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# ELECTRONICS, ECONOMIC GROWTH AND EMPLOYMENT - REVOLUTION OR EVOLUTION

by

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Abstract

The "new electronics technology" in its various manifestations has been very much in the limelight during recent years. It has been associated with future massunemployment or scary visions of a Brave New World, a grand discontinuity in economic and cultural development. Governments are worried about the effects of the same technology on the international competitiveness of their industries and public investigative committees abound among the western industrialized countries. Some economists regard micro electronics as the new technology that will generate the next Kontradieff cycle. The vast attention paid to this technological phenomenon in itself warrants a serious inquiry into its potential macroeconomic implications even though much of the speculation around it may seem farfetched to the majority of professional economists.

This paper will hence be concerned with the interaction of a particular, "new" technology (electronics) and the growth processes of the entire economy. Emphasis is on the use of the new technology in the production process of domestic industries - not the spectacular performance jumps of electronics hardware, which have so far been the fashionable theme of literature on the matter. Electronics has to be viewed as an integrated element in a more general form of technical change affecting the supply characteristics of the economy.[1] We have to take measurements down to a level where technical change can be meaningfully observed. We do this in two steps, first to the firm or plant level,

[1] With this approach electronics will be very broadly defined, including the computer and associated software development, even though much of the recent excitement refers to the very rapid miniaturization of electronics hardware (micro electronics).

then into the workshop. One also has to consider the possibility that fast technological advances occur in other countries and affect the own economy through foreign trade competition. In short, the evidence presented below does not support the use of simple diffusion models to highlight technical change in the economic growth process.

The paper argues three points; one methodological, one empirical and one speculative.

First, the macroeconomic consequences (employment, economic growth etc.) of microeconomic phenomena like technical change is similar to a dynamic general equilibrium problem in the sense that everything depends on everything else and that interactions are cleared through markets. Such problems cannot be studied by partial or static analytical methods. Models with an exogenous supply side and sticky relative prices generally lead to erroneous conclusions, especially with respect to the employment consequences. So there is no useful standard theory available within which to discuss and even more so to quantify these problems.

Second, the major factor behind total factor productivity growth as measured at the macro level (production function analysis) seems to be just the efficiency of the capital and labor allocation process between plants and firms. Less then 50 percent of total factor productivity growth in Swedish industry 1955/75 can be described as caused by technical change at the firm level.

Third, there is no evidence to suggest that the miraculous hardware developments in micro electronics in the recent past will cause rapid productivity increases at the firm or factory levels of equally stunning proportions. Performance improvements at the shop floor level rest on a combination of electronics with other techniques. Mechanical engineering and sensory equipment techniques may not advance as fast. A necessary factor that definitely is lacking in firms is centrally based, detailed process knowledge (human capital). It is not even clear that the microelectronics revolution will take productivity growth at the factory sector or industry levels of the 80s back to the high rates of productivity improvement of the 60s. Time is the important factor to consider and understand in this assessment.

It is not inconceivable that the industrial nations of the west are on the threshold of a "technological revolution". But if so - and that remains to be seen - the revolution will not depend on electronics alone. If it occurs it will only be observed in retrospect because of the time it requires to materialize and it will depend on a new organization of production that combines knowledge with new materials, new designs and manufacturing methods and perhaps electronics. Above all it will require a much advanced educational level of the working population. This new production life will certainly be more theoretical to the employees and much more human capital intensive than present production techniques. It will be typical of the successful industrial nations in the future and it will require a fast scrapping of present factory organizations in engineering industries around a collection of materials and tools, the basic designs of which have been around for some 100 years by now. But it won't arrive faster than the complementary growth of human capital takes place, and the nature of that human capital is still well beyond a generalized understanding and a theoretical representation.

Hicks (1977) observed that the down to earth and piecemeal development and use of machine tools in engineering industries towards the end of the 19th century meant much more for the industrial revolution than the textile machines that most has been written about. There may be a parallel to draw for the long-run future with new materials, electronically guided new tools and very new factory designs.

A development like this may eventually leave a different ranking among nations in terms of industrial advance which will depend on the social and economic capabilities of accommodating structural adjustment. This third point about the importance of an efficient complementary socioeconomic technology was the last speculative point.

## 1. Method - Micro-to-macro quantification

The arguments will be structured according to Figure 1. The basic idea for micro-macro quantification is to take measurements down from industry or sector levels to the decision unit - a firm or a factory. Technical change studied here applies to and affects a decision unit - in our case a firm. All higher level effects between the firm and the macroeconomy relate to responses of the firm and its interaction with the rest of the economy. This interaction has got nothing direct to do with electronics. To handle such interactions we need a general model that relates micro decision units through the market machinery to the macro aggregates and that forces dynamic thinking. This will be possible by the help of a firm based macro simulation model developed at the IUI and its data base of some 140 real Swedish firms (Eliasson 1978, 1979).

We begin (section 2) by reporting briefly on the rate of technical advance (labor productivity) at the micro (firm, factory) level (B figure 1)[1]. For various reasons these measurements are on labor productivity change[2]. From this we go on briefly (section 3, C in Figure 1) to evaluate the macroeconomic consequences of differently sized technological advances. We distinguish between such advances

- among foreign competing nations
- universally in domestic industries
- in particular industries or firms

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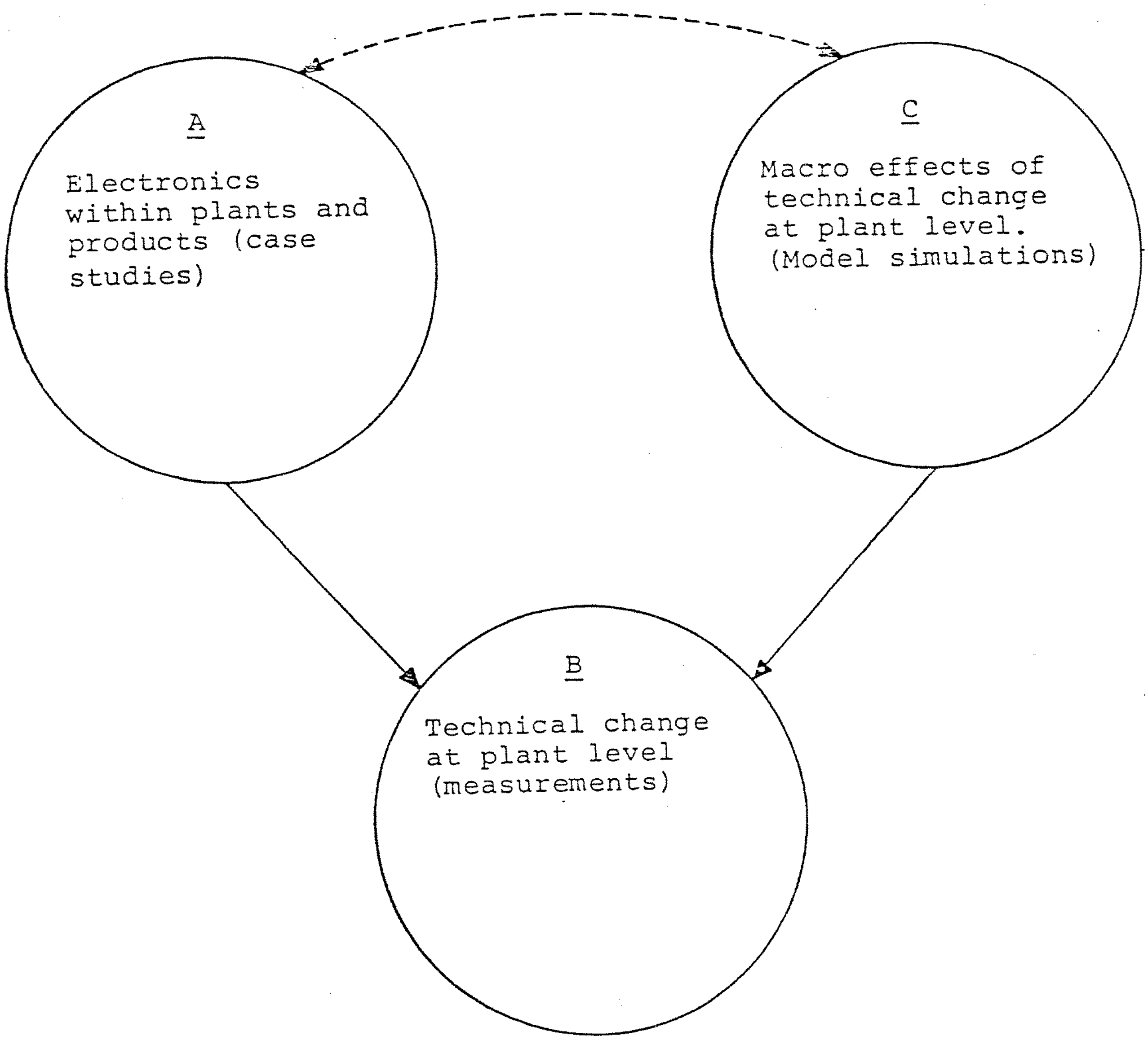
1 These results draw directly on Carlsson (1981).

2 The reasons are of course mainly practical. It is difficult to measure for instance total factor productivity change at the firm level. Thus, even though we would have liked to use the broader technical change measure that the model system allows in the simulation experiments, we fall back on - but do not accept - an assumption that has become received wisdom, namely that technical change during the postwar period to the beginning of the 70s has been mainly of the labor saving type. See Bentzel (1978) and Albrecht (1978).

From there we turn to our main problem of identifying electronics in the production process and technical change (section 4 A in Figure 1) to combine the results and to generalize into some sort of an industrial scenario for the future - should we expect a new industrial revolution?

The reader should not forget that the empirical results reported on refer to the Swedish economy.

Figure 1. Electronics, technical change and macroeconomy - the empirical method



## 2. The rate of technical change - falling or increasing?

Total factor productivity growth in Swedish manufacturing as estimated by traditional production function techniques explains a growing proportion of output growth that reaches 95 percent around 1970 and averages 75 percent for the whole postwar period.[1]

When the same measurement technique is applied to each of 13 subsectors of Swedish manufacturing it appears, however, that only some 70 percent of it can be referred to as total factor productivity growth at the subsector level, while the residual 30 percent is due to changes in the composition of output between sectors. When we probe deeper into one subindustry (the town gas sector) and perform the same calculation on each individual plant it again turns out that more than some 70 percent of the sector total can be explained by technical change at the individual plant level.[2] Generalizing these estimates to the entire manufacturing sector, more than 50 percent of total factor productivity growth appears to be the result of structural changes in the composition of output.

This result is supported by a "bottom up" analysis on the IUI micro-to-macro model. In this model micro productivity performance at the firm or plant level is linked to macro performance by way of the long-term investment decision and the short-term production decision of individual firms - in short the market allocation machinery of the national economy. It appears that an estimated average labor productivity growth in best practice technologies in new plants of 2.5 percent per annum 1955/75 compares with an

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[1] See Carlsson (1981). There is a body of literature on the biases in and the interpretation of such estimates that we acknowledge as relevant. For purposes of this discussion we simply apply this wellknown measurement technique whatever its merits as a wellknown standard of reference for our own measurements.

[2] See Grufman (1978).

Table 1. Examples of Labor Productivity Change in New Plants 1955-1975

| Industry | Productivity Measure | Annual percentage change 1955-65 (1) | 1965-75 (2) | 1955-75 (3) |
|---|---|---|---|---|
| Extractive industries | | | | |
| Iron ore industry | Tons of rock/man hour | 7.9 | 3.4 | 5.6 |
| Forestry (logging) | $m^3$/working day | 7.2 | 11.6 | 9.4 |
| Raw material processing | | | | (5.9)[c] |
| Pulp and paper industry | Tons/man hour | 11.6 | 0-3.4 | 5.6-7.4 |
| Ethylene production | Tons of ethylene/man hour | 14.5 | 6.0 | 10.2 |
| Intermediate goods | | | | (3.0)[c] |
| Commercial steel | Tons of crude steel/man hour | 6.0 | 4.8 | 5.4 |
| Steel pipes | Tons/man hour | 3.6 | 5.8 | 4.7 |
| Steel forging | Tons/man hour | 6.5 | 2.5 | 4.5 |
| Investment goods | | | | (2.6)[c] |
| Heat exchangers | $m^2$ of heat absorbing surface/man hour | 7.2 | 7.2 | 7.2 |
| Hydro-power generators | MVA/man hour | 1.0 | 3.6 | 2.2 |
| Marine turbines | kW/man hour | 7.2 | -4.5 | 1.2 |
| Shipbuilding | Tons of steel/man hour | 7.2 | 1.0 | 4.1 |
| Consumer goods | | | | (0.4)[c] |
| Pharmaceuticals | Tons/man hour | 1.4 | 2.5 | 1.9 |
| Food industry | | | | |
| Canning and freezing | Tons of finished goods/man hour | 13.1[a] | 4.3 | 5.4 |
| Sugar industry | Tons of beets/man hour | 2.7[b] | 4.1 | 3.4 |

[a] Refers to 1960. [b] Refers to 1960-1970.

[c] Figures within brackets are sector estimates from model simulations. See B Carlsson and G Olavi (1978).

Sources: B Carlsson (1981) and B Carlsson and G Olavi, "Technical Change and Longevity of Capital in a Swedish Simulation Model", in G Eliasson (ed), A Micro-to-Macro Model of the Swedish Economy. IUI Conference Reports, 1978:1. IUI, Stockholm, 1978.

average productivity growth for all manufacturing close to 6 percent per annum for the same period, or just above 40 percent (see Table 1. Figures within brackets are sector estimates from model simulations).

These two quantification methods are entirely independent of one another and they both point to the importance of the economic allocation mechanisms in explaining technical change as measured at the macro level of an economy. Less than 50 percent of it can be explained as "pure technical change" at the plant level. This importance of the allocation mechanisms or "the organization factor" will appear again in the next section when we move from the aggregate level of a plant down to the machines on the shop floor. Only at that level we can identify "electronics" as a production factor.

Will electronics produce a new industrial revolution in the west? Electronics is a factor behind technical change measured at the level of the firm. The revolution hypothesis would imply a speeded up rate of technical change at that level. Table 1 tells the opposite story. The rate of (labor) productivity improvement in new plants seems to have slowed down between 1955/65 and 1965/75 in those sectors that are shown in the table. This was only an indication. The table is biased towards fairly old production sectors. One would expect new technologies like electronics to produce large performance increases in the new (modern) industries.

## 3. Dynamic resource allocation and growth - a micro-to-macro analysis

It appears from the previous section that most of technical change as measured by production function analysis at the total industry level may be very much dependent on the performance of market allocation mechanisms between firms, most notably the allocation of investment and labor across the market and over time. Technical change associated with new capital goods sets the upper limit for growth. Actual performance of the entire economy can, however, fall very much below what is feasible depending upon the state of the resource allocation processes. Technical change at the macro level is predominantly an economic phenomenon. This conclusion is reinforced by the results from simulation experiments on the IUI micro-to-macro model.[1] By varying parameters that guide the speed of response of labor and firms to relative price signals and in turn the speed at which supply and demand adjustments affect relative product and factor prices in the model, different results of the magnitude shown in Figure 2 can be obtained in long-term growth rates of the entire econo-

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[1] Insufficient space is allowed in this paper to explain this somewhat unconventional model to the extent needed for an independent evaluation of the simulation results. The results reported on are, however, published in Eliasson (1979) and an earlier version of the model has been presented in sufficient detail in Eliasson (1978) and in outline in (1980). Suffice it to mention here that the model very much represents a formalized Schumpeterian economy. Market processes are explicit at the micro level. The long and the short-term supply sides of the individual firms are very elaborately modelled. Firm responses to changes in the environment are endogenous but all firms together very much determine the environment, most notably relative prices. As with Schumpeter, technical change is an exogenous factor "affecting" the firm, in this micro-to-macro model in the form of labor productivity advances associated with new investments as measured in Table 1. New technologies are available in new capital goods. They affect capacity to produce through new investment. The investment decision is endogenized with each firm and is guided by a capacity-planned production adjustment mechanism, the speed of which depends on current cash flows and profitability of the firm in excess of the loan rate. See Eliasson-Lindberg (1981).

my, holding the rate of technical change in new investment applied at the firm (plant) level constant. More particularly, even for the rates of technical change exhibited in Table 1 for Swedish industry different sets of market response parameters generated growth paths as different as that for Sweden and the UK in Figure 2.

These results appeared again when we used the same model to study the macroeconomic effect of market imperfections due to the Swedish corporate income tax system[1] and most notably the extreme subsidy program administered to ailing companies in the late 70s.[2]

Reversing the same argument we also find that well-defined variations in "pure technical change" in new investments at the firm level (as measured in Table 1 and called DMTEC in Figures 3) do not produce straight-forward one-to-one relationships to economic growth, either at the firm or the industry levels. The whole architecture of the market machinery intervenes and produces a "soft" dynamic relationship that cannot easily be captured by simple macroeconomic relationships.

Figures 3 A to D exhibit the results from a series of simulation experiments with different assumptions as to the rate of technical change (DMTEC) at the firm level.

First we increase and lower the rate of technical change in all firms in the economy (universal technical change). Figure 3 A shows that growth effects are very slow in coming with the model parameter setup that captures postwar growth trends of the Swedish economy well. In the longer term a one percent increase in the rate of technical change yields a 0.6 percent increase

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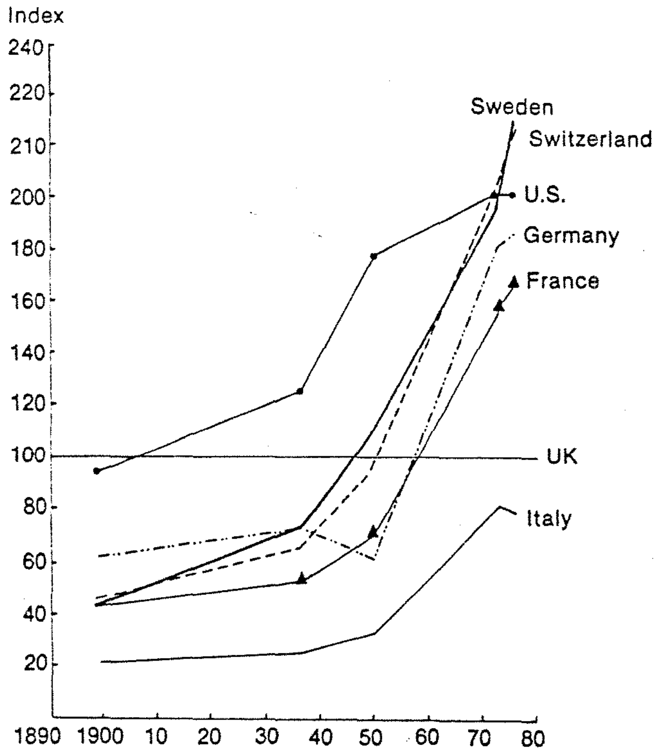
1 See Eliasson-Lindberg (1981).

2 See Carlsson-Bergholm-Lindberg (1981).

Figure 2. GNP per capita in different countries, 1890-1975
Index UK = 100



in output growth. The relationship is not symmetric. A corresponding decrease takes full effect faster by constraining the output potential. Two things are interesting to note. First, an improvement in technical change coupled with an increased competitive pressure from abroad (an annual rate of decrease in foreign market prices called DPFOR in Figures 3 A and B) of the same order of magnitude as that assumed for domestic technical change, takes away the positive output effect. Less investment, due to a worsened profit performance, is the reason. The second interesting thing has to do with employment. While the technical change produces an immediate but very small reverse impact on total employment there is no long-term trend in all three cases at all, only a new cyclical pattern. Factor price (wage) adjustments force a quite fast reallocation of labor to secure long-term full employment.

The foreign price change assumption above can be interpreted as the effect of foreign competitors realizing the 1 percent change in technical performance, and responding by cutting their prices as much as is consistent with maintenance of their profit margins, thus reducing the export market price level. When this occurs universally (not shown) or selectively in one industry, while Swedish producers lag behind in technical performance, the sector impact on both output and employment is quite strong. Again, there is no long-term effect on employment. The sector impact is shown in Figures 3 C and D.

These experiments exhibit some of the dynamic properties of the model. A technical improvement local to the consumer goods sector generates a gradual improvement in output of the sector over the reference case (dashed line A), but the output effect is slow in coming, and the reason is that firms take their time in realizing the productivity potential, if not forced by competition. The initial effect is a small temporary decrease in sector employment

(Figure 3 D). The unemployment is rapidly reallocated to other industries so that the total manufacturing growth effect begins earlier and is much larger than the sector effect.

In the alternative scenario foreign competitors lead in technological advances and respond by lowering prices in foreign markets for consumer goods. Domestic industries respond by increasing efficiency/reducing slack, but that is only possible for a few years. Then a fast decline begins and the sector settles on a size at 80 percent of its original level after some 20 years.

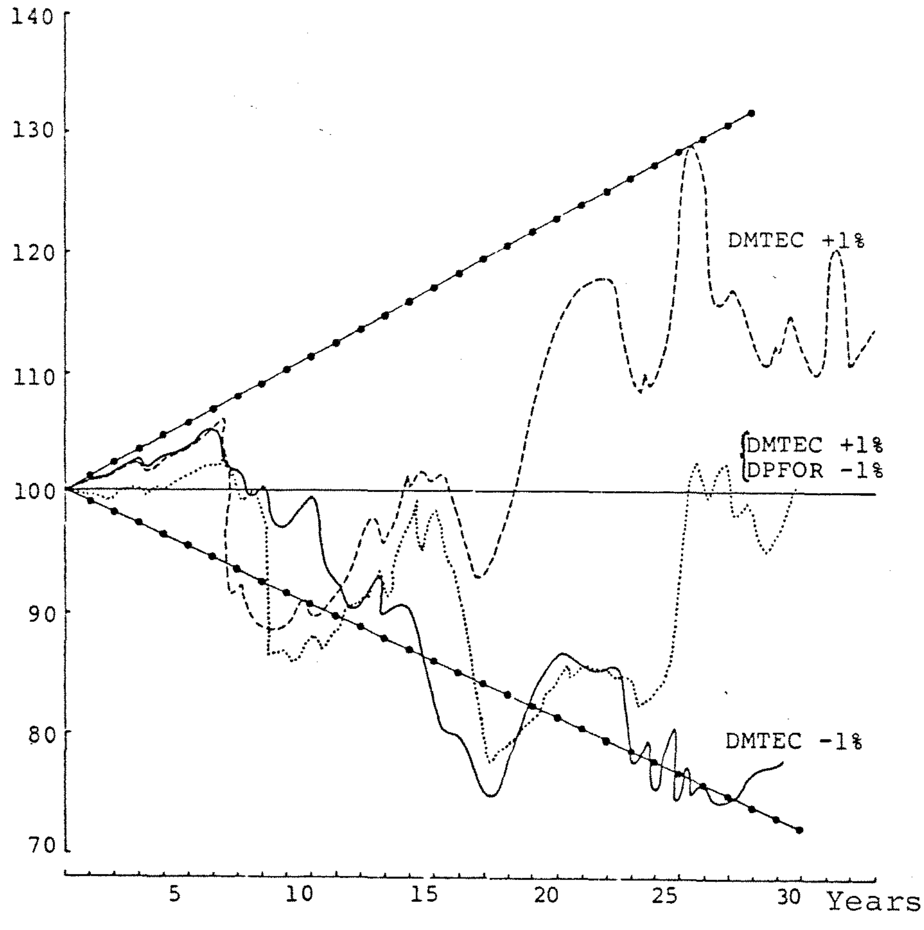
This contraction process generates a slowdown in overall industrial growth. It is interesting to note, however, that eventually labor has been reallocated to relatively more efficient firms in the economy and growth sets in (line D). After some 20 years the net output effect is in fact positive.

In conclusion then employment at the macro level appears to be no problem if viewed in the time perspective of a few years or more. And this is so, despite substantial structural adjustments forced on the economy at the micro level because of technical change domestically or through changes in the foreign competitive environment. It is obviously the case that these results very much depend on the market adjustment mechanisms incorporated into the model by assumption and deliberate design. However, these mechanisms are general enough to allow the results summarized above to materialize any time between next quarter and close to never. The time profiles of the diagrams depend entirely on the parameter specification that has been used and that has been obtained from those empirical data bases at micro and macro levels that are at all available in Sweden. This includes a survey sent to all Swedish manufacturing firms with more than 200 employees that was designed specifically to suit this model and that is now running on its sixth year. Empirical testing, estimation and calibration is by no means completed, but this is what can be done for the time being.

Figure 3 A. Output effects of a general change in the rate of growth in labor productivity in best practice new investments (DMTEC)

Index 100 = Reference case

Index (Industrial output)




Note: Symbols are explained in text.

Figure 3 B. Effects on Manufacturing Output of Two "Comparable" Changes in DMTEC and Foreign Relative Prices for Non Durable Consumer Goods Production

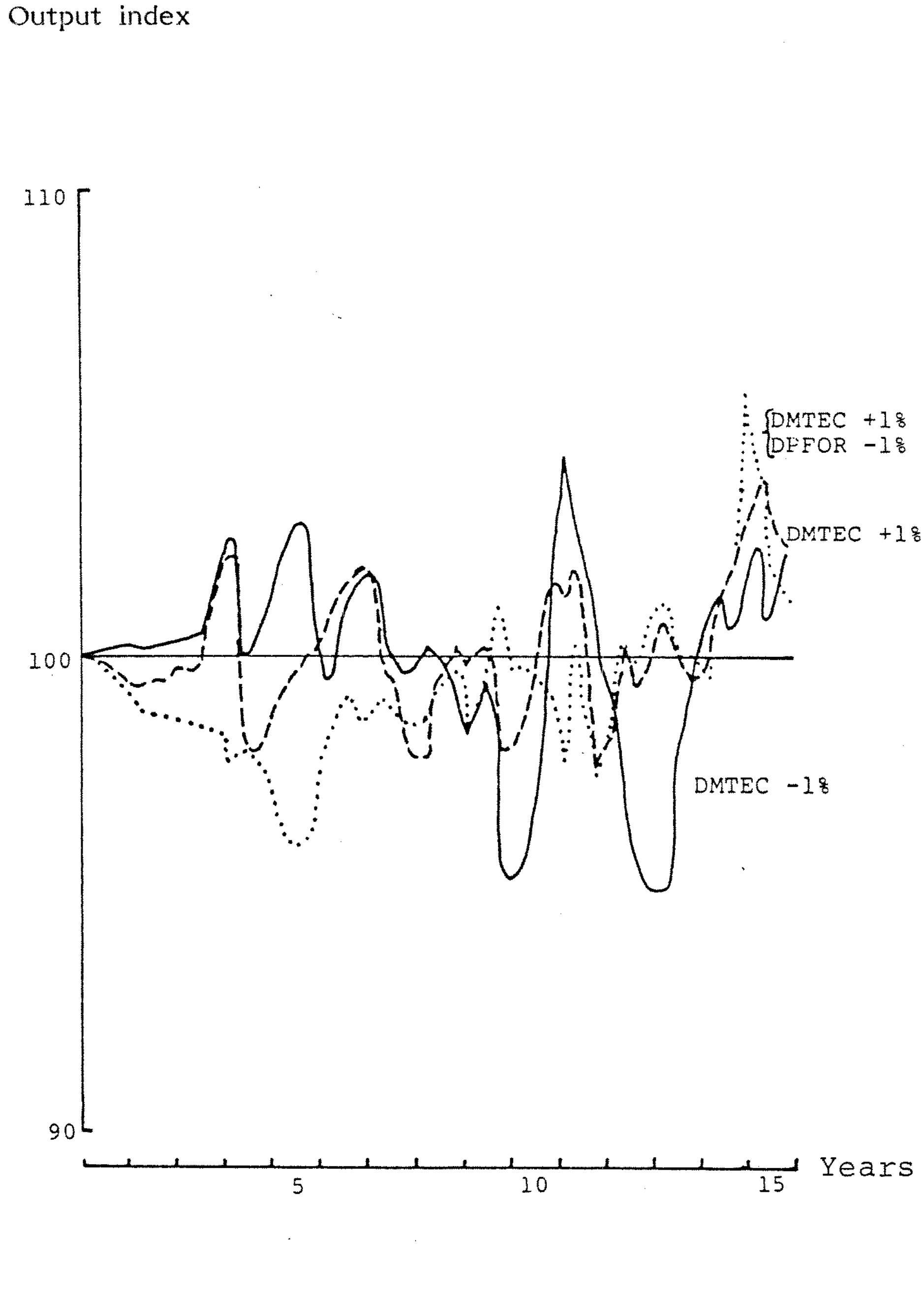


Figure 3 C. Employment Effects. Same experiment as in Figure 3 B

Index 100 = Reference case

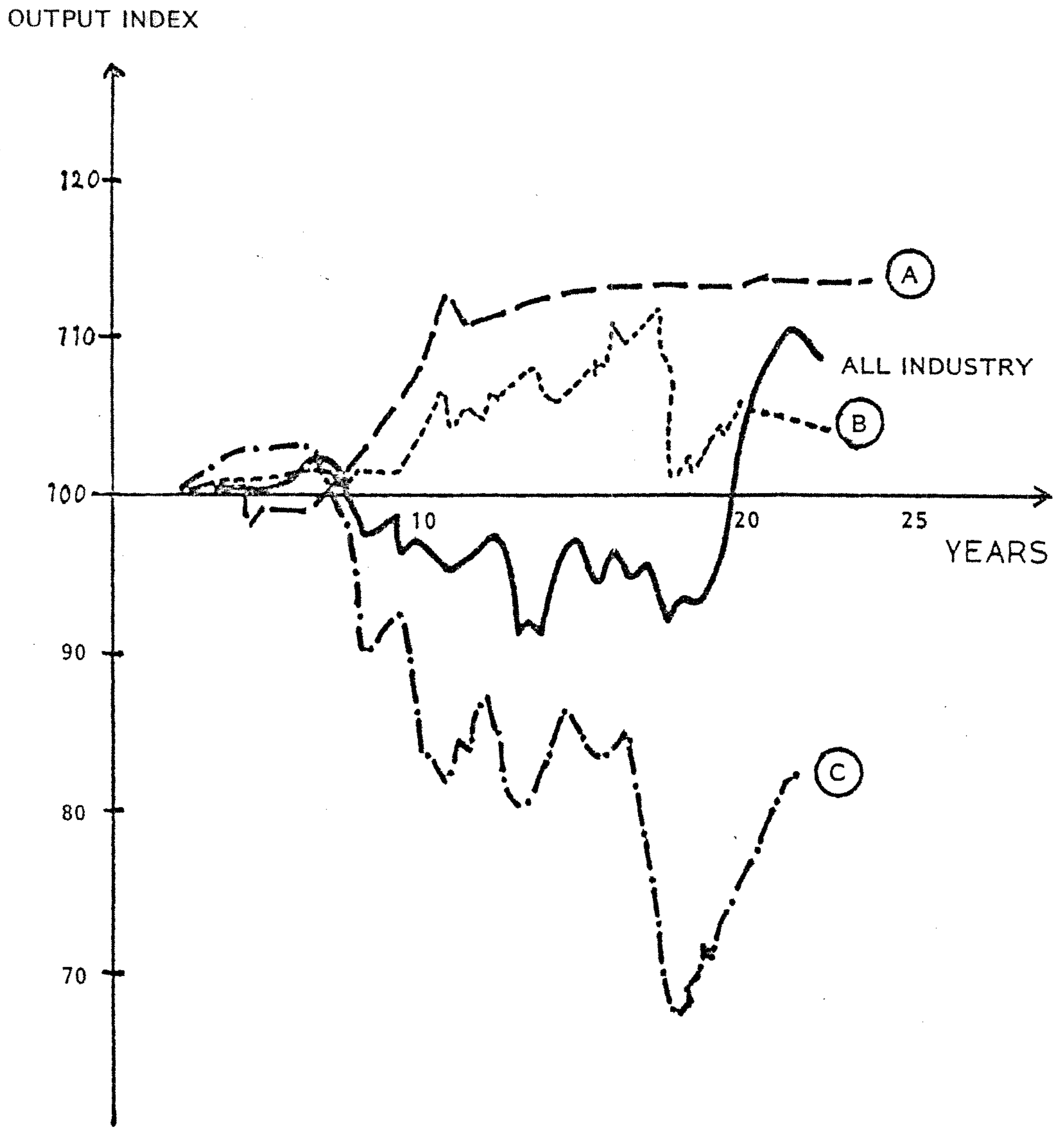
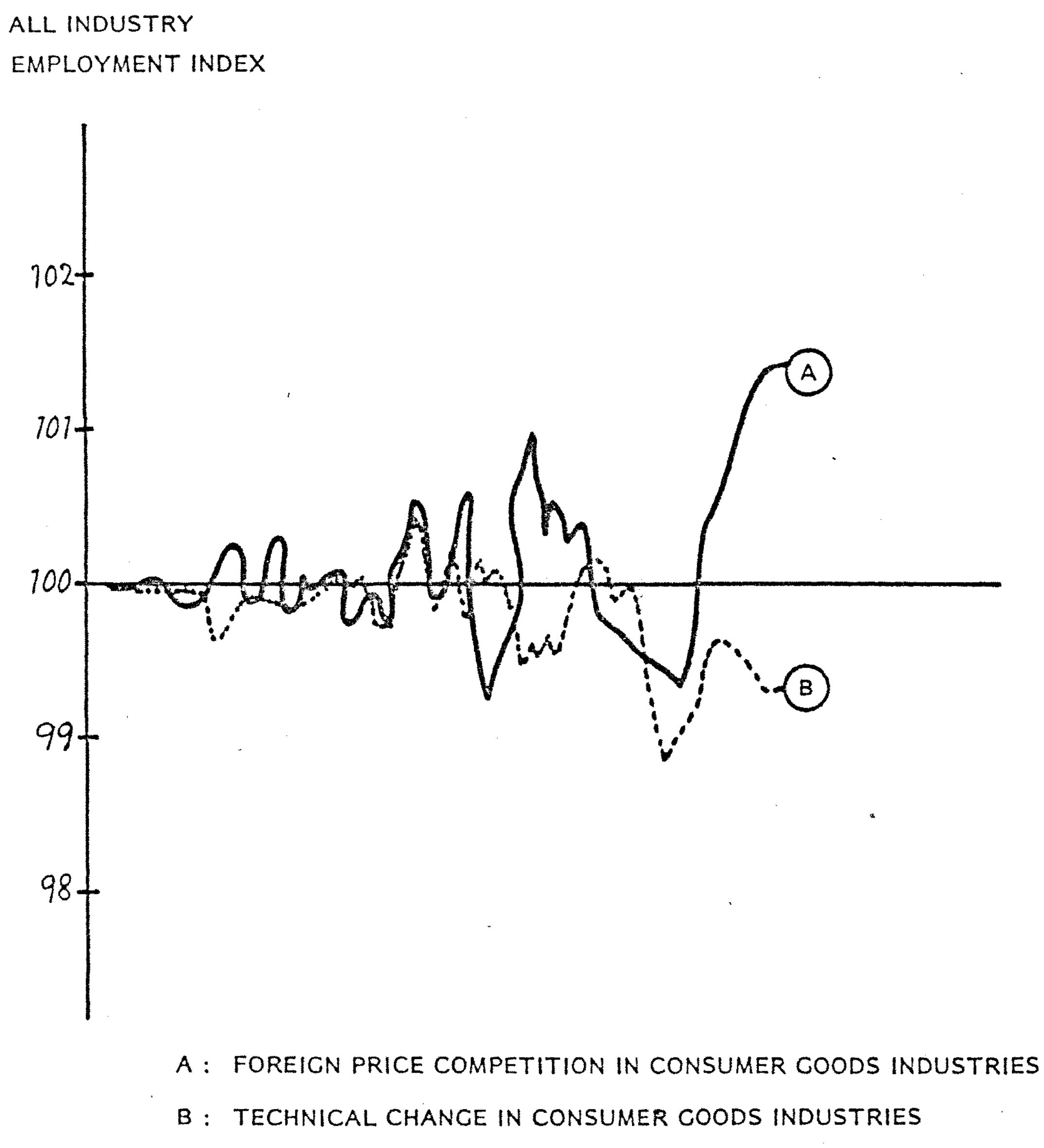


Figure 3 D. Employment Effects from Experiments in Figure 3 C



On the other hand, models of a more traditional kind that do not endogenize either relative price change or the structural adjustment process, tend to incorporate a growing unemployment problem by assumption because of technical change. For instance, large scale demand driven macro models with input-output type production technologies exhibit such properties. Technical change, incorporated by external surgery on the coefficients, reduces manpower requirements to produce an unchanged output. At best demand feedback through income generation helps to increase growth and to reduce the negative employment effects. But such models should not be used to analyze the macroeconomic consequences of microeconomic phenomena if the implicit assumption in most macro economic models of sticky relative prices is not done away with. Sticky relative prices is an empirical absurdity in any analysis stretching beyond the next few years. The degree of stickiness in the relative price system has to be endogenized as in the micro-to-macro model used here. To add a Schumpeterian flavor to this discourse it should be made explicit that the relative price stickiness assumed to be prevailing in advanced industrial economies very much depends on Government intervention in markets through regulation, legislation, taxation, wage setting etc. What we have demonstrated so far is that by manipulating the model parameters that control the market allocation processes, much as Governments often do, we can reproduce widely diverging results on long-term growth of the model economy.

## 4. Electronics in the factory

The dynamic aggregation problems of the previous section appear in an even more difficult form within the factory[1] or the firm. Electronics is no simple factor of production. It always combines with other factors and technologies and has to be seen in the general context of productivity advance in a plant or at a production line. We will have to illustrate by way of examples and a couple of cases and then generalize the results in the form of a few hypotheses that still need further testing.

Common propositions are that electronic applications appear predominantly in the form of improved process performance (doing the same thing faster and with less people) and not in the form of product improvements. Hence demand will remain fixed, and productivity will increase and unemployment will follow[2]. Besides being based on a typically static and partial analysis, and hence wrong (see section 3) the two underlying assumptions also appear to be entirely wrong. As long as the results from the IUI inquiry goes, electronically based techniques to replace existing operations may look spectacular in isolation (a few process operations) but they normally appear quite small, or normal, when viewed from the level of an aggregated production line. Electronics seems to be a very potent technology when it comes to improving product designs or developing entirely new products. One main conclusion from the IUI study is that the magnum jumps in productivity performance that may occur at the level of a production line normally come together with the introduction of new

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1 The discussion will be carried out in terms of an engineering workshop. The results from a special study of the Swedish computer and electronics committe is that the situation is very similar in process industries.

2 This three step argument is an only slightly pointed version of the base argument in Barry Sherman's widely read paper: Technological Change and Collective Bargaining, ASTMS Discussion Document 1979.

product designs whether based on electronics or not. This is the reason why the current emphasis on robots replacing human beings in the rationalization of production of given products probably gives a misleading view of what this technology is all about in a production context. Integrated computer aided design (CAD) and manufacturing (CAM) systems on the other hand may eventually prove to be a vehicle for a fast upgrading of manufacturing performance. If combined with new tools and materials better suited for automatic control this technique may allow continuous adjustments in design and process techniques close to the shop floor that may prove very favorable to efficiency advancements in the manufacturing of sophisticated products. Thus, for instance, the substitution of composite materials for metal in automotive and aircraft manufacturing has strongly reduced the number of parts on the assembly line and the development of new process techniques is in progress. These conclusions are illustrated in the case description below.

## A case description

This case description covers a sophisticated engineering factory in the Stockholm area that is part of a large multinational company. The factory unit only engages in physical production. Product innovation and design takes place in other parts of the company as does distribution, marketing and financing. The case illustrates (1) that even with this strong concentration on production, production in the sense of "mechanical handling" only accounts for some 33 percent of labor input (see Table 2). Automation by way of electronically guided machine tools, hence, only affect part of (and not a large part of) employment in this firm.

Second, the introduction of automation devices along a production line is normally a quite slow process, that takes place in a piecemeal fashion. The electronics potential is held back by insufficiencies on the mechanical and sensory equipment side. And above all, centrally located process knowledge is missing and takes a long time to accumulate. Figure 4 A shows the impact of some new "devices" on labor productivity. Some of the devices meant personnel savings from seven to one man years for a particular element of production. Apparently these automation devices do not even show up as "steps" in the smooth curve of productivity improvements.

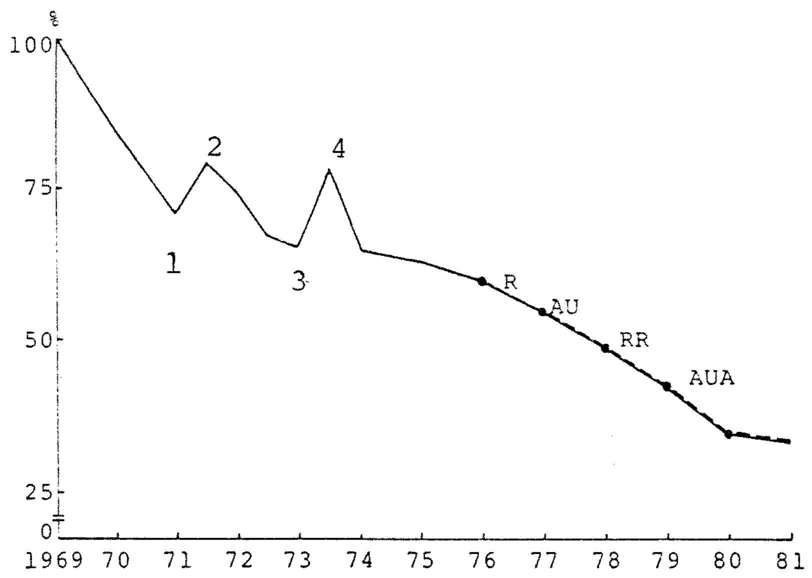
Third, the major part of productivity improvements occur simultaneously with product design changes that make it possible to organize production more efficiently. This is illustrated in Figure 4 B.

These results refer to one particular case. Results from other case studies carried out by the IUI or through the Swedish Committee on Computers and Electronics point in the same direction, although this information has not been gathered in a manner that allows statistical generalizations.

Table 2. Labor input by type of work, manhours
Percent of total, averages for 1974-79.

| | Percent |
|---|---|
| 1. Work scheduling | 51 |
| of which | |
| a) administration/planning | 38 |
| b) technical preparation | 13 |
| 2. Production | 49 |
| of which | |
| a) supervision, service, quality control etc. | 10 |
| b) direct production | 33 |
| c) transports, inventories | 6 |
| Total | 100 |

Figure 4 A. <u>Change in labor productivity in the production of a particular part remained identical as to final specification since 1969</u>

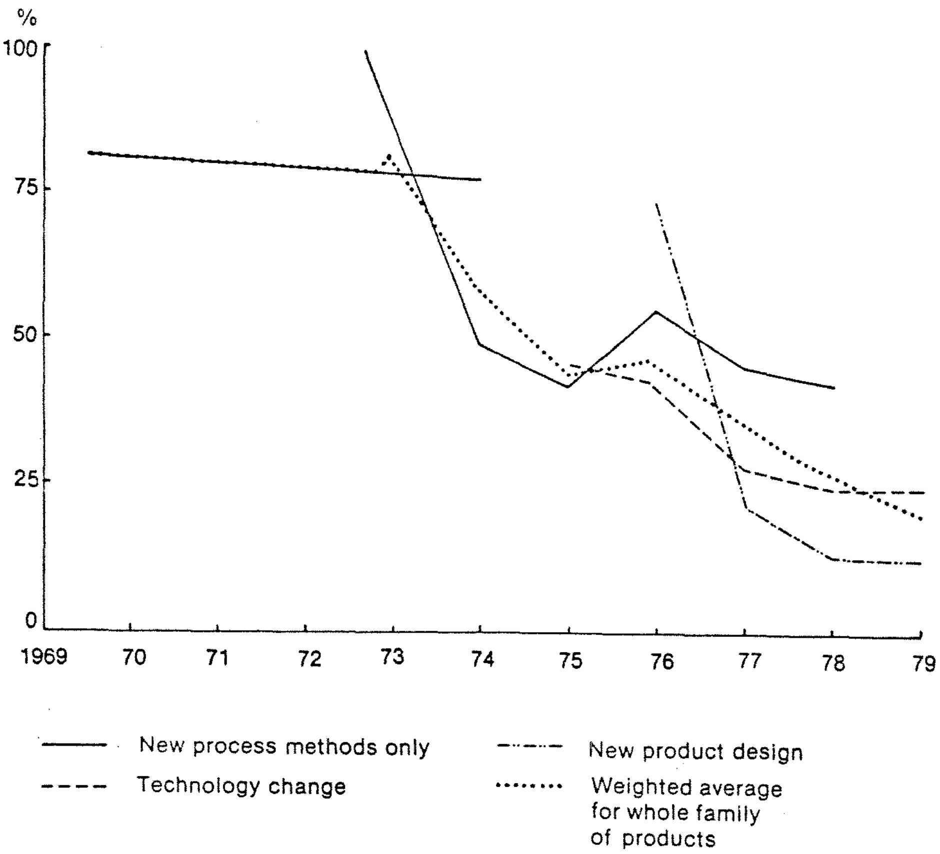



1. Learning phase. Hours used for supervision and quality control can be gradually reduced.
2. Subcontractor takes over. New learning phase.
3. Production moved back to own factory.
4. New subcontractor.

R Pick and place robot installed.
AU Automatic engraving + multiple machine servicing begins.
RR Electrochemical grading + extra robot, etc.
AUA Automatic grading begins.

<u>Note</u> that the inverse of labor productivity change is shown in figure.

Figure 4 B. Total factor productivity change for a family of sophisticated engineering products




Note that the figure shows the inverse of total factor productivity.

## A production system, not a function

A factory or a firm is an organization of interacting humans and machines (a system). It is not a big piece of hardware the performance of which is constantly improved through technological change - the way production is typically viewed in production function analysis. A system for one thing can be organized more or less efficiently and we have frequently observed how new, expensive and very efficient machinery has been installed in such a system without producing any noticable effect on the productivity performance of the entire system. On the other hand, we can report on many cases where simple reorganizations of the flows of intermediate parts between old machines and the men allocated to them have produced very large improvements in systems performance.

Secondly, a typical feature of a modern industrial firm is that a fairly small and diminishing fraction of value added is created in the process ("mechanical handling") departments. The value of a product depends very much on its being designed for and delivered to the right customer at the right moment. R&D, design, work preparation, purchasing, inventory handling, marketing, distribution, finance, administration, etc. are activities that in many large firms add more value to final output than the actual, physical manufacturing of the product.

## A more theoretical production life

Electronically based monitoring devices for production flows within factories and the "flows" of entire firms have become of increasing importance for total firm efficiency during the 70s. The fashionable manifestation of this is the "fully automated factory" which is not yet by far a viable real-life thing. Within the foreseeable future all commercial automation installations will be of the interactive, monitoring type with human beings actively involved in production. A centrally based representation of the entire system in increasingly efficient electronics hardware seems to make a better overview possible that in turn makes a more efficient organization of activities possible. The role of logic in production life is enhanced. The benefits seem to be a better overall flow control that helps to stabilize flows, cut underutilization of installed resources and save on capital, so far mainly inventories. The first common wisdom to part with here may turn out to be that electronics in a broad sense may move technical change from being predominantly labor saving - if that contention were correct to begin with[1] - towards being also capital saving on those items that are typically activated in the accounts of firms.

A second and very common observation that we have made is that electronic monitoring devices may be available for very far-reaching automation of whole factories but that other factors, those needed to make automation economical, are holding back a fast introduction. Typical examples are unsatisfactory precision and reliability of measurement and sensory equipment and crude mechanical installations that lag behind in development.

Central process knowledge lacking

Far more important, however, is the lack of centralized knowledge of the production process itself. The typical organization of an engineering workshop of today is based on a specification of the product (blueprints, drawings) telling in what order machine tools should operate on pieces of metal. The basic functional principles of these machine tools date back a hundred years or so. They are manned with skilled craftsmen and subjected to a monitoring system of supervisors and maintenance crews responsible for keeping the flows running. The main process know-how resides with the individual craftsmen, one by one.

[1] See Bentzel (1978).

Automation requires that these craftsmen divulge their knowledge in extreme detail, for somebody else to program and to guide numerical machine tools, robots etc. So far only the simpler process routines have been successfully automated and those only in isolation. Economic considerations hold back a rapid introduction of automation, except where production lines are long and stable over time. In general, this has shown to be a very gradual and slow process.

It is rarely a matter of simply imitating what the craftsmen have done. Automation has typically been entered in the context of new product designs. And - an important conclusion for the next section - it has reached an advanced stage in the new industries using new materials, new tools, new production techniques and very differently trained people at all stages compared to traditional industries. Such industries are electronics hardware production itself, the air craft industry, fine chemicals etc. where steel is notably absent.

However, the main consequence for the existing factories where these new techniques have already been introduced has been a massive substitution of human capital for physical capital in production. The number of hours worked may decrease per unit of capital, but measured in quality equivalents they may have increased.

The human capital accumulation consists in making the process knowledge explicit, logically ordered and central in a digital machine. This can be characterized as a new type of organization of production which was also the main characterization of the "industrial revolution". It will not occur if there is no economic rationale behind it. The main catalyst will be the "educational endowment" of the working population in a broad sense. Considering the nature of the educational system even in advanced nations my personal opinion is that the effects will be slow to manifest themselves on a grand scale.

The proper analogue would be the use and the effects of the printed word. In the long-run the effects will be overwhelming - a cultural revolution. In the more short-term the impact will be much smaller but very unevenly distributed, especially between nations that may be more or less inclined to adjust their social, mental and economic habits. This may constitute enough of a problem.

In conclusion, there is ample reason to ask whether "electronics" will at all cause technical change at the firm level to advance faster than it did for other reasons during the sixties (see Table 1). We know from experience that structural change then was fast but in no way impossible to cope with.

A final point that also points to the next section is that humans have been further removed from the physical side of the production process. Production life has become more distant, more "theoretical" and more "difficult".

Production is being represented on blueprints, TV-screens or computer printout in a removed way. To what extent this forces a polarization of the labor market into low-skill, low-prestige jobs on the one hand and high-skill, high-prestige jobs on the other[1] is in my view the only important employment problem to consider in the context of technical change.

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1 See Rada (1980).

## 5. A new industrial revolution?

The "so called micro electronics revolution" has been a celebrated cause for concern, inspiration and imagination for quite a long time. The computer revolution was discussed already in the sixties. Simon (1965) predicted that in 25 years the computer would take over essential intellectual tasks from the business leaders. Evans (1979) argues that in less than 20 years we will be talking about the "world transformed" because of the computer, a new industrial revolution but much faster. Sherman argues in his 1969 ASTMS paper that massunemployment is likely to follow from a laissez-faire type policy towards electronics in all its manifestations.

Two main conclusions flow out of this paper. First, in industrial countries with a reasonable built-in price and structural flexibility the negative macroeconomic effects are minimal and of a short-term adjustment type. They will probably be smaller than those caused earlier by other types of technical change, for instance the magnum jumps in scale economies in the steel industry since the 60s that have affected the Swedish industry profoundly. Larger negative effects are likely to occur through competitive changes in foreign trade if Swedish industry lags behind in the introduction of these new technologies. Besides the universal nature of new technologies based on electronics, their multiple manifestations in the economy makes it close to impossible to foresee the consequences with any accuracy. Hence, any type of managed introduction of electronics into the domestic economy as proposed in many labor circles or by advocates for "industrial policy" action is likely to do more harm than good. Worries in fact should be directed towards the state and nature of the economy rather than towards electronics.

Second, at the shop floor level "electronics" is highly complementary to other factor inputs, notably human capital of particular specifications. Change won't come faster than the corresponding human skills develop. Evolution is the characteristic label, not revolution.

Two qualifications should be added to this "scenario". For one thing, other countries may be more able to adjust rapidly to the new technological levels made possible. Societal attitudes may be more positive and their educational systems at large may be more efficient than those in other countries.

As a consequence, changes in the competitive situation in the international market place may play havoc with some national economies. We have demonstrated that negative effects then may be larger and more sudden than when technological initiatives are taken domestically.

Moreover, whatever we conclude for the short and the intermediate terms on the basis of what we observe just now, in the very long-run something very new may be in the offing because of the new technological advances. The combined impact on the organization of production and work life of new materials development during the past 20 to 30 years, the electronics and computer technologies and a matching development of human skills is yet to be seen. The synergy effects of the development of standard machine tools some hundred years ago is the quoted analogy. The main theme of this paper, however, is that these effects are by their very nature impossible to predict meaningfully. If they are large enough they may quite easily leave a revamped ranking order among the industrial countries in the end, compared to what is exhibited in Figure 2. This has happened many times before in economic history.

Now, as before, the best preventive cure for negative national experiences is not to be concerned and agitated about particular details in a complex economic process that nobody understands well, but to keep the economic and political machinery in good working order.

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