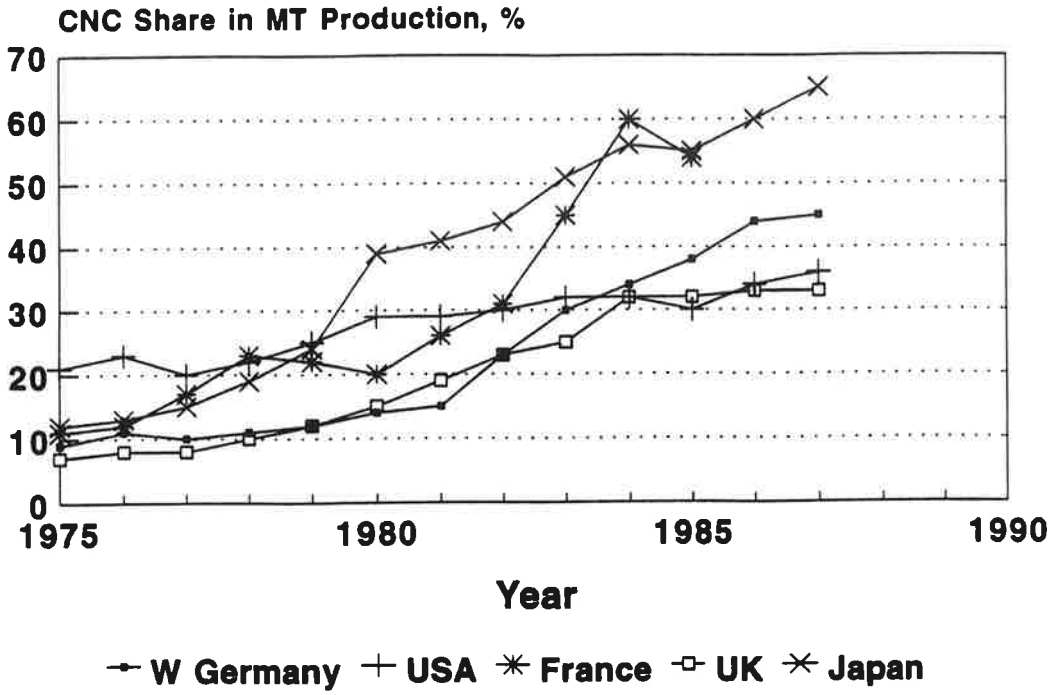
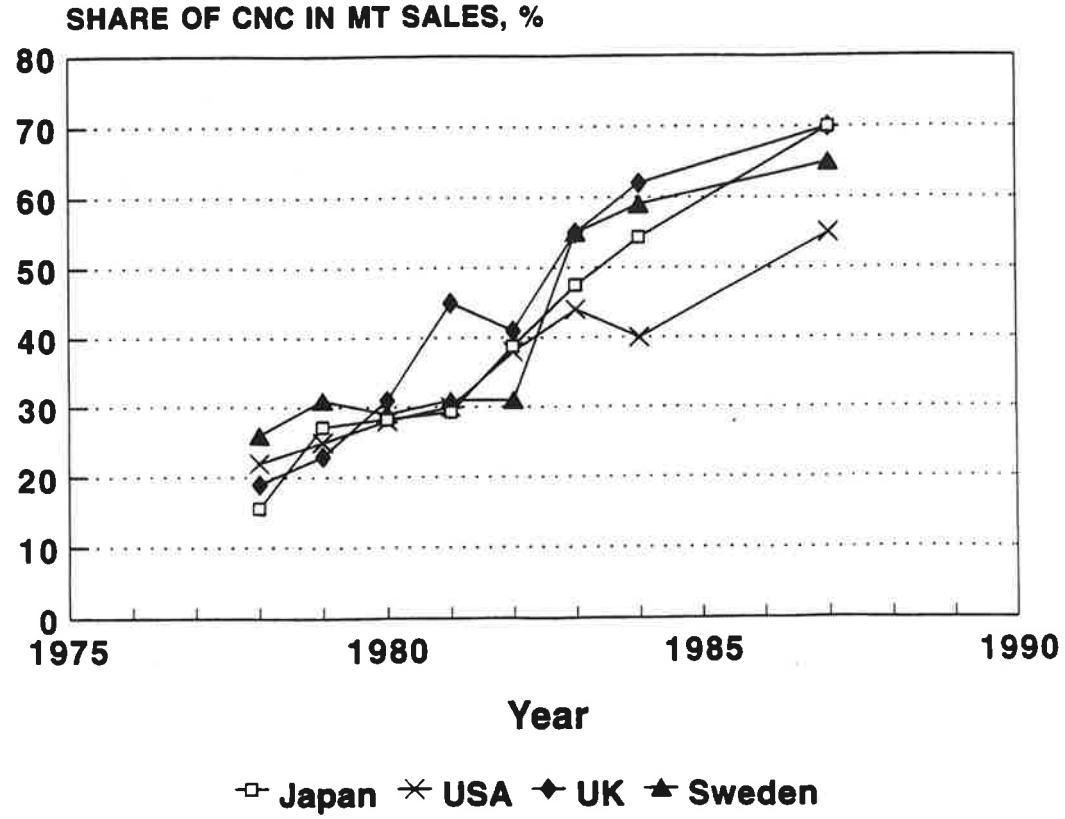
The latest figures are not available from most OECD countries and only details of development can be given. NCMT's share of total sales (consumption) measured in value terms in 1987 was about 70 % in West Germany, Japan and France but was lower in the US and Italy. West Germany imported 25 % of its NCMT requirements, UK 68 % and Japan only 6 % of NCMT sales (Nachricten 1990). In 1989 NCMT's accounted for 82.5 % of total MT orders in Japan (Japan 1990).

To protect local manufacturers, US government applied in 1986 so-called Voluntary Restraint Agreements (VRA) against Japan, West Germany, Taiwan and Switzerland. VRA's have helped domestic firms to control just over a 50 % share of consumption (Wall Street

Figure2: Machine Tools Market
CNC PENETRATION



Source: Carlsson (1989)



Source: Carlsson (1989)

Journal 1991). On the other hand, Japanese firms are involved in American MT production to avoid VRA and GM-Fanuc produces CNC units. In 1990 the US Department of Commerce estimated that Japanese firms may export US made NCMT's worth about USD 300 million (Comline 1990). As a consequence of the VRA's Japanese firms exported NCMT's to Finland originally aimed for the US market at a reasonable price and this kept the price level low in 1987-1988.

Developing countries are following this model although the labor cost is not the reason. South Korea alone is expected to invest in some 3000 NCMT's, of which about 640 would be machining centers (Korea Economic Daily 1990).

To give a picture of NCMT production structure and development in Japan, which in 1983 supplied about 40 % and now about 50 % of total world production, we present table 1. As we can see, the real NC era started and continued with NC lathes until 1980, but after that the importance of lathe production declined. In the 80's other NCMT's and MC's became dominant, which meant a trend towards smaller units, and in a case of MC's, more FMC/FMS -based automation.

Table 1: Production and composition of cutting NC machine tools in Japan in 1971-1990.

	1971	1980	1990
Production in Units			
NC lathes	629	9.911	25.319
NC machining centers	333	4.820	15.805
Other NCMT types	491	4.813	20.778
All NCMT's	1.453	19.544	61.902
Share of Units			
NC lathes	43.3	50.8	37.6
NC machining centers	22.9	24.7	25.5
Other NCMT types	33.8	24.5	53.1
Total	100.0	100.0	100.0
Share of Value			
NC lathes	40.2	42.3	29.1
NC machining centers	25.5	33.5	34.0
Other NCMT types	34.3	24.2	36.9
Total	100.0	100.0	100.0

Source: Metalworking Engineering and Marketing. Various issues.

Finnish machine tool market

The structure of Finnish MT consumtion can be seen in figure 3. During the last 20 years over 95 % of consumption has been net by imports, which mean a total dependence in the engineering industry on foreign supply. In 1990 the value of the Finnish MT consumption was FIM 765 million in import and production prices (in market prices consumption reached FIM 1160 million). The value of imports was FIM 718 million (FIM 1090 million at market prices) in the same year.[2]

Since the last peak in MT demand in Finland in 1975, the local consumption as well as the import volume has been stable. Only during the last two years of 1989 and 1990 has the market clearly increased.

On the production side, an average 83 % of production has been exported in the last five years (figure 4). Thus the local MT industry depends on the access to foreign marketsand marketing efforts abroad. The value of the gross machine tool production in 1990 was about FIM 324 million, of which FIM 277 million was exported.[3] Local MT production was mainly built in the 70's.

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[2] Without tools and parts. Import of tools and parts is about 65 % of MT import value.

[3]. Tools and parts increase this figure by about 50 %.

Figure 3: Metalworking Market in Finland
Machine Tools Demand and Output

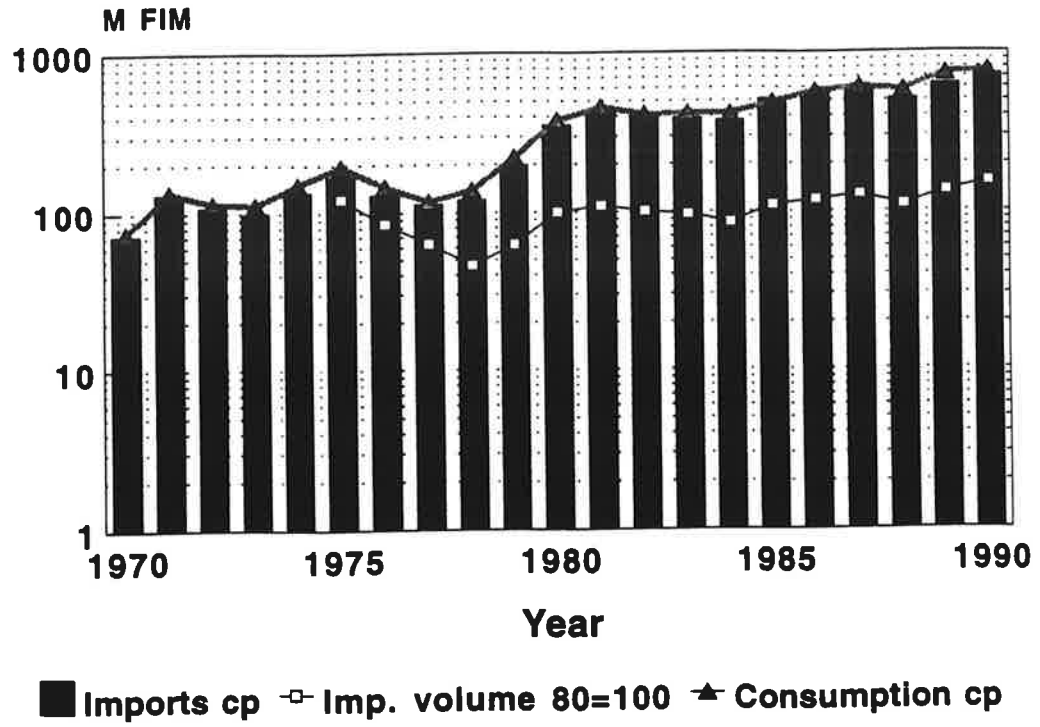
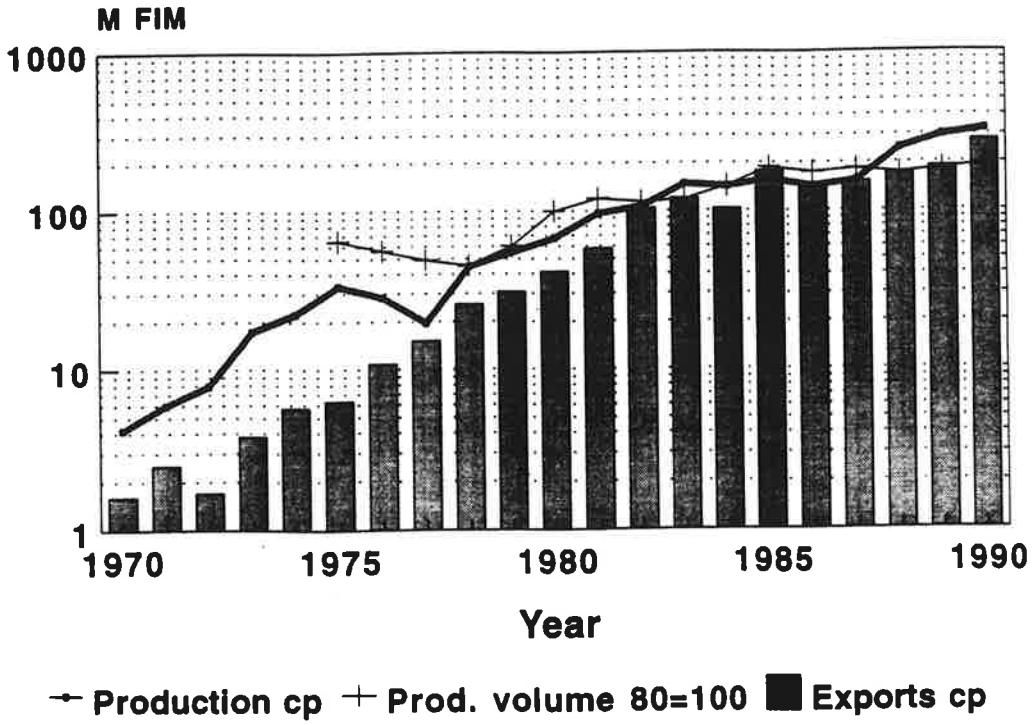


Figure 4: Metalworking Market in Finland
Machine Tools Demand and Output



During the 80's the production increase has contunued (see later section: Finnish metal working MT industry).

As a consequence of the Finnish market situation, in the following sections we concentrate on analyzing MT imports to find out the role and development of NCMT's in Finland. Local production exists, but it has played a minor róle. All figures presented are estimated or collected by the author, if a source is not mentioned.[4]

NC age in Finland and conditions for technology diffusion

The first NCMT in Finland was at a show at the Helsinki International Technical Fair in February 1962 and was sold to the Valmet Aircraft factory. It was a bulky MT of US origin and its hard-wired NC unit alone consisted of a 4-5 meter long panel according to an eye witness. The sale of NCMT's was small in numbers until the late 70's, since sales exceeded 10 units in 1970 and 100 units in 1980. All NCMT's were imported until 1977, when the first cutting NCMT was produced locally. 1983 witnessed production of the first locally-made forming NCMT .

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[4]. Early development of NCMT's in Finland had been presented in earlier reports by author (Luukkanen 1985 and 1987). For this paper earlier figures for 1984-1985 were revised and new figures for 1986-1990 were collected or estimated. Official trade and industry statistics are available starting in 1988, but this is incomplete and for the figures presented, include many errors.

The NC age in Finland was opened six years after the commercial NCMT was introduced in the U.S. In the early 80's all traditional western supply sources - and Japanese firms as a new source - geared their production toward NCMT's. This supply-side pressure was also noticed in Finland, where the engineering industry had expanded extensively using traditional machinery and employing new labor.

From the beginning of the 80's, MT importers (Finnish trading firms) took over responsibility for their NCMT's products and could offer technical sales support. This was an important prerequisite for the small and medium-sized engineering firms to buy sophisticated new NCMT's. Because of continuing supplier-dealer relations, traders/importers act as important agents in transfering sophisticated NC technology to their clients. Before that period the buyers of NCMT's had to rely on foreign factories, help in all aspects. Thus Finnish customers and markets were ready for a larger-scale NCMT's expansion in the early 80's.

Also other market factors contributed to the further expansion of NCMT's. In 1980 engineering industry investments had recovered from previous downswing and in 1985 the level of investments started to expand. This cycle continued until 1990. In the latter half of the 80's the engineering industry had also difficulties in getting new skilled workers and thus an increase in productivity was nessessary. The stock of MT's and large-scale investments dated

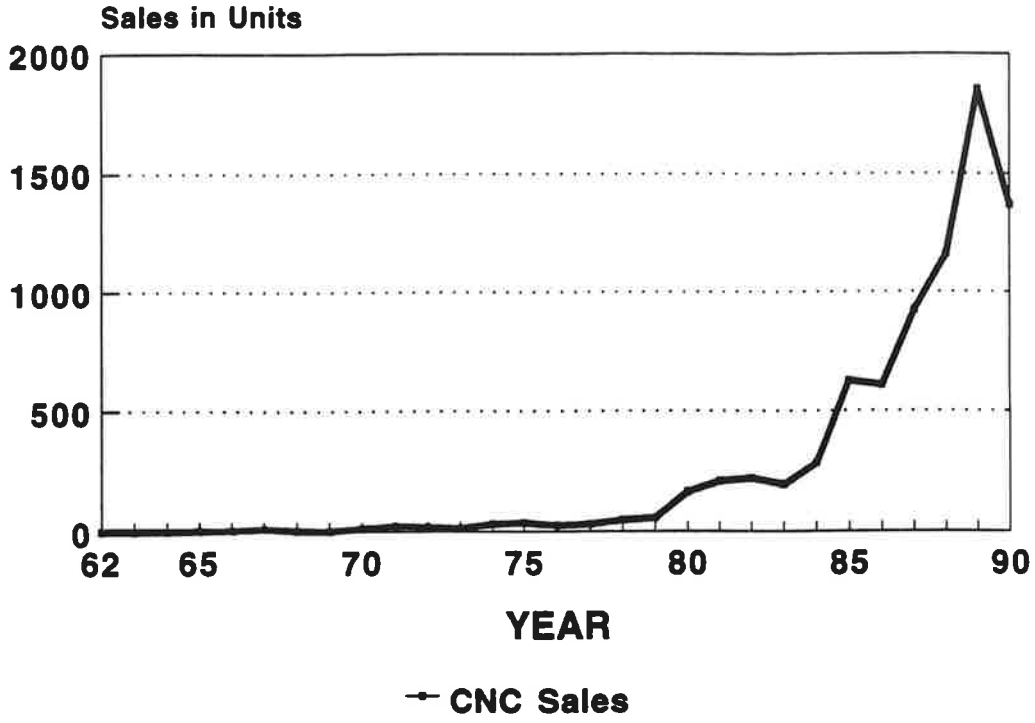
1975 or before was ready to be replaced. When the MT stock was replaced, the large engineering companies opted for NCMT's and this solution was followed by many small and medium-sized firms.

Maybe the strongest factor which resisted NC diffusion was the weakness of the local MT industry. The local MT industry was small and had very weak knowledge of NC technology. It could thus not guide firms in their choices, and could not effectively speed up the technical and marketing process at the turning point.

Sales and stock development

In figure 5 we have two different views of the NCMT sale. In nominal terms we can see the market exploding from a level of 200 units sold in 1983 to a market of 1850 units in 1989. In log scale we can notice that this sales trend about a 28 % increase per year, has continued actually from the mid 60's. Table 2 presents this development in numbers.

Figure 5: CNC MT'S IMPORTS
FINNISH MARKET 1962-1990



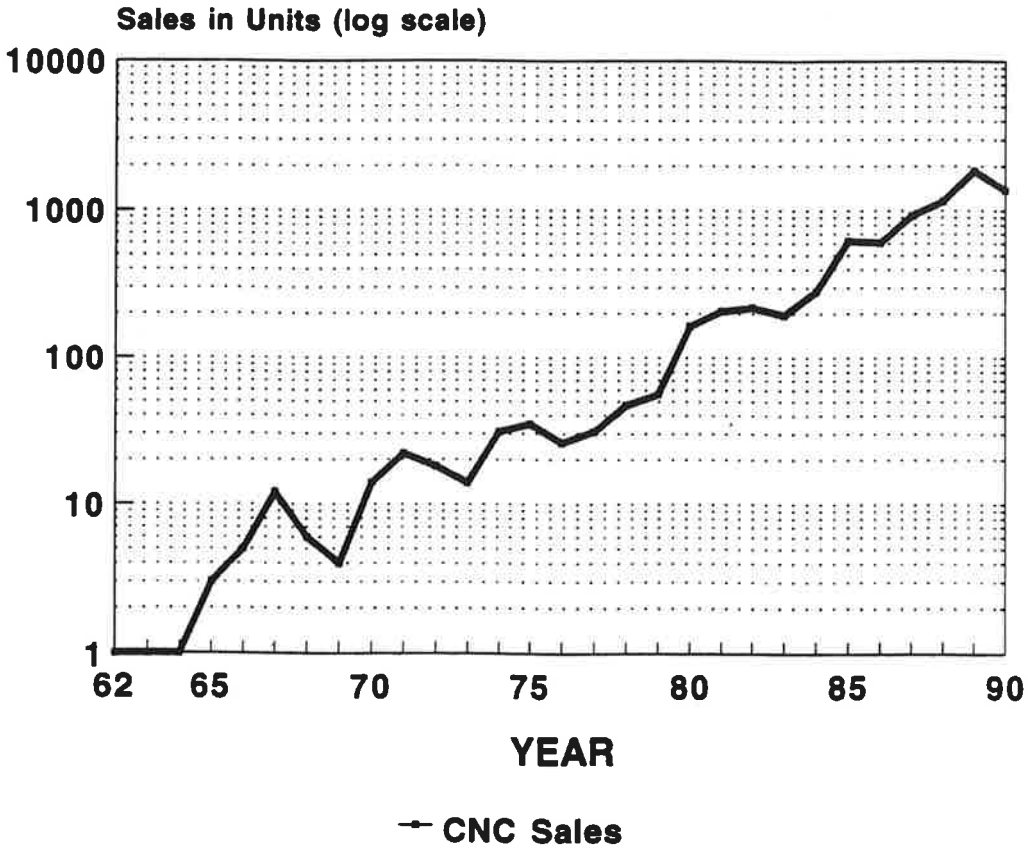


Table 2: Sales and stock of imported NC machine tools in Finland 1965-1990. Volume in units and value in current FIM (millions).

	Sales Units	Stock Units	Sales Value
1965	3	6	..
1970	14	47	..
1975	35	167	6
1980	164	491	46
1985	626	2024	186
1986	608	2632	168
1987	923	3555	244
1988	1160	4715	249
1989	1854	6569	338
1990	1368	7937	465

Source: TKC Intel Ltd estimates.

The machine park or the stock of NCMT's is a direct result of the sales. Because most of the valuable old large units have been repaired and up-dated, as far as the wearing mechanical parts and the CNC unit are concerned, almost all imported NCMT's are still in

use.[5] In figure 6 we can recognize the steady increase in the stock. In 1973 the stock exceeded 100 units and in 1983 the level of 1000 units was reached. During 1988 to 1990 the stock increased by 4380 units catapulting the total stock figure to about 7 940 units. Thus half of the NCMT parks in Finland are less than three years old.

Diffusion of NCMT's

Competing on the MT market are two different technologies, namely conventional MT's with manual operation and the new numerical control. If one of them can substitute the other, the peneration of new technology (or degree of diffusion) can be measured by its share of total sales.

This measurement of penetration has been used for similar competing technologies and product markets (see the method developed by Peterka 1977)[6] and while the development of the market share is very constant, it can be used for forecasting the future

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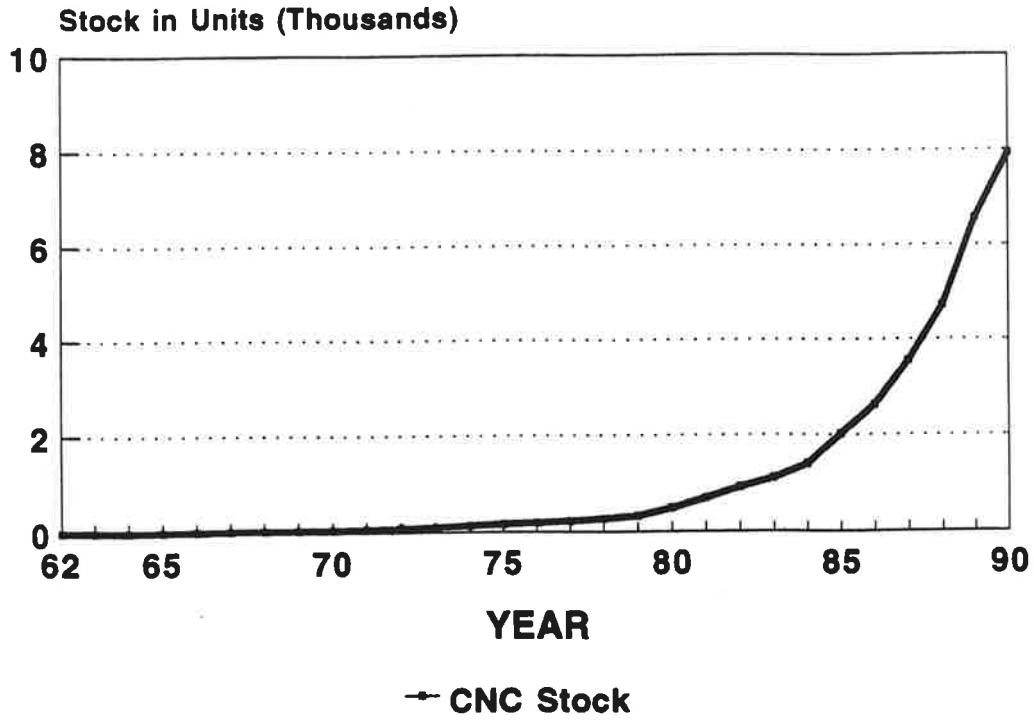
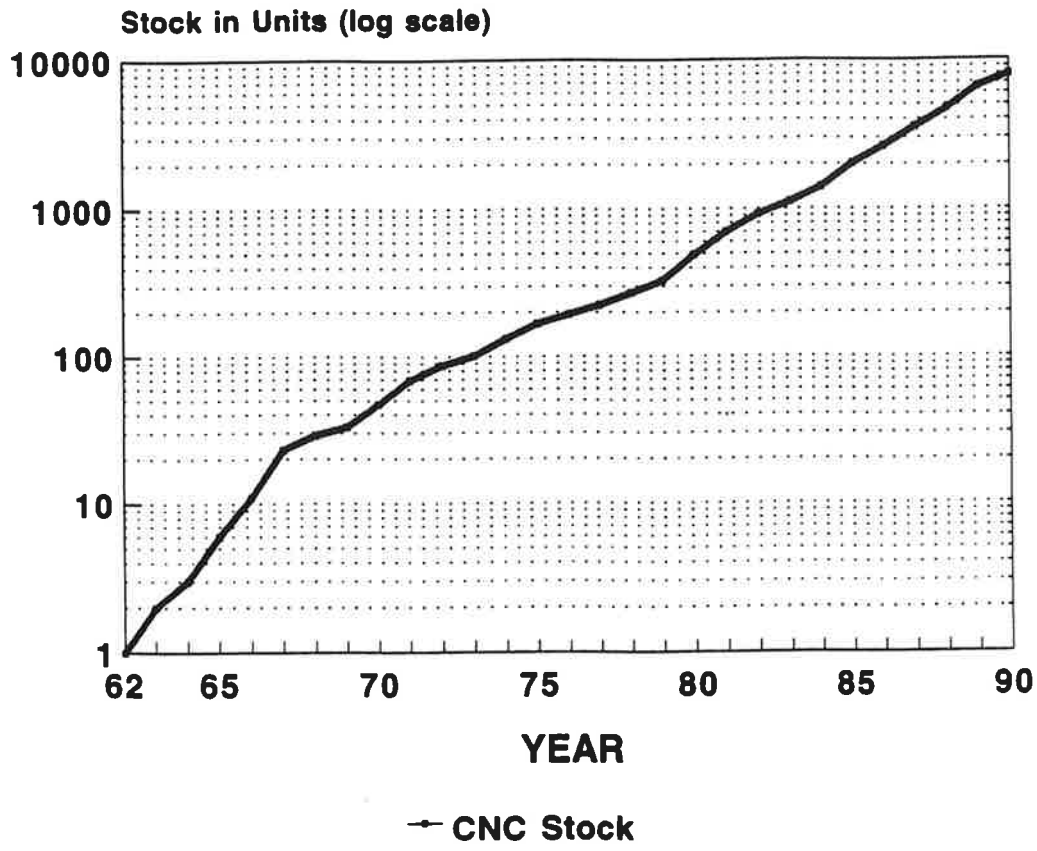
[5]. Some old and new units are of course re-sold or re-exported, but this does not change the cumulative stock appreciably.

[6] The method is based on a logistic curve where market share (in per cent) of a new technology is plotted on a log scale. The important points are the 10 % and 50 % shares of new technology. If we know the time needed for new technology to grow from 10 % to 50 %, we can calculate the take-over time, or time for new technology to reach 90 % of the market.

Figure 6: CNC MT'S IMPORTS
FINNISH MARKET 1962-1990





penetration (see the application of the method in NCMT's sales forecasting by Luukkanen 1985).

In this brief paper our main aim is to highlight the past diffusion of NCMT's for historical reasons, since even the history and dominance of NCMT's is not very well known in Finland. Very few scholars have ever paid attention to the NCMT market and most of the data regarding this field has been produced by the author.

In figure 7 we present a brief history of NCMT's penetration. The history of Finnish penetration is shown against the average of some main industrial countries (USA, Japan, Sweden, UK). Table 3 presents also facts in numbers about local penetration.

Although Finland had a penetration degree of 65 % in 1990, this country seems to lag behind foreign competitors, which reached the same degree in 1987. On the other hand, the penetration of NCMT's in Finland has been very fast during the last few years and the time-lag has become shorter than what it was in the mid or early 80's. And as discussed in subsequent sections, the Finnish engineering industry and NCMT market appears to have a unique profile.

As regards stock peneration this supposed time-lag means that in OECD countries nearly 50 % of MT's sold in the last ten years were equipped with numerical control (in value terms). Inherited time-

Figure 7: Machine Tools Market
CNC PENETRATION

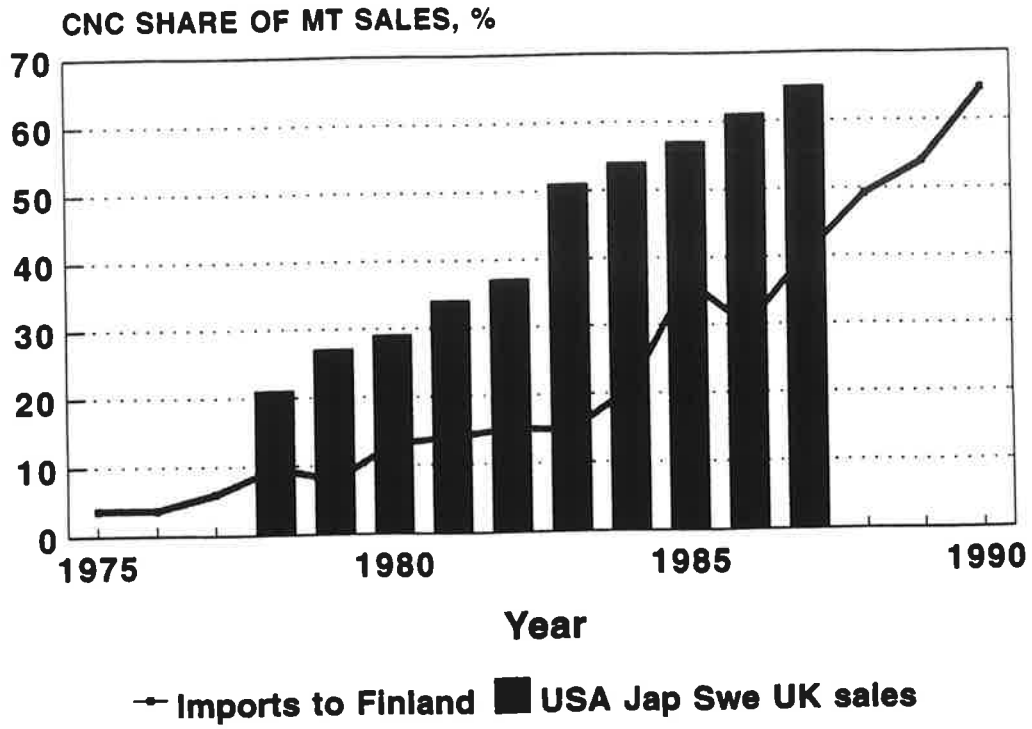
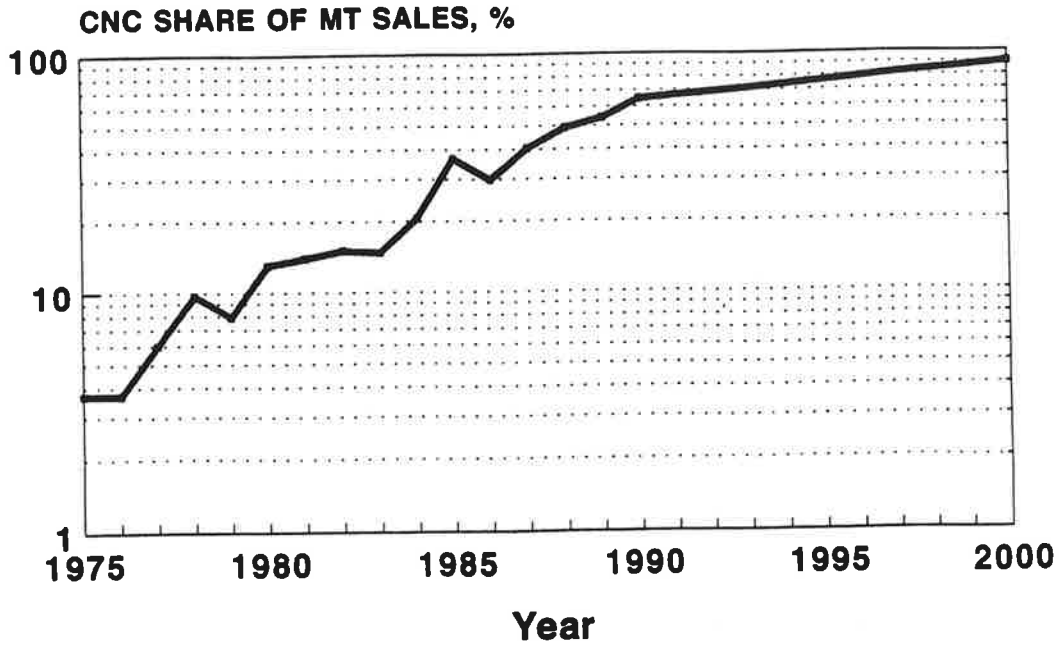


Figure 8: Machine Tools Market
CNC PENETRATION



lag in Finland put the respective share during the last 10 years is maybe only 25 to 30 %.

Table 3: The market for NCMT's and penetration degree in Finland 1975-1990. Market in units and value in FIM (millions), penetration degree in % of total MT sales.

	MT import value	NCMT market value	Penetration degree, %
1975	169	6	3.7
1980	352	46	13.1
1985	508	186	36.6
1986	564	168	29.8
1987	604	244	40.4
1988	507	249	49.2
1989	626	338	54.0
1990	718	465	64.7

Source: TKC Intel Ltd estimates

In figure 8, the penetration degree is plotted in log scale and shows a steady increase in Finland. This trend will continue in the future. According to the terms and method developed by Peterka, it

took about 11 years to increase the penetration from 10 % to 50 % (from 1978 to 1989). Thus the full takeover-time for NCMT's could be 22 years. It would mean that by the year 2000 NCMT's should have a dominant position of a 90 % market share in Finland.

Structure of Finnish machine tool demand

To complete the paper on NCMT's we briefly also study the structure of Finnish imports, which - we assume - describes also the market structure. We focus our attention on the following key questions:

- What role is played by machining centers (MC) in engineering industry automation? MC's are forerunners of FMC/FMS but as Finland is lagging behind, their share would also be small.

- What are the shares of metal-cutting and metal-forming NCMT's in imports? Normally cutting MT's should outnumber the forming but is Finland a normal case?

- Heavy and small NCMT's. How many units are heavy and how many are small? In Japan there is example shows a trend towards smaller units but what about Finland?

- Second-hand machine tools? How big is their share of imports? Due to the technological time-lag, traditionally Finland has decades importes second-hand equipment, for example, from Sweden, which has up-to-date MT's.

In table 4 we present the results of MC calculations. Contrary to our expectations, MC's play a major role in Finnish metal-cutting imports. The three-year average share is as high as 34 % in value terms (same proportion as in Japan's production) but in units terms only 16 %. MC imports over the three-year period totalled 471 units and their number is clearly increasing.[7]

Table 4: Import of NC machining centers in Finland 1988-1990. Number in units, value in FIM (millions) and share in %.

	1988	1989	1990	Total
Number of MC's	140	134	197	471
Value	76	72	135	283
MC's share of metal-cutting NCMT's, %				
In number	16	13	21	16
In value	37	29	35	34

Source: TKC Intel calculations

[7]. This same conclusion was made already earlier. It was stated that FMC/FMS density in Finland is at the top of all industrial countries (The FMS number was compared to engineering industry investments). See: Mieskonen 1989.

Table 5: Structure of imported NC machine tools in Finland 1989. Figures in units.

	Heavy	Small	Total
Metal-cutting			
New	626	290	916
Scond-hand	72	54	126
Sub-total	698	344	1042
Metal-forming			
New	46	523	569
Second-hand	-	243	243
Sub-total	46	766	816
All MT's			
New	672	813	1485
Second-hand	72	297	369
Grand total	744	1110	1854

Source: TKC Intel Ltd estimates based on Custom statistics

In import statistics we can find 17 product groups where NCMT's are dominant. According to the average unit price, each group can be divided into heavy and small NCMT's. In our classification heavy NCMT's have an average price of over 300.000 FIM and small units a average price of 100.000 FIM. Calculations concern 1989 imports and based on them, nearly 60 % of all NCMT's are small units (table 5).

The balance between cutting and forming NCMT's is almost equal. The Finnish engineering industry has a high demand for metal-forming NCMT's, which is very exceptional and a result of engineering industry production (see also the next section). Because forming MT's are usually small, it also affects size calculations.

We have set a "shadow price" for imported NCMT's which is equal to the price of new NCMT's. Based on the "shadow price", we can calculate the share of second-hand MT's, and further, turn this estimate into unit numbers. The "Shadow price" for metal-cutting NCMT's was 75 FIM per kg and for metal-forming NCMT's 70 FIM per kg (Probably the shadow price for metal-forming MT's is too high, which affects the results).

According to our calculations, Finland imports a high number of second-hand machinery. This is a sign of the technological time-lag or a sign of a thin local market for second-hand MT's. The share of second hand metal-forming machinery is 30 % in units. This is not a very surprising result knowing the keen demand for forming

NCMT's. In imports of metal-cutting NCMT's the share of second-hand equipment is only 12 % in units.

Finnish metal working machine tool industry

Finland produced metal-cutting MT's for local consumption until the 50's to supply machinery for the war-reparations to the Soviet Union. When the trade channels to the West were again established, many well known firms like Tampella and Strömberg switched over to imported MT's. Only a few firms like Valmet stayed in the metal-cutting business to safeguard local arms production.

The modern MT industry in Finland was founded in the 70's while new metal-forming firms contributed to volume growth. In the 80's the increase continued thereby doubling production volume. The remaining firms and newcomers give the industry its typical outlook. A feature that stands out is that, more than any other country, the Finnish MT industry has concentrated on metal-forming MT's, according to the American Machinist list of 36 nations.

Two strong factors have given local MT demand its shape. One is the sizable steel plate and sheet production by Rautaruukki and its manufacture of other steel products. A second factor has been the wide ship and off-shore oil platform production, which is mainly metal-forming work.

On the MT industry side, skill factors have also been crucial. Manufacture of metal-forming MT's is much easier than metal-cutting, where sound knowledge of technology and state-of-the-art sub-contractors are nesessary. Firms involved in NCMT manufacture need also a three times greater R&D effort than companies manufacturing conventional MT's.

Table 6: Metal-working machine tool producers in Finland 1989.

Factory size	Factories
Persons	Number
5-9	5
10-19	9
20-49	25
50-99	7
100-199	4
200-499	1
over 500	2
Total number of workers	3442
Total number of factories	53
Average factory size	65

Source: Industry statistics (1989). Includes factories with more than 5 persons.

A big share of the national market is not guarantee, of course, of success for a firm in the MT industry . Typically the firms in the industry are small and the range of MT types is wide. About 30 basic MT types are produced in various sizes and for many special applications. Thus Finland's 0.3 % share of world MT consumption and 0.1 % share in MT production is not nesessarily a hindrance but not also a plus. As seen in table 6, an average factory in Finland employs 65 persons. The biggest companies in the industry correspond well to the international average-size (120 in Europe) and many of the small MT firms are concentrated in MT repair.

Finnish NCMT production was started in 1977. The industry automation division of the Valmet company introduced the Valmet Multiway CNC8 machining centre for which it had developed its own numerical control. Tractor manufacture at home and abroad within the same company gave a boost to the development of special purpose MT's. In the mid 80's half of all metal-cutting MT's were equipped with a CNC unit (Luukkanen 1985), Valmet has subsequently directed its efforts to FM systems. In the 80's Valmet bought two small MT firms in West Germany and has a co-operation agreement with a Japanese MT producer.

In 1983 the Jaromet company, then a division of the Nokia company, developed its first metal-forming MT, which had a Swiss CNC unit (Heidenhein). In the mid 80's about half of the MT's shipped had a

CNC unit. Lillbacka engineering workshop, now also an owner of Jaromet, has grown into a large metal-forming MT company in Finland. The company developed punching and sheering lines which had a German Sinumeric CNC unit. Today Lillbacka is the biggest producer in the Finnish MT industry.

Table 7: Machine tool production and export in Finland in 1970-1990. Value in FIM (millions) and share of NCMT's in %.

	Production value		NCMT	Export value		NCMT
	Total	NCMT's	share	Total	NCMT's	Share
1970	4.2	..	..	1.6	..	..
1975	34	..	..	6.3	..	..
1980	68	22	32	41	11	27
1985	157	48	31	177	24	14
1988	246	145	59	172	47	28
1989	295	179	60	187	107	57
1990	324	210	65	273	142	52

TKC Intel Ltd estimates

The development of the Finnish MT industry is presented in table 7. Production of NCMT's has grown faster than average due to their

increasing share in total production and exports. Market factors abroad and at home have thus changed the production structure radically in five years. In 1990 the value of NCMT production was about FIM 210 million or 65 % of total. In 1988 the production value of metal-cutting NCMT's was FIM 66 million or 45 % of total and in 1989 only FIM 61 million or 34 % of the total. Thus dominnance of metal-forming NCMT's is clear.

In the last few years production has been directed towards the domestic market where demand for all kind of MT's has been high. In exports NC technology is a prequisite and without it there will be no success. Exports to the EC, EFTA and US markets are about equal in value. The traditional market of the Soviet Union has been lost.

The number of NCMT's produced or exported is difficult to estimate, since the value includes also big FM systems costing over FIM 10 million. Thus value of production or exports is a better measure of development. According to our estimates, in 1988 exports totalled 190 units (of which 38 were second-hand), in 1989 some 300 units (22 second-hand) and in 1990 about 170 units (15 second-hand). Exports also include new imported units which are part of bigger FMC/FMS systems.

Conclusions and forecast

The diffusion of NC technology is taking its last steps in the OECD countries. In the next few years all the main MT units are equipped with a CNC unit. All countries will try to make full use of new technology and to get a competetive advantage to raise their productivity. In some countries like Britain, government funds are directed to small and medium-sized firms to support NCMT investment (this could be also a model for Finland). In western countries it will take five more years for full NCMT penetration, i.e. to reach a 90 % share of the MT market (in value terms).

Finland seems to have a time-lag in use and manufacture of NC technology and we have to wait until the year 2000 before full penetration is achieved, but this is not the complete picture. Finnish engineering industry is a heavy-user of metal-forming machine tools and NCMT's in particular. Metal-cutting MT sales have comprise a large share of machining centers, which indicates a high degree in automation.

The MT industry in Finland is very small and has had a minor impact on investments in and sales of NCMT's. Like the engineering industry the production profile indicates that, more than any other country, Finland has concentrated on the manufacture of metal-forming MT's. The present recession in the engineering industry will affect imports of NCMT's. We could estimate a 40-50 % decrease

in the next two years and recovery in the mid 90's to last year's sales figures.

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