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THE USE AND PRODUCTION OF NUMERICALLY CONTROLLED MACHINE TOOLS IN ARGENTINA

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INTRODUCTION

With the development of the microprocessor, the chip, the electronics sector has become regarded as a key technological sector in the OECD countries. Massive government intervention programs have been designed, not only for the production of these integrated circuits, but also for their incorporation into products e.g. robots and for the diffusion of microelectronic controlled processes.

It is the all-pervasive character of the chip that has justified these programs. In particular, it is the microprocessor's low cost, high reliability speed and flexibility in information processing; these attributes have been perceived to have broken down some technical and economic barriers to automation in many industries and services.

Hence, any system which involves the processing of data, decision making, control of systems and equipment, in short, any task involving logic is a candidate for the application of microelectronics. A list (not exhaustive) of these tasks includes [1].

1. controlled movement of materials, components, products
2. control of process variables
3. shaping, cutting, mixing, moulding etc. of materials
4. assembly of components into sub-assemblies and finished products
5. control of quality at all stages of manufacture by inspection, testing or analysis
6. organisation of the manufacturing process including design, stock-keeping dispatch, machine maintenance, invoicing and the allocation of tasks.

Given the perceived importance of microelectronics for downstream industries, it seems fruitful to pose a number of question regarding the impact this change will have on developing countries. Without attempting to be exhaustive we may identify two interrelated problems.

Firstly, what is the pattern of diffusion of microelectronic-based processes in developing countries? Are there any particular obstacles to such a diffusion, and what would be required at the level of technological and industrial policy in order for these countries to reap the benefits from this 'revolution'?

Secondly, for the developing countries with an incipient capital goods sector we may ask how the 'learning' process, or the process of capability generation, has changed with the introduction of electronic control systems. Will the Newly Industrializing Countries (NICs) have the capabilities to incorporate microelectronics into capital goods? Is it socially profitable to foster capabilities in this field in these countries?

To study these questions, we have chosen numerically controlled machine tools as a case study. The main reasons for this choice are a) the inclusion of electronic control systems to machine tools, e.g. lathes, milling and drilling machines has a relatively long history and one may therefore more clearly see the implications here than in other capital goods. b) the strategic role machine tools has in the capital goods sector.

The paper is structured in the following way. In chapter 2 we describe what the technology is, and what has happened on the technical side. An understanding of this is essential for the rest of the paper. In chapter 3 the process of diffusion is analysed for the Argentina case. In chapter 4, we look in detail at one Argentinian firm which has moved into production of a Numerically Controlled Machine Tool (NCMT). Finally, in chapter 5, we draw some conclusions for technology policy.

2. TECHNICAL CHANGE IN MACHINE TOOLS

Production in the engineering sector[2] may be divided into two main areas characterized by different technical conditions of production. The production of long series of standardized products, e.g. cars, has for some decades been subject to mechanization efforts. Large production volume justifies extensive development of expensive, special purpose built and inflexible equipment.

The second area is characterized by batch production. With relatively low levels of standardization of the products, the demand for flexibility in the production system is very high. Massive investments in special purpose, "stiff" production systems, do not make economical sense. Instead, batch-production has historically been undertaken by a set of standard, multi-purpose and hand operated, machine tools. This has ensured a high degree of flexibility but at the same time, the advantages of automated systems have not been reaped.

In the operation of a machine tool one may identify the following sequence[3].

1) The workpiece is transported to the machine
2) The workpiece is fed into the machine and fastened
3) The right tool is selected and inserted into the machine
4) The machine is set (operation speed etc)
5) The movement of the tool is controlled
6) The tool is changed
7) The workpiece is taken out of the machine
8) The workpiece is transported to another machine tool or to assembly

Traditionally, in batch production, all these elements are performed manuly. The consequences are that batch production is associated with very high costs. High quality is difficult to achieve; it is very tedious to set the machine and change the tools so the level of utilization of the machine tool is very low. Furthermore, very skilled people are necessary to perform these functions.

which optimises the whole manufacturing process. Thus, once a computer controls a machine tool, the performance of several machine tools can be integrated, not only with one other, but also with design - an integration between Computer Aided Design and Computer Aided Manufacturing and Computer Aided Production Planning may be achieved.

2.2. Implications for the nonelectronic parts of the machine tool

We have, hence, had fast technical change in the control side of the machine tool. What effects has this had on the rest of the machine tool? One may identify three, partially opposing effects [8].

a) The mechanical content has been reduced in favour of electrical and electronic solutions. For example, in the main spindle drives, large mechanical gear-boxes with hundreds of parts have been replaced by a variable speed DC motor. There has been a simplification due to fewer moving parts.

b) On the other hand, the demand for high quality on the remaining parts is much higher, in particular in relation to the frictional behaviour of the parts and the servomechanism[9] as well as the demand for reliability and durability[10]. As a result, the design of the mechanical parts has been very much influenced by developments in the control system. As one report[11] states:

"In the early days of numerical control it was not uncommon to fit NC systems to existing machine tools as distinct from machine tools designed and made for use with NC. Retrofitting, as this is called, did produce some successful NC machines but it also produced many unsatisfactory ones. The mechanical characteristics of conventional machine tools made prior to 1955-60 - stiffness, frictional characteristics of slideways, and feed drive systems - were often unsuitable for use with NC and retrofitting of this kind is now unusual except for some of the simpler and cheaper NC systems".

c) The design process has become more complex. Other disciplines, than mechanical engineering, have entered the design task such as: electrical engineering, electronic and lately small computer techniques and servo-techniques. As a result, machine tools are no longer designed by inventive mechanical engineers but require a team with a multidisciplinary approach.

In conclusion, whilst there has been some simplification due to a reduction in the number of parts, the skill requirements for both production and design have increased with the introduction of electronic control-systems.

2.3 Economic aspects of this technical change

The technical advances in numerical engineering and in the design of NCMTs have led to a wider diffusion at these machines. This can be seen in table 1 in the case of Sweden and the U.K.

Table 1.
Consumption of NCMTs in Sweden and U.K. in % of apparent consumption* of all machine tools

	Sweden	U.K.
1974	12.4	7.3
1975	18.0	8.3
1976	15.6	8.8
1977	19.1	9.7
1978	24.5	12.7

*) apparent consumption is equal to production - export + import (in value terms)

The trade data for Sweden does not include various specialized machinery such as CNC grinding machines. Hence, the figures are minimum figures.

Sources: For Sweden - Ljung (see reference 12). For UK - elaboration on Machine Tool Trades Association and Metalworking production: Machine Tool Statistics, 1980.

We should note however, that the diffusion of CNC is mainly restricted to lathes, milling, boring and drilling machines. In the case of Sweden, the share of numerically controlled machines in the apparent (i.e. production minus export plus import) consumption of these types of machines rose from 28.7% in 1974 to 44% in 1977[12]. This data is a better reflection of the growth in importance of NC today.

Given the decrease in price and increase in reliability of the CNC system, the wider diffusion of this flexible automation can be explained by various factors;

1) The labour saving nature of the NCMTs, and in particular their saving on skilled labour. As one report points out[13]: "The main incentive for management to purchase NC machine tools in the last several years is their potential for increasing the output obtained from a given number of skilled workers".

2) The flexible character of the NCMTs means that capital embodied in work in progress (through faster throughput) and inventory (through reductions in the batch sizes) may be substantially cut. This is extremely important as, for example, in the case of the Swedish mechanical engineering sector in 1977, 30-35 billion crowns were tied up in goods and only 15-20 billion crowns in machines and buildings[14]. Thus, capital rationalisation seems to have been a major factor in determining the diffusion of NCMTs in Sweden. Indeed, one leading representative of the management said in 1975 [15]:

"The decisive argument in favour of robots and NC is that the turnover speed of the total productive capital is increased, not that the wage costs are cut".

3) The existence of a flexible manufacturing system which can cut the lead time has been noted to play an increasingly important role in firm strategies in the face of increasing competition[16].

4) Increased machine utilization through faster changeover time - 4 seconds have been mentioned - and a reduced need for jigs, fixtures and tools (the savings in tools represented 26%(!) in a 'typical' case[17]) will to some extent (fully?) counteract the increased initial capital expenditure of the new machine (an NCMT may substitute for between 3 and 8 traditional MTs).

5) The introduction of NCMTs is seen in the context of a long term strategy of moving towards fully automated mechanical engineering, including not only production but also production planning and computer aided design (CAD).

6) Finally, automatic positioning and control allows for greater precision and uniformity of quality.

Clearly, several of the factors mentioned are not only important to developed countries but also to the less developed ones which have a substantial and growing metalworking sector. This is particularly so since the advantage of NCMTs lies primarily in the production of small batches i.e. production for small and shifting markets.

One would, a priori, therefore suspect that these types of automated machine tools may also find a market in the most technically advanced LDCs such as India, Republic of Korea, Taiwan, Argentina, Brazil and Mexico. Some preliminary investigations show that this is the case.

3. THE DIFFUSION OF NCMT IN ARGENTINA

In this section we will analyse the diffusion of NCMTs in Argentina in detail and, when data is available, make comparisons with other NICs and developed countries.

3.1. Some comparative data between NICs, U.K. and Sweden

In table 2 (a) and (b) we can see that there is a substantial and growing demand, even though it is less than the absolute demand in Sweden and U.K., for NCMTs in a range of NICs. It is important though to set this absolute demand in relation to total demand for machine tools to get an idea of the magnitude of the use. In table 3 we can see how the apparent consumption of NCMTs as a proportion of total machine tool consumption has changed in a set of countries.

We may note from these tables the very high relative values in both Argentina and the Republic of Korea. They are actually equal with the U.K.

We should also note the high absolute values in both Brazil and Korea in 1978 (80% of Sweden) and in Korea in 1979 when it is very likely that Sweden was surpassed in terms of absolute demand for NCMTs. Clearly, this indicates a sharp increase in the rate of diffusion in NICs as compared with the historical rate of diffusion of NC in Europe in the 1960s. This is worth nothing since NCMTs was a technique with a relative fast rate of diffusion as early as 1969 indeed, with recent advances on the control side, it seems as if NC technology has taken as large step towards maturity as a process.

This fast diffusion of flexible automation to NICs opens up the possibilities that these countries may in a few years time start competing strongly in engineering products too. In particular, this is likely to be the case for engineering products with a mature product technology such as electrical motors and high quality standard machine tools, as well as for a wide range of standard components e.g., cogwheels. The export oriented Republic of Korea, may thus have found a way to overcome the restrictions given by its relative lack of skilled labour for a successful move into the more advanced engineering sectors.

Table 2(a) EXPORT* OF NCMT TO SOME NICs - millions of current US dollars

	Argentina	Brazil	Mexico	Taiwan	Rep.of Korea
1974	1.5	7.5	1.6	0.9	0.5
1975	2.8	26.3	2.4	0.5	6.7
1976	3.3	17.8	3.4	3.5	12.5
1977	2.4	17.3	2.0	2.7	7.0
1978	12.2	22.3	4.6	4.1	22.9
1979	9.2	20.8	3.8	10.3	47.1

Table 2(b) CONSUMPTION OF NCMTs in U.K. and Sweden millions of current US dollars

	U.K.	Sweden**
1974	37.2	21.2
1975	52.7	43.1
1976	48.1	32.2
1977	58.6	26.9
1978	102.5	27.6

*) The data refers to exports from: Japan, US, EEC and Sweden. The data are minimum data as the US trade statistics do not identify more than one type of NCMTs. Also, the Swiss export figures are excluded as are the Swedish figures for 1976. If one assumes that there is no internal production of NCMTs in these NICs, which is not entirely correct but we have not data on that value of production, table 2a and 2b are compatible.

**) The Swedish data excludes specialized machinery such as CNC grinders as these are not identified in the trade statistics. In 1978 Sweden produced CNC grinders, planers etc for roughly 6 million dollars.

Sources: Table 2a. for the EEC data, Eurostat: NIMEXE Analytical tables of foreign trade; For Japan: Japanese Ministry of Trade; For US: US Department of Trade; For Sweden SCB: Sveriges Officiella Statistik: Statistiska meddelanden. Currency conversion rates are from OECD Economic Outlook.

Table 2b. See table 1.

Table 3. CONSUMPTION* OF NCMTs AS % OF APPARENT CONSUMPTION OF ALL MACHINE TOOLS (in value terms)

	1974	1975	1976	1977	1978
Sweden	10.4	18.0	15.6	19.1	24.5
U.K.	7.3	8.3	8.8	9.7	12.4
Brazil	4.3	n.a.	4.6	3.9	4.9
Argentina	2.8	4.5	4.2	2.4	11.3
Mexico	0.7	n.a.	1.7	2.3	5.1
Taiwan	2.1	n.a.	8.5	6.2	4.5
Rep. of Korea	n.a.	n.a.	12.5	3.8	9.3

*) Please see qualifications from table 2(a).

Sources: Sweden and U.K.: See table 1; For the remaining countries table 2a and American Machinist's yearly data on world consumption of machine tools.

3.2. Diffusion in Argentina at present[18)]

For Argentina, the data suggests that there was a discontinuity in the process of diffusion and data on the diffusion of NCMTs in terms of absolute numbers is consistent with this.

In table 4 we can see how the number of installed NCMTs has grown over time in Argentina. Note that the data for 1980 is for January-September only.

Table 4
Number of installed NCMTs in Argentina

—1975	15 units
1976	8 -"-
1977	22 -"-
1978	32 -"-
1979	47 -"-
1980	63 -"-

Source: Interviews with suppliers of CNC equipment.

Thus, the high figures in table 2a for 1978 and 1979 seem not to have been an oddity but reflect a new phase in the diffusion process.

Why then this pattern of diffusion? It may depend on changing potential for the profitable application of NCMTs and/or on a better realization of an existing potential. Apart from technical demands of production, i.e., need for flexibility and high quality, which will be dealt with below, two factors may have determined a shift in the potential for NCMTs during this time period (1975-80).

a) We noted earlier that a reduction in price of the NC equipment has taken place and that the reliability of the equipment has been enhanced. The cut in price of the less flexible types of equipment, sold mainly by Fanuc/Siemens and General Electric, has been particularly important for the diffusion of relatively simple lathes where the mechanical parts are less costly.

b) Change in relative prices: As we mentioned on p. 8, NCMTs substitute for skilled labour, a factor of production which is scarce in most economies. One would then expect that changes in the salaries of skilled labour and the price of new machinery would affect the latter's rate of diffusion. Due to an extraordinary policy of the government to overvalue the peso, there has been a tremendous shift in relative prices. Detailed data from one machine tool firm - data which is supported by other data covering the whole metalworking sector[19)] - shows that between 1975 and 1980, the relative prices changed with 220% (!) in favour of imported equipment!!

As far as the realization of this potential is concerned, two factors are critical:

a) Availability of skills to use NCMT: There are four types of skills which are absolutely essential for a diffusion of new technology. These are: maintenance of both the electronic and mechanical parts, programming skills, skills to realize the need for NCMTs and skills to utilize NCMTs.

The CNC systems is usually maintained by the local branch of the electronic firm which produced it e.g. General Electric or Siemens and not by the supplier of the machine tools which may be a local firm. An electronic firm needs between 15 and 30 units installed in an economy in order to justify employing a qualified engineer for the maintenance. With a slowly growing market for NC machine tools, and with a multitude of brands, problems of a deficient supply of this types of skill must exist and certainly have done and still do in Argentina. Of course, with a faster growing economy, the anticipation of a NC supplier may be such that he takes the initial costs of overheads.

We noted earlier that the mechanical parts of the machine tool have been altered significantly in response to the opportunities of NC. This has also affected maintenance problems. Thus a similar problem exists also with the mechanical parts even if it is not so accentuated.

One may also note that the division of labour between the users and suppliers of NCMTs has altered very little over time. Most importantly, this means that the teaching function of the supplier is still extremely important. This refers to both programming, where slight progress is taking place, and most importantly, to the utilization of the new machinery. This refers to production planning, tool choice etc. which alters signficantly with the use of NCMTs. One may also note that there is only one consulting firm in the field of teaching and programming.

Therefore, the initial very slow rate of diffusion could partly be explained by a deficient supply of all the above types of skills. In 1977-78, two more CNC firms opened up in Argentina and this could partly explain the discontinuity in the rate of diffusion from these years. However, it is also important to note that the establishment of a maintenance function, not always covering teaching, of these firms was in response to the demand from their customers who had seen the particular brands in exhibitions in Europe. Thus, there has been and still exists a lack of will to invest in the quite expensive overheads related to the service and maintenance functions.

b) Public investment: There is an established relationship between growth in the size of the market or rate of investment and the introduction of new technology. However, the market for Argentina's metalworking sector has been constant since 1974[20]. Thus, there has been, on an aggregate level, very little stimulus for investment in new equipment in the Argentinian economy. However, whilst the private sector has reduced its investment since 1974 the public sector investment has become much more dynamic and grew by 67% between 1974 and 1978[21]. In particular investments in the petroleum and both hydro and atomic power sectors have generated a demand for NCMTs among the supplier of parts and components e.g. valves and pumps. Indeed, between 35 and 40% of the installed NCMTs are found in firms which directly serve sectors experiencing heavy public investments[22].

3.3. A discussion of the future rate of diffusion in Argentina

Whilst the present rate of diffusion is fairly high, it seems important to ask whether it will continue or not in the future. That is, what is the potential for NCMTs in Argentina and will it be realized?

Concerning the potential for profitable application of NCMTs, it was mentioned above that the advantage of NCMTs lies in their flexibility, i.e., production for small and medium series and in their high quality performance.

This is reflected in the sectoral distribution of NCMTs in both the U.K and Sweden. In table 5 we can see the dominance of non electrical machinery - a typical small batch production sector - as a user of NCMTs. We may also note the relatively low demand for NCMTs in the transport sector, ISIC 384. This is due to the existence of longer series e.g. in car manufacturing, where special purpose machinery is most advantageously used. The subsectors using NCMTs in 384 are mainly spare parts production, gear and engine production and aerospace industries.

Table 5 The distribution of NCMTs by sector in Sweden and U.K. (% of numbers)

Sector*/ Country	Sweden** (1979)	U.K. (1976)
381	22	11
382	42	46
383	19	24
384	13	18

*) 381: Manufacture of fabricated metal products, except machinery and equipment
382: Manufacture of machinery, except electrical
383: Manufacture of electrical machinery, apparatus, appliances and supplies
384: Manufacture of transport equipment

**) Sector 385 (instruments etc) and shipyards are not included in the analysis. Together they have the remaining 4 %.

Sources: For Sweden - Ljung (reference 12). For U.K.- N. Isherwood and P. Senker (reference 13).

Given these "natural" differences in demand for NCMTs between sectors at 3 digit level, it is revealing to compare the relative importance of these industries in Argentina and Sweden. In table 6 we can see that

a) sector 384 is relatively more important in Argentina (43-44%) than in Sweden (25%).
b) sector 382 is relatively less important in Argentina (19-23%) than in Sweden (33%).

Furthermore, we can see that, roughly speaking, the relative importance of these sectors have not changed during a ten year period in Argentina.

Hence, there is an important structural difference between the Argentinian metalworking sector and the Swedish one.

Table 6

Relative distribution of value added at three digit sector level in Argentina and Sweden

	Argentina		Sweden
	(1963)	(1973)	(1977)
381	20(24)*	22(22)	20.9
382	21(20)	19(23)	32.8
383	13(13)	16(12)	20.8
384	46(43)	43(44)	25.4

* The figures in paranthesis are 1960 prices whilst the other are in current prices.

Sources: For Argentina, Banco Central, unpublished data and 1973 years Census (provisionary data). For Sweden, Sind 1979:11.

Having established the importance of structural differences in assessing the future absolute demand for NCMTs, we also need to look at the use of NCMTs at the sector level.

Table 7

"Intensity"*in use of NCMTs in Argentina and Sweden by sector in terms of number of NCMTs over value added

Sector	Sweden	Argentina
381	444	-***
382	543	128 (142)**
383	388	-***
384	207	39 (53)**

* The data was calculated by changing crowns and pesos to dollars and then multiplying the ratio of NCMTs over value added with 10^6. The exchange rates used were 0.83 peso in 1960, 11.29 in 1973 and 4.48 crowns for a dollar.

** The figures in paranthesis refer to the use of 1960 prices, instead of 1973 years prices.

*** Less than 10 NCMTs were utilized and the ratio was not calculated. The value added was from 1977 in the case of Sweden and the number of NCMTs from 1979 in Sweden and 1980 for Argentina (only to August).

Sources: For Argentina, Interviews with suppliers ofCNC systems and the same sources as for table 6. For Sweden; Ljung (Reference 12) and Sind 1979:11.

In table 7 we can see that:

a) the diffusion of NCMTs in Argentina is for all practical purpose restricted to sectors 382 and 384.
b) in sectors 382 and 384 the "intensity" in use of NCMTs was 4-5 times higher in Sweden than in Argentina.

From this data it is however extremely difficult to conclude that in, say sector 382, the stock of NCMTs in Argentina may be increased by a factor of 5 (to 550 units) in the near future. First of all, the potential for NCMTs is not stable but alters as a response to technical change and to changing relative factor prices.

Secondly, the technical demands from production differs between countries. For example, the electrical machinery sector in Sweden is relatively intensive in its use of NCMTs, whilst the same sector in Argentina uses practically none. This can probably not be explained fully by different factor prices (as other sectors use NCMTs in Argentina), nor by a different rate of technical change in machine tools, as the same types may be used in both sectors. Instead, it is probably so - as was indicated by several interviewees - that the technical demands of production were different in Argentina than in Sweden. Whilst in Argentina the output of sectors 383 e.g. electrical motors and generators etc, is less complex and are produced in larger series, the production in Sweden in concentrated on more complex items which are more advantageously produced with NCMTs. That is, larger and more complex motors and generators, but perhaps primarily complex telecommunication systems (LM Ericsson). Hence, without an analysis at product level, it is very difficult to estimate the potential intensity of use of NCMTs.

Thirdly, whether the potential will be realized is another matter which primarily depends on: a) the availability of the lower level capabilities dealt with above and b) the rate of investment. Concerning the first factor, it seems probable that the present growth rate will go some way in establishing a service and maintenance structure. Furthermore, it will diffuse information about NCMTs and allow for an accumulation of experience in using NCMTs, which is so essential for further diffusion. Concerning the latter point, the present (private) investment crisis in Argentina seems to be a function of governmental policies to restructure the economy through drastically reducing tariffs. The outcome of this policy is impossible to speculate on and it seems reasonable too that government investments cannot continuously create a sufficient demand. Today, the majority of the NCMTs in sector 382 serve the needs of public investment programs.

In conclusion, whilst the present rate of diffusion is high, the structure of the metalworking sector in Argentina, will, if it does not alter, probably put a relatively low ceiling to the potential use of NCMTs. At the moment, though, the main problem is to realize the present potential in a situation of investment crisis and shortage of very critical skills.

4. THE PRODUCTION OF NCMTs IN ARGENTINA

NCMTs consist of two parts; the control equipment which is either a mini- or a microcomputer and the mechanical/electrical parts. As these parts normally are produced by separate firms and the problems for technology policy are very distinct for the two parts, we will discuss them separately.

4.1 Is the production of Computer Numerical Control Systems feasible in Argentina?

Production of CNC systems is very different from producing integrated circuits. This is quite essential to establish as they are often confused. Whilst the production of 'chips' is concentrated in a few firms in the world - often heavily fostered by governments - the task of applying these chips to industrial use via CNC system is spread amongst a wide range of firms. In the world there are nearly 100 brands of CNC equipment [23], and in Scandinavia alone there are at least four different firms producing CNC systems.

The main explanatory factor for this wide dissemination of knowledge of how to produce CNC systems is that the main part (roughly 70%) of the production costs consists of programming costs. The knowledge required may therefore be embodied in a limited number of people - one firm started with ten qualified engineers - who design the software. The assembly of the chips, which are bought in, is the relatively less skill intensive part of the operation.

Even though development costs are heavy, there seems to be little appropriation or monopolization of this software design knowledge. The scope for local production in NICs may therefore seem great. However, as we described above, there are two main types of CNC systems. One which is flexible and one less flexible. It is necessary to look at the programming process for the two types of systems in order to fully understand the scope for local production.

In the more flexible systems, the programming is done in three phases. Firstly, the computer is 'taught' the art of mathematics. Secondly, a basic program, which contains functions particularly important for machine tools in general, is designed. Lastly, the CNC is given instructions reflecting the requirements of a particular class of machine tools e.g. a particular type of machining centers or of a specific customer who produces a specially designed NCMT or production system. Hence, the production of this type of CNC system is designed to meet specific users' needs and often they are linked with large, more complex NCMTs.

The vast majority of needs are however not specific, and a higher degree of standardization of the software is therefore the main advantage of the less flexible CNC system. Thus, in these systems, possibilities for custom design do not exist. These CNC systems are usually applied to cheaper and less complex NCMTs, in particular to smaller lathes.

The international market is very different for these two types of CNC systems and therefore the possibilities for local manufacture differ. During the last 3-4 years, one has noted a strong movement towards - as price competition is still fierce - an international oligopolistic market for the less flexible systems.

Today, three firms, one Japanese, one German and one North American, dominate the world market. This dominance can be explained both by scale advantages arising from the standardization of the software and from agressive marketing strategies.

The situation is very different for the more flexible systems. Scale advantages are less important here due to the custom designed nature of the systems. Instead, links with machine-tool firms are essential for survival. Conversly, local machine tool firms producing more complex and less standardized NCMTs need to have links with a CNC producer for the development of the software.[24)]

The implication for NICs depends therefore on the type of NCMTs they are producing or planning to produce. In Argentina, The Republic of China and the Republic of Korea there are all in all 8 local firms producing NCMTs.[25] However, they mainly produce lathes, and more importantly, smaller lathes which typically use the less flexible CNC systems. Hence, there is no or little demand for the more complex custom designed CNC systems and there will probably not be any in at least the medium term. On the other hand, the international market for the less flexible CNC systems is already dominated by the three big firms and it would be extremely costly to try to break into that market. Hence, at least in the medium term, it would be unwise for any of these countries to try to establish a local competence in this field.

4.2 The production of the non-electronic parts in Argentina

important factor determining whether a country or firm may have a comparative advantage in producing a good, is skill requirements.[26] In an earlier section we noted that the skill requirements in both the production and design of a NCMT are more advanced than with standard machine tools. Given the growth in the demand for NCMTs in some NICs it seems fruitful to analyse empirically if and how any machine tool firms in NICs have taken the step to produce these more advanced machine tools and adapt themselves to the new electronic era. We have chosen Argentina to begin with as it has a long tradition of machine tool production and it satisfies roughly 50% of its consumption with its own production.

Argentina has about 100 machine tool firms.[27] The majority of these are very small and are still at quite a rudimentary stage in their technological development. However, there are a limited number of firms which have taken the step into more advanced production. According to Cortez[28], only 8 firms have reached a stage where the design is not done by copying imported equipment, but where qualified engineers are included in the design team, and where fabrication of prototypes is a systematic activity. Only 1 of these firms has moved into production of NCMT, a CNC lathe.

How can this be explained? First, we have to ask the question why has a NC lathe been developed and not other NCMTs? The reason for this can be found on both the supply and demand side. Whilst there is a substantial production of several types of MTs, it is only in lathes and grinding machines that the supply structure is not atomized. In, say, boring machines 4000 out of 6650 are of a very light type which is not suitable for NC and the rest of the production is divided so that each firm has only about 15% of the market share. With lathes, however, 2 or 3 firms dominate the fairly large market. It is only with such a level of output that it is possible to develop an advanced division of labour in a firm which permits good quality control and the use of precision instruments, process engineering departments etc.

On the demand side nearly 70% (!) of the installed NCMTs are lathes whilst the remaining units are divided between machinery centers, milling, drilling and boring machines. Consequently, only in lathes is there a significant market and a sector structure which allows for a minimum scale for some firms.

Why then only one firm and why this particular firm? Several factors, mainly related to the firm's technological policy seen in an historical perspective, may give the answer.

A) Engineering Design Capabilities: Since the early 1960s, when the firm initiated its first prototype developments [29], the firm has placed very heavy emphasis on product design in its long term technological strategy. This meant that it had, already by 1965, gained a position as technological leader in the Argentinian market. During the last 15 years the firm has thus gradually created a product design capability which is the result of a high degree of 'self reliance' in design. This in turn, has enabled the continuation of self reliance as a strategy.

The transition into design and production of NC lathes began four years ago and has been very gradual. The first step was to buy a NCMT, study it and learn how to use it. During this time the firm also sent people abroad to learn programming.

In the actual product development work, one may separate the mechanical parts and the electro/electronic parts. For the former, which are all (except for the ballscrew) produced inhouse, there were little or no problems during the development work (all in all roughly four man-years were spent on design work). This may seem rather surprising since only 40% of the value of the mechanical parts are the same in their NC lathe as in their conventional lathes. The remaining 60% are very distinct. The ease of solving the problems was due to two factors (a) the two people responsible for the mechanical parts both had between 20-25 years of design experience and, (b) the firm already produced very high quality conventional machine tools. It was, therefore, not too big a step to develop the mechanical parts of the NC lathe. The electro/electronic parts of the machine-tool, i.e. the control system, the motor and the electronic parts of the spindle, are brought in from abroad. The design work here was undertaken by one engineer with only 3-4 years of experience. His competence was created through a gradual process. Firstly, he was responsible for the electrical parts of a copying lathe. These are more complex than in a parallel lathe, which is the main output of the firm. Secondly, he designed and produced a simple form of electronic control unit. The last phase was the NC where he, among other things, designed the whole interface between the CNC unit and the machine tool.

B. Process Engineering Capabilities and Equipment: Equally important in the development of the firm has been their emphasis on the generation of process engineering capabilities, i.e. the skills to know how and when to produce, and the investment in advanced equipment enabling high quality output. At the end of the 1960s the firm invested very considerably in qualified engineers and technicians, and laid the foundations of an elaborate division of labour in design and process engineering which became effective in the early 1970s.

It would therefore be very misleading to overemphasize the importance of product design capabilities in the success of the firm. There are very strong complementary links between the two. These work in many ways: a) Plant layout and production planning skills are necessary in order to fully utilize advanced machinery e.g. NCMT, which in turn is necessary to produce a high quality output. b) An elaborate division of labour with a well developed quality control section is indispensable for the production of advanced machinery. c) Without engineering process skills a firm may not apply such advanced concepts as modular design and group technology which both link process and product design capabilities. Thus the costs and difficulties of taking the step into design and production of NCMTs is determined by the capabilities in both these areas.

C. Modular design: The link between process and design efforts is modular design. That is, the firm strives to achieve as high a degree of interchangeability of parts as possible between its different models. Also in this area, the firm has invested in capabilities. (They started about 12 years ago). As noted above, 40% of the value of the mechanical parts are the same as in their conventional machine tools and this is partly the result of an effort to design the NC lathe so as to utilize modules that were developed earlier. As a consequence, the firm has reduced the minimum efficient scale of output for their NC lathe which is very important in times of great market uncertainty. Hence, here too the previous generation of skills has benefited them today.

D. Design of the NC lathe: It is clear that within the group of NC lathes there are relatively simple and relatively complex types. Factors which determine the degree of complexity are: a) the motor power. The strength of the motor significantly affects other aspects of the design such as need for rigidity in the structure and the type of control system needed. b) accuracy class; and c) the three dimensional shape of the piece that is to be worked upon in the NCMT. The firm has chosen to develop a relatively simple type of NC lathe which - and this is very important - can be produced with the same equipment and organization as the standard lathes. This is a considerable advantage when the market is very insecure and when only a very gradual growth of the share of NCMT in total production is possible .[30)]

Such a gradual introduction of the NC lathe was furthermore clearly dependent on their own design capability;as production with a license would have demanded a different scale of production using other layout and equipment. Indeed this was an important part of their decision not to license. Others were a) an expressed desire to continue their capability generation, something which was perceived to be hindered by licensing and b) the fact that licences do not allow for the continuous need for minor product developments, that is, for the adaption of designs to particular submarkets. c) they would anyway have had to undertake a lot of R&D as the component industry in Argentina is weaker than in DCs.

E. Risk capital: Whilst the technological capabilities are wholly Argentinian the firm is owned by a Swiss consortium which bought it in 1960. This has meant that over time, risk capital has been provided in time of heavy investment and in time of financial crisis. The larger consortium has thus acted as a risk reducer and in many ways substituted for an active State industrial policy. This support is particularly important in an economic environment of extreme fluctuation such as the Argentinian. In fact, today's economic crisis with stagnating investment in conjuction with reduced tariffs may conceivably have the effect of destroying very much of the capabilities in some competitive firms which do not have the support of a larger group.

In conclusion, the central theme of the history of the firm is continuity in the creation of a technological competence, and the dependence of their present success on their historical investment in skills. The full benefits of the previous investment were not reaped until now. Hence, very few of the skills generated both through minor and major process and product developments became out of date. Skill generation and industrial competence have, in this case, been a cumulative process where it is very difficult to identify the beginning and the end. This is quite important as it means that a technological strategy of a gradual acquisition of skills is feasible in this sector.

4.2.1 Some notes about future prospects

Three factors seem important in deciding the future success or failure of this enterprise, which has recently started a batch of 7 NC lathes.

In Europe the demand for NC lathes is increasing as a proportion of the total NC market. For example, in Italy, the share of NC lathes of the total number of installed NCMTs rose from 15% in 1972 to over 52% in 1978.[31] Furthermore, in the UK industry, there is an increasing demand for smaller NC lathes suitable for lighter metal removal.[32] In general, the enormous increase in overseas sales of Japanese NCMTs has been due to their success with the smaller NC lathes. For example, the unit price of the Japanese NC lathes exported to UK in 1978 was 36,370 pounds whilst the German was 83,000 pounds.[33] Hence, the Argentinian firm has developed a type of lathe for which there ought to be a growing demand, not only in Argentina but in Brazil and other Latin American countries.

The tremendous success of the Japanese in smaller lathes - in 1979 2,357 units were exported to the US!! - may however pose a threat to newer, smaller entrants in the field. For example, the British have pumped money into Herbert to develop the 'Huskie', a small CNC lathe, which may have considerable problems with the Japanese competition. In 1979 the Japanese exported 368[34] NC lathes to the UK which is 28% more than the total sale of NC lathes in the previous year. However, as yet the Japanese have not entered the South American market but with the recent growth in that market it would be surprising if they did not. Indeed, several interviewees mantioned that the Japanese were setting up a sales office with maintenance and service personnel (August 1980).

A basic difficulty in NICs seems to be a lack of vertical disintegration. This process is continuously going on in DCs and the machine tool firms here are tending to become design offices [35] relying on an extensive subcontracting network. With a small market, an elaborate division of labour is not possible and the parts and components either have to be imported, with all the problems of costs and slow delivery, or be produced inhouse with problems of lack of scale advantages. With a high degree of integration, scale becomes very critical to attain a low price. For the Argentinian firm, an increase in production from 15 units/year to 50 would cut their price from 110-120 thousand to 85-90 thousand dollars. This is particularly critical as the Japanese and others too, already enjoy the benefits of scale from mass production. Hence, the development of the market in the next year or two seems vital for the success of the local Argentinian firm in particular.

5. <u>CONCLUSIONS</u>

The electronification of machine tools is progressing fast. Flexible automation in the engineering sector in developed countries is looked upon as the key to future competitiveness. However, the character of the technical change with its savings in skilled labour, working capital and the increase in machine utilization etc appears to be equally relevant to a set of NICs with a growing metal working sector.

In the introduction we asked questions about a) the process of diffusion of NCMTs in NICs and b) how the 'learning process' in the production of machine tools alters as they are changed over to being electronically controlled.

To try to answer these questions, it is helpful to look at a list of some of the main skills associated with NCMTs:

1. Production and design of integrated circuits
2. Design and production of the hardware of the microcomputer
3. Designing the software in the microcomputer
4. Design and production of the machine tool
5. Identifying the need for NCMT
6. Reorganizing production planning etc. i.e. utilizing the NCMT
7. Programming at plant level
8. Repair and maintenance of both NC equipment and the mechanical parts

The first conclusion we can draw is that the diffusion process in Argentina has been characterized by a significant deficit in the skills required for incorporating and utilizing the new technology (skills 5-8 on the list). For countries which enter this first phase of diffusion it seems justified to a) support firms performing the teaching function and diffuse information and b) rectify the very serious problems of scale economies in the maintenance and technical service function. As the demonstration effects, both negative and positive, are strong, a good (a bad) supply of these skills clearly has cumulative effects for the diffusion process. In other words, significant externalities exist and should be the object of a technology policy. Programs designed to increase the rate of diffusion already exist in several OECD countries.

The second conclusion is that the time has not yet come for a local production of the control units. Instead, any government program in the electronic sector should be fostering skills in sectors where custom designed solutions are required.[36] However, as the development in numerical control systems is accompanied by a strong tendency towards standardization, this should not create any serious disadvantages to local machine tool firms moving into production of more simple types of NCMTs.

As far as a technology policy for the local machine tool firms is concerned we may identify three factors which determine the social profitability of production of NCMTs in Argentina.

Firstly, the knowledge of how to design and produce NCMTs. In the case of NCMTs, it is freely available and is held by hundreds of firms in the world. Hence, there is no way developed countries can control the flow of knowledge in this field. Instead, the opportunities for local production are considerable.

Secondly, in at least one, and probably one or two more, firms, there exists a technological capability which is far superior than in the rest of the sector. Hence, it would be meaningless to say that Argentina has or has not a potential for comparative advantage in the production of NCMTs, some firms may have, others not. This implies that a technology policy would have to have some selective features.

Thirdly, the size of the local market is clearly very important for deciding on the generation of production and design capabilities. In fact, the normal case for machine tools seems to be that firms develop capabilities in the types of machine tools which are demanded by local firms, and only after local demand is saturated do they expand to external markets. A very considerable problem in the design of an industrial policy for this sector is that the potential of the local market is extremely difficult to estimate due to the heterogenity of the products in the engineering sector. What may be concluded though, is that any intervention policy for the generation of capabilities in NCMTs production has to be coordinated with the overall industrial policy as the structure (at product level) of the internal market is the basic determinant of the potential demand for NCMTs. In any case, the level of uncertainty, in the absence of an analysis at product level, which presupposes a well functioning statistical collection service, will be rather high.

In spite of this uncertainty, there seems to be a good case for arguing that this particular firm should be able to develop a competitive advantage in the production of smaller NC lathes. There are, however, several problems which warrant state intervention.

Government intervention in the process of capability generation can be justified on the basis of a) differential risk aversion between firms and government, b) different discount rates, i.e. time perspective in planning and c) the existence of externalities. For the firm that 'has made it', it seems as if the larger consortium has filled the role of the government by providing financial backing. This has had the effect of allowing for a long term view of technological development and decreasing the risks of such development. Externalities arising from mobility of skilled labour, were not considered important. A considerable problem is however lack of scale advantages in many of the mechanical components. In this area the government could intervene by creating a market for locally made NCMTs in order to increase production, so that scale advantages could be reaped. Alternatively, the state could subsidize the price of locally made NCMTs by a sum equivalent to the lost opportunities for economies of scale. This problem may be particularly critical during the next 2-3 years if the Japanese are planning an entry into the market. Indeed, it may be a coincidence, but the price of the Japanese smaller NC lathes are just below the price of the locally made ones. Furthermore, there is a positive relation between local production of NCMTs and the rate of diffusion. This will most probably apply also to Argentina where a local firm has all the more incentive to develop the market than importers. This would in practical terms mean that skills 5-8 (except repair and maintenance of the electronic units) would be in greater supply with local NCMT production.

For the potential entrants among the local firms, the main problem today is probably the investment crisis which threatens the existence of several firms. For example, one firm which started to expand rapidly in 1974 employed increasing numbers of qualified engineers and planned to start production on license, is now practically reduced to an importer! Without the backing of a larger consortium, the risks of technological development in an erratic economy are probably too great. Indeed, today Argentina faces the possibility of losing some of the competence that has been developed at great expense over the past 20 years.

Of course, this points to the problem of the implicit technology policy in the government's general economic policy. For example, the present (October 1980) exchange rate policy with an overvaluation of the peso clearly has detrimental effects on the domestic capital goods producing firms. Hence, if the intervention policies suggested above are to be meaningful, they would have to be implemented in conjunction with a general economic policy which is condusive to investment and growth in the industrial sector and which does not contain discriminating elements against local equipment manufacturers.

This leads in turn to another point which stands out clearly, namely the need for continuity in, and a long term view on, technoloigcal and industrial development. Industrial capabilities are not created overnight but take years if not decades to develop. This, in turn, means that the organisation of a society sets very critical restrictions on technological development.

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