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TECHNICAL CHANGE AND PRODUCTIVITY IN SWEDISH INDUSTRY IN THE POST-WAR PERIOD

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CONTENTS

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FOREWORD

The present study is one of three IUI papers presented to the symposium on Industrial Policies for the 80's arranged by the Spanish Ministry of Industry and Energy in cooperation with the O.E.C.D. in Madrid, May 5-9, 1980. Partial financial support from the O.E.C.D. and from the Swedish Government Committee on Computers and Electronics is gratefully acknowledged.

The paper is a part of a larger study which the Institute is conducting for the Committee. The paper has been written by Dr. Phil. Bo Carlsson. We also want to thank Professor Robert Lipsey and Professor Eric Dahmén for valuable comments on earlier versions of the paper.

Stockholm, May 25, 1980

Gunnar Eliasson

TECHNICAL CHANGE AND PRODUCTIVITY IN SWEDISH INDUSTRY IN THE POST-WAR PERIOD

Long Swings in Innovation?

During the 1970's there has been a slowdown in productivity advance in many industrial countries. This has been associated with a decline in the economic growth rates from the extremely high levels in the 1960's. Observations of this kind have led to speculation that the industrialized world is now in the downward phase of a long swing of the Kondratiev type.[1]

In interpreting Kondratiev's long swings, Schumpeter emphasized the role of innovation.[2] Thus, he attributed the upturn in the first Kondratiev cycle (1790-1813) largely to the dissemination of steam power, the second (1844-1874) to the railway boom, and the third (1895-1914/16) to the joint effects of the automobile and electricity.[3]

To support his view of long swings in the business cycle, Mensch has studied the varying frequency over time of what he calls "basic innovations". He defined basic innovations as "technological and social innovations that create completely new social benefits, new lines of service or industrial products in the public sector and in private business, for which there exists a need, and for which the manufacture and distribution necessitate the creation of new markets, many new jobs, and profitable investment possibi-

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[1] See e g G Mensch, Das technologische Patt, Frankfurt, 1975; and G Ray, "Innovation in the Long Cycle", Lloyds Bank Review, No. 135 (January 1980).

[2] J A Schumpeter, Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process, McGraw-Hill, New York-London, 1939.

[3] G Ray, op cit, p 15.

lities".[1] Further development of products and processes in already existing lines of activity (established through earlier basic innovations) are called "improvement innovations".[2] In Mensch's view, it is characteristic of basic innovations that they appear in clusters, even though they may pertain to entirely different fields. This is because they are all influenced by the same "spirit of the times" ("Zeitgeist").[3] As basic innovations are introduced on a large scale, it is inevitable that they generate improvements both in the basic technology itself and in surrounding technologies. This is the mechanism by which long swings in economic activity are generated. Unless the rate of innovation continues to increase, the economic upswing is eventually broken, and a period of decline in economic activity sets in.[4]

In studying inventions and innovations over the past 200 years, Mensch concluded that peaks had occurred in 1770, 1825, 1885, and 1935.[5] Thus, his peaks differ somewhat from those of Kondratiev - the last one by some 20 years. If peaks repeat themselves at 50-year intervals, Mensch's next peak would occur in 1985 while that of Kondratiev would have been placed in 1966. Thus, it is not easy on this basis even to determine in which phase of the long cycle we are at present.

A skeptical view is also substantiated if one examines the growth of GNP per capita in industrial countries over the past 100 years. See Figure 1. Whereas one finds two long cycles in the Swedish growth curve (with peaks in the first decade of the 20th

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[1] Ibid, p 15, italics mine.

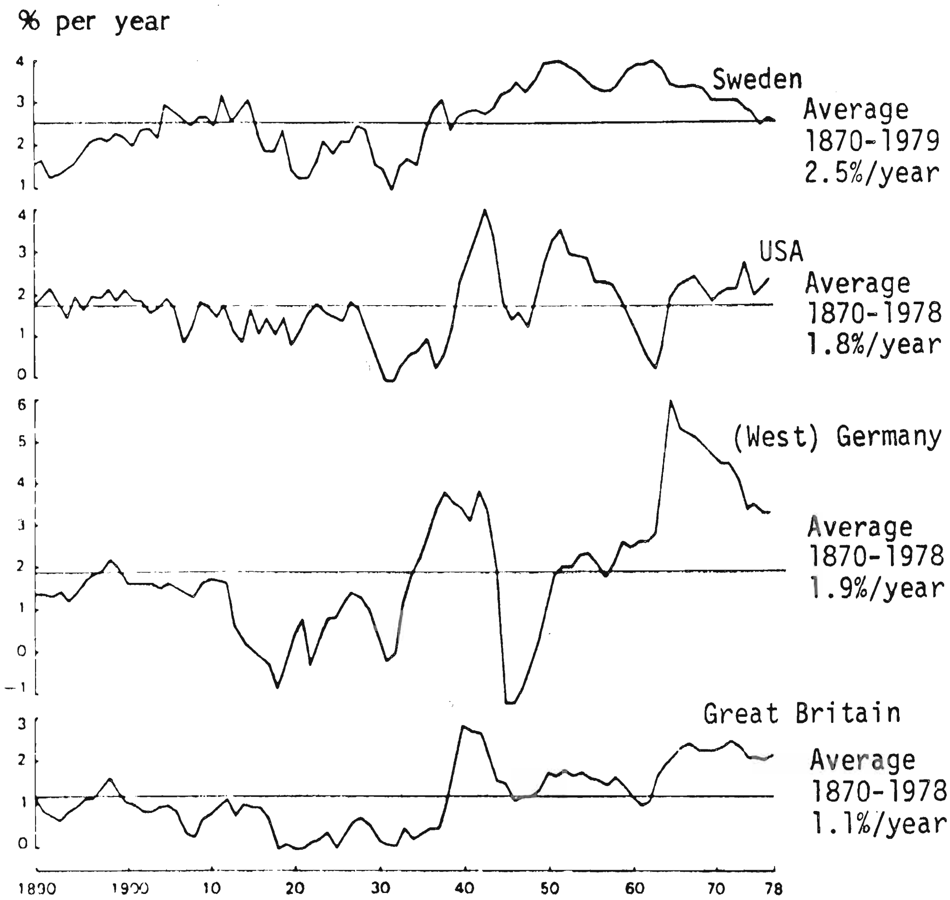
[2] G Mensch, op cit, p 55.

[3] Ibid, p 196.

[4] This has been shown in simulations on a Swedish micro-to-macro model. See G Eliasson, "Technical Change, Employment and Growth", IUI Research Report no 7, 1979.

[5] G Mensch, op cit, p 142.

Figure 1. GNP/capita growth rates in Sweden, USA, (West) Germany and Great Britain 1870-1978
Moving 20-year averages



Note: The average for each 20-year period is shown for the final year of each period.

Source: G Eliasson et al, IUI:s långtidsbedömning 1979 (IUI Medium-Term Survey 1979), IUI, Stockholm, 1979, p 71.

century and 1950-60), it is difficult to find a similar pattern in the other countries in the Figure. Instead, one notes that the post-war period stands out as an era of extremely rapid growth, practically without historical precedent. Thus, rather than trying to look for long cycles, one may want to explain why economic growth has been so rapid in the 1960's in comparison with all other periods.[1]

Perhaps the present crisis in economic growth is not attributable solely to failures in innovation (as e g Mensch argues) or to globally declining marginal productivity of investment in R&D (as Giarini and Loubergé hypothesize)[2] but also to generally poorer conditions for economic growth? The latter argument is put forward by Abramovitz and Klein among others.[3,4]

Scope and Purpose of the Paper

No matter which view one takes of long swings in the business cycle and their relationship to great spurts in innovation, it is useful and enlightening to examine post-war economic growth from a micro perspective. Most studies of economic growth and productivity are macro-oriented and may therefore overlook im-

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[1] For a disscussion of this, see B Carlsson and E Waldenström, Technology, Structural Change, and Economic Growth in Sweden - A 100-year Perspective, IUI, Stockholm, mimeo, 1980.

[2] O Giarini and H Loubergé, The Diminishing Returns to Technology. An Essay on the Crisis in Economic Growth, Pergamon Press, Oxford, 1978.

[3] M Abramovitz, Rapid Growth Potential and Its Realization: The Experience of Capitalist Economies in the Postwar Period, Stanford University, mimeo, 1977.

[4] B H Klein, Dynamic Economics, Cambridge, Mass, Harvard University Press, 1977. See also Klein, "The Slowdown in Productivity Advances: A Dynamic Explanation", in C T Hill and J M Utterback, Technical Innovation for a Dynamic Economy, Pergamon Press, New York, 1979.

portant factors which emerge only if one digs a little deeper. However, in order to secure the link between micro and macro - which in the author's view is absolutely essential in understanding economic growth - such a micro study would have to cover a large number of areas, making the task inherently difficult.

A step in this direction was taken in a research project which the IUI recently carried out jointly with the Royal Swedish Academy of Engineering Sciences (IVA).[1] One of the aims of the study was to gain insight into the extent to which the Swedish economic crisis of the 70's can be attributed to technological failure and to what extent other factors are responsible.

The purpose of the present paper is to characterize technical and technological change in a number of industries in order to clarify the relationship between technical change and productivity. In particular, what are the constraints which have led to declining productivity growth in recent years? The bulk of the empirical results presented here derive from the IUI-IVA study but also from other IUI studies. But before we go into the micro material, an overall view of the development of labor productivity and output in Swedish manufacturing industries is presented.

Industrial Production and Labor Productivity in the Post-War Period

In Figure 2, annual rates of growth of production and labor productivity in various industries in each five-year period since 1950 are represented. There was a tendency in virtually all industries for both of these variables to increase up through the period 1960-64 (in several cases through 1965-69) but then to decline.

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[1] B Carlsson et al, Teknik och industristruktur. 70-talets ekonomiska kris i historisk belysning (Technology and Industrial Structure. The Economic Crisis of the 70's in Historical Perspective), IUI, IVA, Stockholm 1979.

Figure 2. Annual increases in production and labor productivity in Swedish manufacturing industries 1950-1977

Percent

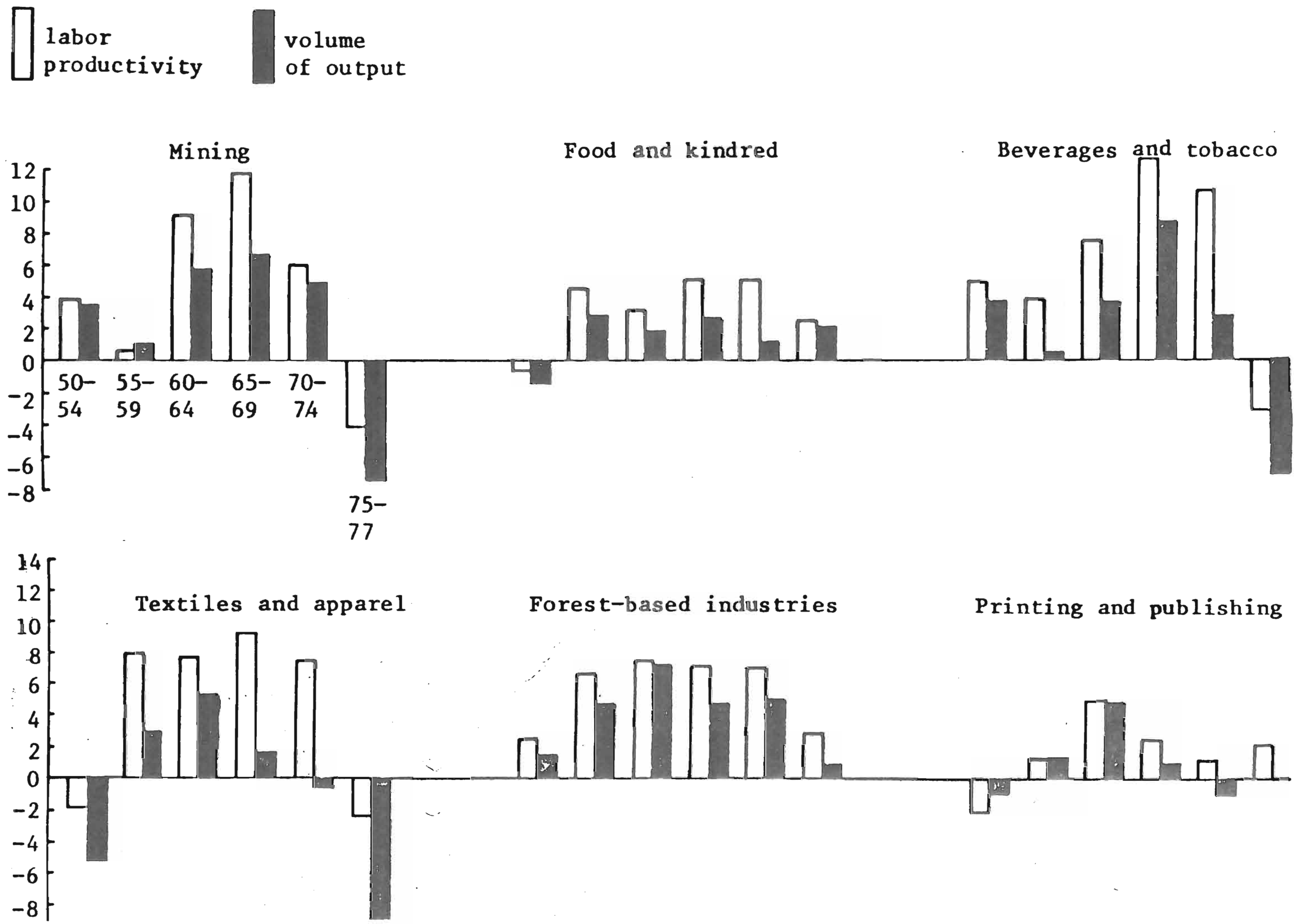
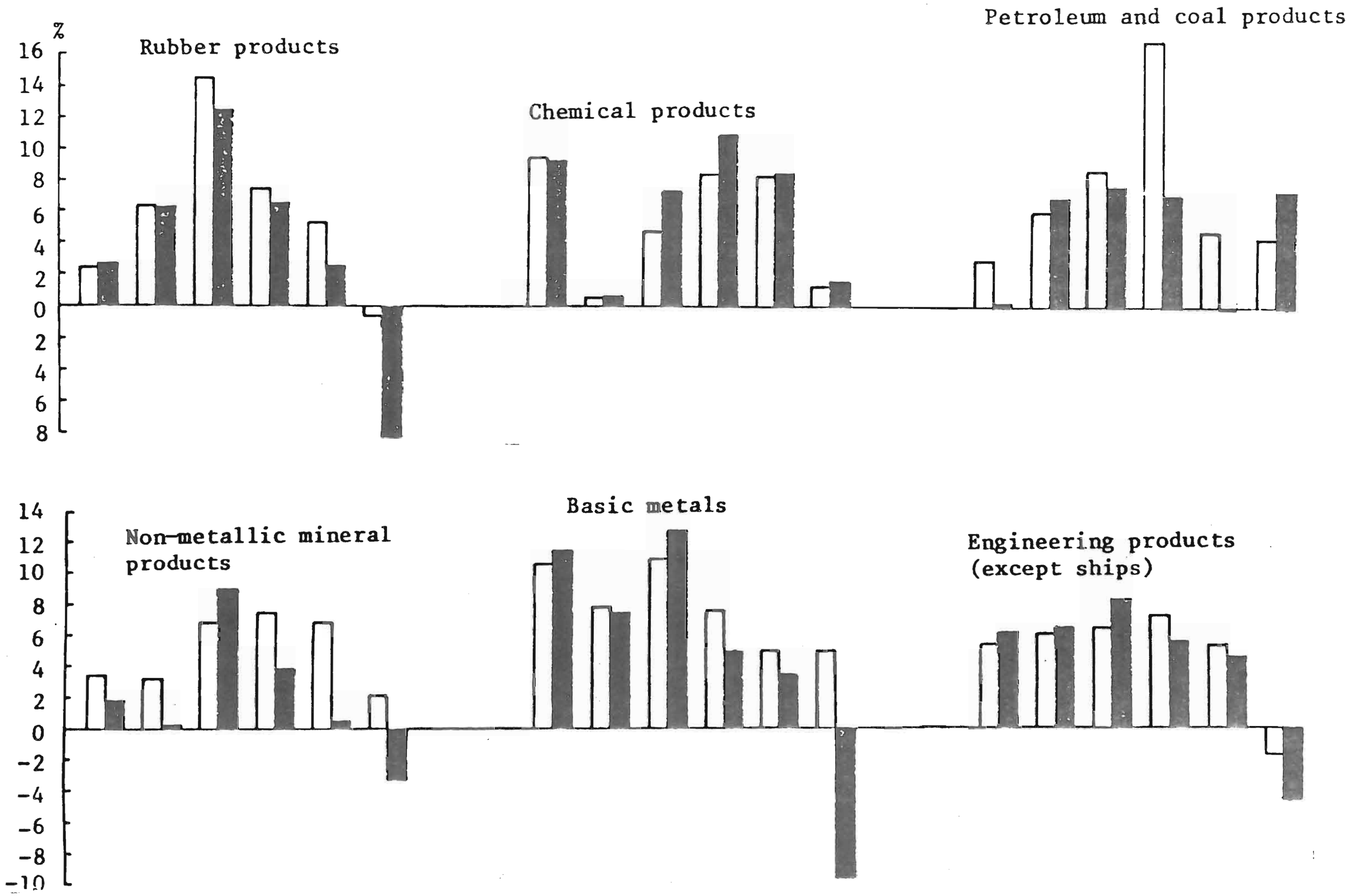


Figure 2. Continued



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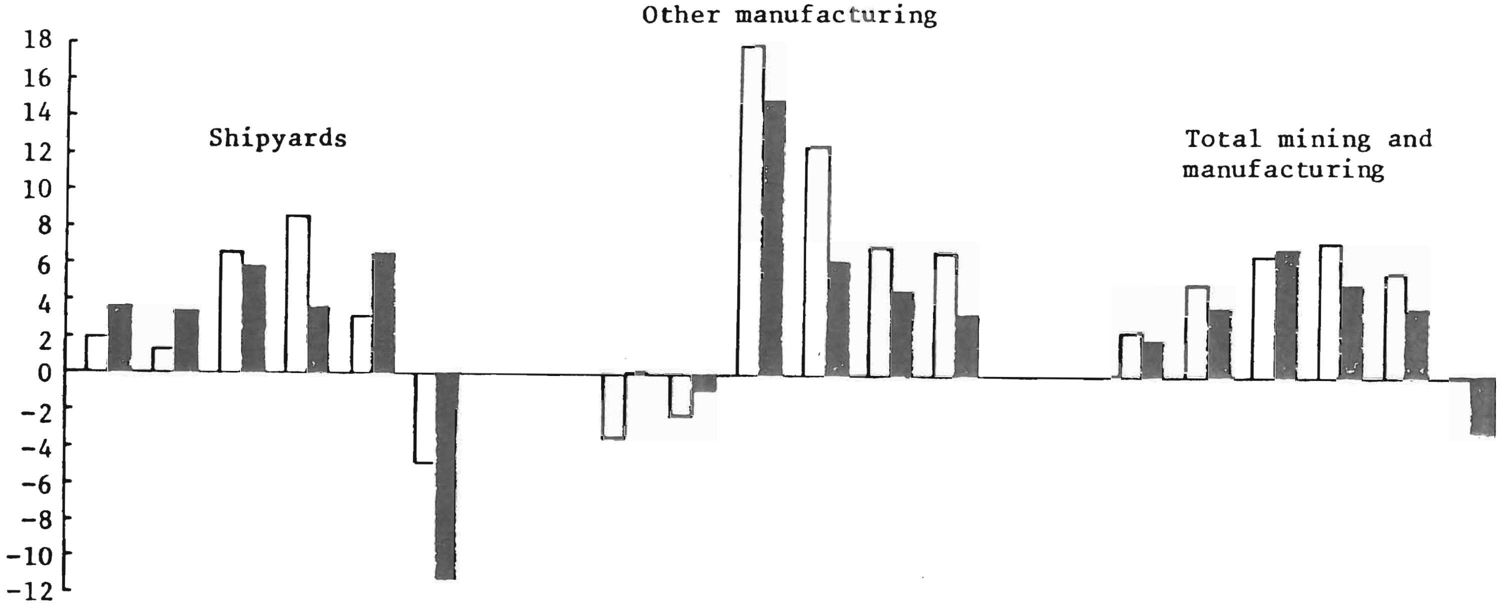

Source: Swedish National Central Bureau of Statistics, *National Accounts Statistics*.

This seems to follow the pattern observed in other countries as well.

Upon closer examination, it turns out that until the mid-1960's there was a tendency for output and labor productivity to increase at roughly the same rate. After that, the rate of growth of production fell while that of labor productivity remained at a high level until the mid 1970's. But then it not only diminished but it actually became negative in many industries. This suggests that up to 1965, investments tended to increase output, whereas after that the element of rationalization or capital substitution for labor seems to have increased in importance. If this is true, it would be consistent with the view that major or basic innovations were exploited up to 1965 and that beyond that time innovation has been largely of the improvement type.[1]

Labor Productivity in New (Best-Practice) Plants

In connection with the IUI-IVA study, a questionnaire was sent out to a number of persons (mostly engineers and members of the Royal Swedish Academy of Engineering Sciences, IVA), each with a great deal of experience of a particular technical field, covering at least the period since 1955.[2]

Among other things, these persons were asked to describe the major technical (or technological) changes which have occurred in the post-war period in their respective fields. They were also asked to supply data on the development of labor productivity in new (best-practice) plants in their own field over time. The results in the latter regard are shown in Table 1.

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[1] See the definitions on p 7-8 above.

[2] The questionnaire was sent to 58 persons out of which 47 responded. However, 10 persons answered only part of the questions or referred to other persons.

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)
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)
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)
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)
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 1960-1965.

[b] Refers to 1960-1970.

Sources: B Carlsson et al, Teknik och industristruktur. 70-talets ekonomiska kris i historisk belysning (Technology and Industrial Structure. The Economic Crisis of the 70's in Historical Perspective). IUI, IVA, Stockholm, 1979, p 141.
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.

The table provides a number of examples of the labor productivity change that took place between plants built in 1955 and plants built in 1965, in the first column, and in the second column between plants built in 1965 and plants built in 1975. In all cases the figures refer to newly built plants after debugging. The Table indicates, for instance, that in ethylene production in the petrochemical industry, labor productivity in a new plant built in 1965 was almost three times as high as in plants built in 1955, implying a 14.5 % annual change in best practice labor productivity. However, an ethylene plant built in 1975 had only 80 % higher labor productivity than one built in 1965, i e best practice labor productivity increased by a more modest 6 % annually. An inspection of the table shows that the figures in the first column are generally higher than those in the second column.[1] The Table shows, therefore, that the rate of technical progress measured in these terms has slowed down in many areas in the last decade relative to the earlier decade.

In interpreting the Table, several things should be borne in mind. The technologies listed are relatively old and well-established. If a new technology follows an s-shaped pattern over time (that is, if the rate of technical progress is slow in the beginning, fast during a certain period, and again slower as the technology matures), this slowing is to be expected; it is, therefore, not necessarily true that overall technological change has slowed down in the last ten years. It may well be rapid in other areas not listed in the Table, e g in electronics.

In the Table, the examples have been grouped according to the industrial classification used in a Swedish micro-to-macro simula-

[1] In one area, marine turbines, labor productivity actually fell between 1965 and 1975. This is due to shorter production runs during the crisis in the world shipping and shipbuilding industries from 1974 on. It is somewhat doubtful, however, if the figures given can be said to represent current best practice, since there has been no new plant built in recent years.

tion model. Thus, it would appear that the rate of technical progress was higher in the extractive and raw material processing industries than in other industries in the period 1955-65. For the 1965-75 period it is more difficult to distinguish any such differences among industries. The information is simply too scanty to draw any firm conclusions in this regard.

Simulations carried out on the Swedish micro-to-macro model indicate that the rate of increase of labor productivity in best-practice plants 1955-1975 must have been considerably higher in the raw material processing industries than in other industries; otherwise it is not possible to reconcile observed data on investment with the observed average labor productivity increases in each industry.[1] The figures obtained in these simulations are given in parentheses in column 3 in Table 1. For all manufacturing the estimated rate of increase (a weighted average) amounts to 2.5% per annum. The figure for the raw material processing industry (5.9% per year 1955-75) coincides fairly well with the figures for the paper and pulp industry. This industry makes up a very large part of the whole raw material processing sector. But otherwise there seems to be little correspondence. The labor productivity growth rates do seem to be somewhat higher in the intermediate goods industries listed in the table than in investment goods, in keeping with the simulation results. But the discrepancies seem fairly large for the consumer goods industries.

Of course, we are dealing here with only a small sample of activities in each industry. It is impossible to know how representative they are. But as far as we know, this is the first attempt that has ever been made to measure technical progress in best-practice plants over a wide spectrum of activities. Thus, even though it is not yet clear what conclusions may be drawn, this is a line of inquiry which we intend to pursue in our further research.

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[1] B Carlsson and G Olavi, <u>op cit</u>.

Another thing that should be kept in mind is that the economic growth rates in most industries have been generally lower after 1965 than before. This is true not only for Sweden but also for other industrial countries. It is argued in Carlsson-Waldenström (1980)[1] that for a number of reasons the major benefits of certain basic innovations introduced on a large scale after the Second World War had been reaped by the mid-1960's. In addition, the lion's share of the resource re-allocation resulting from the opening up of trade and factor markets after the War had also been exhausted during the 1960's. This led to a decline in economic growth in the industrialized countries in general.

This slowdown in economic growth may mean (1) that the rate of introduction of new technologies (i e innovation) has slowed down even if the rate of invention has not, and (2) that it may not have been possible to increase the scale of new plants at the same rate as earlier. Therefore, in order to understand more fully what has happened to the rate of technological change and labor productivity in best-practice plants, it is necessary to go considerably beyond Table 1. In the following section an attempt will be made to give a more complete picture of each technical field than can be represented by a few figures. The emphasis will be on the nature of innovations in each field, on the rate of growth of output and on scale economies. The information which is presented is drawn largely from the questionnaires upon which the table is based. For obvious reasons it will not be possible to cover all the areas in detail; only a sample will be examined here.

Iron ore industry. The data for this industry refer to underground mines in central Sweden. In 1955, 75 man-hours were required per ton of rock. This figure was reduced to 35 hours in 1965 and

[1] Carlsson-Waldenström, op cit.

25 hours in 1975. At the same time, the volume of production increased from 2.6 million tons in 1955 to 3.5 in 1965 and 4.0 in 1975 (i e, increases of 33% in the first ten-year period and 15% in the latter period). The main technical changes which facilitated the productivity increase were (1) the introduction of cemented carbide drill bits immediately after the Second World War, which have revolutionized mining techniques; (2) the transition to trackless, diesel-driven transport equipment, which permitted large-scale underground mining operations; (3) further development of flotation processes for ore enrichment, permitting a high degree of ore purification and the production of so-called super concentrates; and (4) improvements in the techniques of grinding and sorting.

Commercial steel. There has been a great deal of technological change in the steel industry since World War II. There have been both process and product innovations. Examples of the former are oxygen steel processes, large-scale and highly efficient blast furnaces, direct reduction processes, AOD and other oxygen processes for stainless steel, so-called secondary metallurgy, i.e. further processing of crude steel after the steel furnace (vacuum and injection methods), continuous casting, wide strip mills for hot rolling of steel, high speed thread rolling mills, precision cold rolling of wide strips, extrusion of stainless tubes (also other alloys), and methods for producing high quality welded tubes.

Examples of product innovations are stainless and acid resistant steel for the chemical industry; new heat resistant steel qualities; new welded and tool steels; nickel, titanium and zirconium alloys; high strength, low alloyed (HSLA) steel; compound materials for tubes and strips; plastic coated galvanized steel; etc.

Before the Second World War there was only one large commercial steelworks in Sweden. During the interwar period and the War the Swedish steel industry became strongly oriented towards the domestic market. At the end of the War, with much of the rest of Europe in ruins, the Swedish steel industry re-oriented itself towards new products and international markets. Two new large-scale steel mills were built, specialized in products for the rapidly growing shipyards both in Sweden and throughout Europe. The Swedish commercial steel output increased from 1.6 Mtons in 1955 to 3.4 Mtons in 1965 and 4.0 Mtons in 1975.

Through the large investments that supported this rapid expansion up until the mid-1960's, new technologies were introduced. Thus, Sweden was a relatively early adopter of both basic oxygen converters and continuous casting. See Figures 3 and 4. Sweden was also in the forefront in research on sponge iron and other direct reduction methods. Up until 1957, Swedish blast furnaces were the most fuel efficient (and therefore among the most economical) in the world. But even though the new plants that were built represented giant steps relative to earlier capacity, they were small in comparison with new steel plants being built elsewhere. In particular, the Swedish steel industry seems not to have been aware of, or to have ignored, the development in the Japanese steel industry. In 1960 there were only a few integrated steelworks in the world which were more than twice the size of the largest Swedish ones. But in 1975 there were at least 50 steelworks more than twice as large.[1]

In the IUI-IVA study an attempt was made to assess the relative technological position of leading Swedish firms in various technical fields over the postwar period. One of the conclusions of this study was that ordinary steel was one of the few areas where Sweden had lost an earlier technological lead. As far as technical

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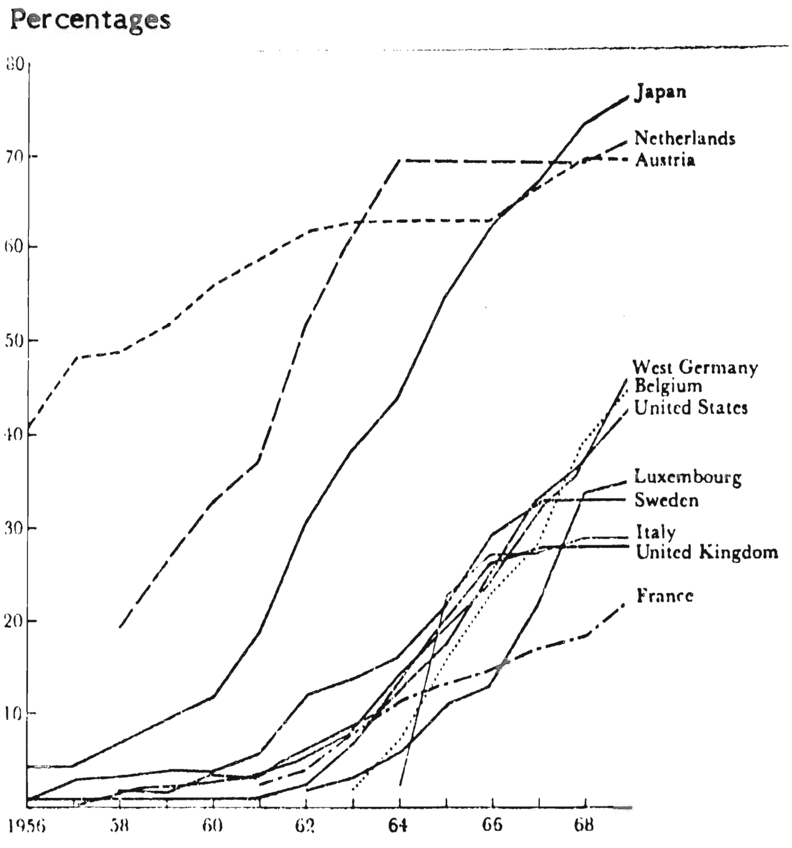
[1] B Carlsson, Internationell konkurrenskraft hos den svenska järn- och stålindustrin och massa- och pappersindustrin med hänsyn till energikostnaden, mimeo, IUI, Stockholm, 1980, p 5.

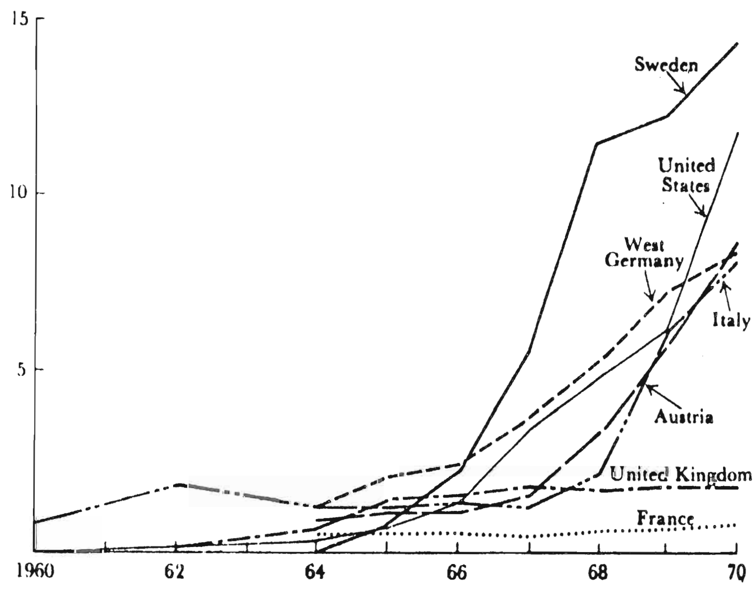
Figure 3. Shares of basic oxygen steel in total crude steel output in certain countries 1956-1968



Sources: L Nabseth and G Ray (eds), The Diffusion of New Industrial Processes. An International Study. London, Cambridge University Press, 1974, p 153.

Figure 4. Shares of continuously cast steel in total crude steel production in certain countries 1960-1970

Percentages



Source: L Nabseth and G Ray (eds), op cit, p 241.

knowhow is concerned, Sweden was found still to be in a leading position. But due to the scale factors and to the situation in the international steel market, it had not been possible in the last ten years, at least, to embody this knowhow in new, large-scale plant and equipment.

A similar development has been characteristic of the Swedish special steel industry as well. Here Sweden has long historical traditions. The share of special steel in total steel production is about twice as large as that of any other major steel producing country (about 25% in Sweden, compared to 15% in West Germany and the U S)[1]. According to the IUI-IVA study, Sweden has maintained a position on the technological frontier throughout the post-war period, although it is no longer ahead of the major competitors. But again, as far as scale is concerned, the Swedish position has deteriorated. See Table 2. According to the Table, the Swedish electric steel furnaces (used for smelting and refining scrap into crude steel) were the largest in Europe in 1960 but the smallest of all the countries in the comparison in 1975.

For comparison it may be mentioned that in a certain stainless steel plant, the labor productivity increased by 7.4% annually 1960-1965 and by 2.8% per year 1965-1975. At the same time, total Swedish production of stainless steel increased by 9.3% annually in 1960-65 and by 4.3% 1965-75.

Steel tubes. The data in Table 1 refer to a company which built a new plant in 1953-55 after a fire in an old plant. In the old plant, 9 700 tons of steel tubes were produced in 1952, with a labor input of 28 man-hours per ton. After the new plant had been brought into normal operation in 1959, the output level was approximately 20 000 tons and the labor input requirement was 13 man-hours per ton. Through growth in demand, the output level

[1] Ibid, p 5.

Table 2. Average annual output of electric steel furnaces in certain countries, 1960-1975
1 000 tons

	1960	1975
Sweden	15.1	22.7
West Germany	12.8	28.2
France	12.3	29.3
Poland	12.5	29.1
USA	25.3	71.9
Japan	7.1	25.0

Source: ECE, Structural Changes in the Iron and Steel Industry, 1979, p 73.

in the new plant was increased to 39 000 tons in 1965, with a labor input of 7 man-hours per ton. The output level reached 49 000 tons in 1970 but fell back to 39 000 tons in 1975 due to the business downturn. The labor input in 1975 was 4 man-hours per ton.

Thus, most of the reduction in the labor input in this case can be attributed to increases in the output level. This has been achieved, in turn, by increasing the speed of the production equipment. The production level in 1980, 49 000 tons, could be increased to 65 000 tons through some minor additional investments. This would correspond to 20 tons of output per hour. In a completely new plant it is estimated that the production level could reach 30 tons per hour - provided that the demand is sufficient. The major constraint on further productivity increases at present seems to be the slow growth of demand for the industry's products in general.

The main technical changes as far as steel tubes are concerned have been improvements in the welding and control techniques which have permitted welded tubes to gain market shares from seamless tubes. Changing from low to high frequency resistance welding has essentially raised the quality of welded tubes, while the introduction of so-called inductive testing and ultra-sound testing has replaced older and slower testing techniques and made the controls more reliable.

The story is very similar for steel forging. The data in this case refer to a plant built in 1952 which has been successively expanded. The production level was 2 500 tons in 1955, 7 000 tons in 1965 and 10 000 tons in 1975.

Technical change in this area has been gradual. The very long production runs which have been achieved in forging axles for passenger cars have facilitated the introduction of mechanized special purpose machines with very high productivity. However, these machines have found much wider application elsewhere than in Sweden where the production runs are relatively short. For special purposes, cold forging, hydrostatic extrusion and powder techniques have been used increasingly.

The petrochemical industry. The production of basic petrochemical products, such as ethylene, was nonexistent in Sweden prior to 1963. Instead, the organic chemical industry was based on wood liquor (for production of ethylene oxide, e g) and on carbide acetylene (for production of carbide and other polymers, such as polyvinyl chloride, PVC), which in its turn was essentially based on cheap hydro-electric power. Up until 1955 this domestic industry was flourishing, but by the end of the 1950's the demand outgrew the supply capacity. For a number of reasons it was found unprofitable to base the future expansion on domestic raw materials.

Instead, a switch was made to imported naftha. A steam cracker was built with an initial capacity of 50 000 tons in 1963. By 1969 the capacity had been raised to 200 000 tons annually and to 325 000 tons in 1975.[1] It is estimated that a completely new best-practice plant by then would have had a capacity of approximately 500 000 tons. Figure 5 illustrates the corresponding development in the part of the petrochemical industry, namely ethylene oxide production.[2]

The labor productivity increases in this industry, therefore, have been the result primarily of increased scale: the labor force of the steam cracker increased from 175 persons in 1965 at an output level of 50 000 tons to 225 persons in 1975 at an output level of 325 000 tons. Besides increasing scale, other technical changes which have influenced the industry have been improved storage techniques (e g through underground storage of liquid gases, a genuinely Swedish technology) and significantly reduced ocean transport costs for oil as well as finished products.

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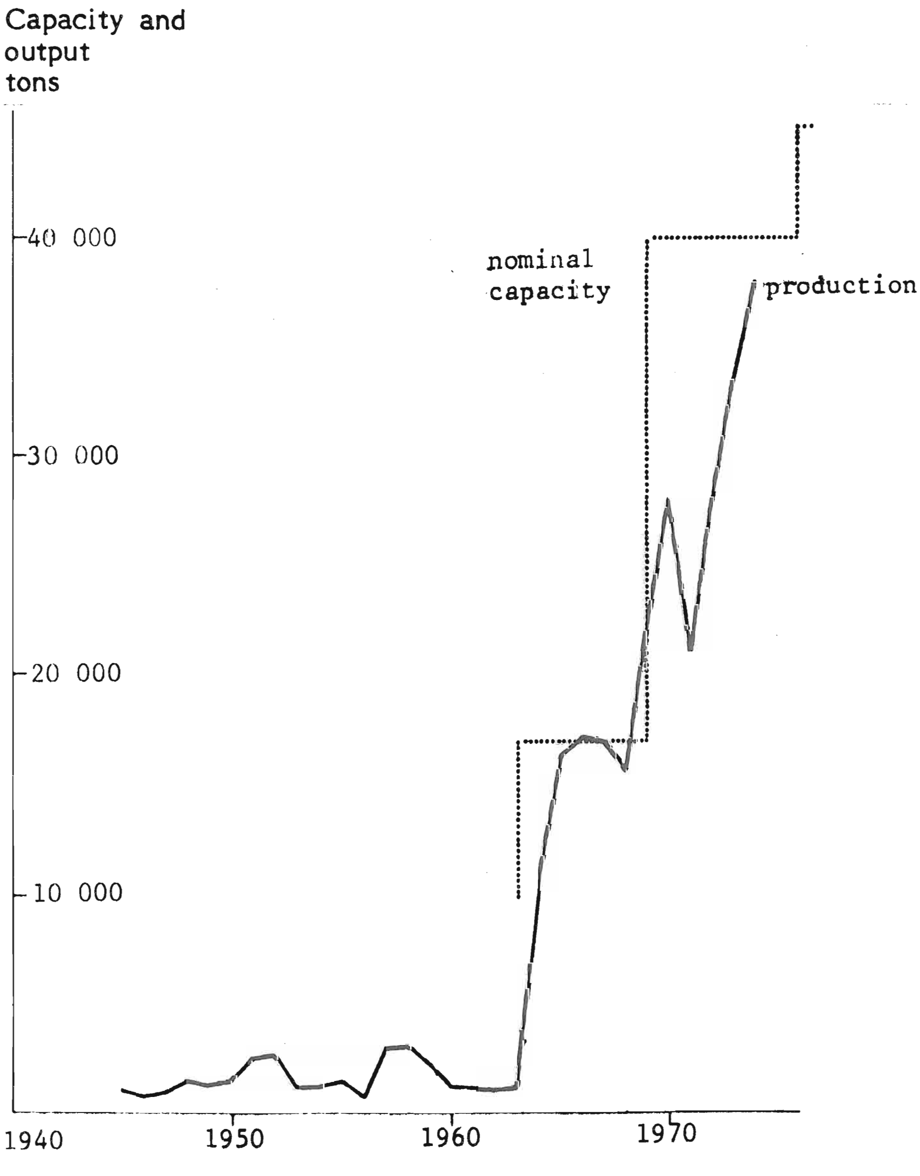
1 L Davidson, M Ericsson, G Norén and E Rensfelt, Organisk-kemisk industri i Sverige (Ingenjörsförlaget AB, Stockholm, 1975), pp 169-196.

2 The figure also illustrates the problem that the meaning of best-practice plants is not always clear. In a given country there may not be any new plants built over long periods; and then, after they are built, it may take a long time before their full capacity is utilized.

Figure 5. Capacity and output in the Swedish ethylene oxide industry 1945-1975



Source: Davidsson et al, op cit, p 184.

Canning and freezing

The main technological changes in this industry since World War II have been the following:

a) Deep freeze technology was introduced on a commercial basis in Sweden at the end of the 1940's. This involved highly effective freezing apparatus and a system of storage and distribution of food in an unbroken chain. More and more products could be frozen at reasonable prices. Sweden is second only to the United States in per capita consumption of frozen food: 21 kg/capita vs. 40 kg per capita in the U.S. (1975 data).

b) Drying techniques permit the food to maintain its sensory and nutritional quality after treatment.

c) Industrially prepared infant foods, both dried (e g in powder form) and sterilized (in glass containers) have gained rapidly in importance since World War II.

d) Continuous processes, such as sterilizing, deep frying, etc, have lowered costs and increased the quality of the products, thanks to improved process control.

e) HTST (High Temperature, Short Time) sterilizing of food is a technology which has been developed since the War.

f) New packaging methods have been developed.

Many of these innovations, particularly having to do with the preparation and distribution of frozen food, have been developed or improved in Sweden. According to the IUI study mentioned above, Sweden has been on the frontier, along with the United States, in this technology ever since the 1940's. But as far as canning (pasteurizing and heat sterilizing) technology is concerned, Sweden remains behind countries such as France and West Germany because of diseconomies of small scale: the Swedish production is too small to support investments in the most modern and efficient equipment.

According to Table 1, labor productivity in canning and freezing increased by 13.1% per year 1960-65 and by 4.3% per year 1965-75.

In the food industry in general, the main technological changes have been new products (i e, various types of industrially prepared food), continuous rather than batch production processes, automation of production processes, so-called Cleaning In Place Systems, the development of non-corrosive materials such as titanium which have led to changes in food processing machinery. All these changes, in addition to the development in the transport systems area, have led to a concentration of the food industry to large, specialized units. This specialization and utilization of scale economies seems to have slowed down in recent years, but the industry has barely begun to apply automation and computer technologies.

Summary of the Empirical Evidence: The Importance of Scale Economies

The conclusion that can be drawn from this survey of various industries is that the slower rate of growth of labor productivity in best-practice plants after 1965 compared with the ten-year period before 1965 can be largely attributed to two factors: 1) The slower rate of growth of demand has slowed down the introduction of new technology. 2) Scale economies seem to have increased generally faster than the rate of growth of production, at least in Sweden. In the expansive period up through the 1960's a great deal of pre-World War II plant and equipment was scrapped and replaced by new and vastly more productive technologies.

The re-orientation of the Swedish economy toward international markets and away from the domestic ones in connection with the liberalization of world trade, the formation of EFTA and EEC, etc, entailed a specialization in areas where Sweden had comparative advantage. This meant, among other things, that scale economies could be utilized, often far beyond the small domestic market. However, the technological and other advantages which Sweden enjoyed in comparison with the war-torn economies of Western Europe immediately after the war began to diminish as the other countries re-built their economies. The degree of international competition increased, making it more difficult to gain shares in the international markets. In the course of the 1960's it became more and more difficult to maintain the rate of growth. If, as seems likely but has not been shown conclusively to be true, scale economies continued to grow at an undiminished rate, a rising number of industries found themselves pushing against the capacity constraints of their present plants but unable to take the giant steps into a new generation of scale-efficient plants. In order to accommodate new plants with relatively slow demand growth, it would have been necessary to scrap older plants which were not yet obsolete. The lure of tremendous scale economies led to world-wide overinvestment. This seems to have occurred, e g in the steel industry, in shipping, and in heavy chemicals. The new and highly efficient plants simply forced down the price, thereby squeezing out many not yet very old but already too high-cost plants.

Thus, part of the decline in the growth rate of demand experienced by Swedish firms after 1965 may be attributable to increased competition in Western Europe resulting from economic integration and reconstruction after the War. Sweden reached a peak in its growth rate earlier than other European countries (see Figure 1). When these countries caught up and built new plants, these were often larger than the newest Swedish ones. This pushed down the price level, making it difficult for Swedish firms to maintain their international market shares.[1] This may have been experienced by Swedish firms as a decline in the growth rate of demand.

Increasing Distance between Average and Best Practice

If it is true that scale economies have outpaced the growth of demand, one would expect the gap in productivity between average and best-practice plants to increase over time. To what extent has this been true?

This is an issue which has been illuminated in several IUI studies in recent years. Several Swedish industries have been studied: milk processing in dairy plants, the particle board industry, the paper and pulp industry, blast furnaces, and hydroelectric power plants. In all of these cases the result is the same, namely that the difference between average and best practice has increased over time. A few examples are given below.

In Figure 6 the shifts of the average and best-practice production function betweeen 1964 and 1973 in the Swedish dairy industry are illustrated. It is easily seen that the difference between average and best practice increased over this period. The same is true also if one looks at single factor productivity (e g labor productivity).[2]

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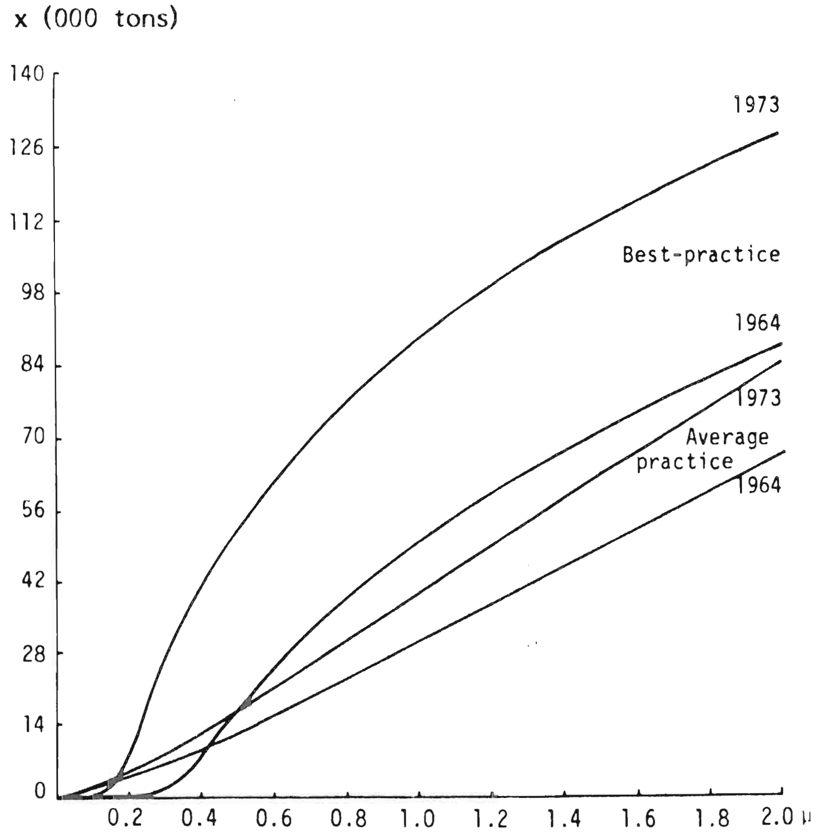
[1] The declining Swedish market shares after 1965 have been analyzed in E Ch Horwitz, "Världshandeln, marknadsandelar och svenska kostnader" ("World Trade, Market Shares and Swedish Costs") in B Axell, S Gustafsson, B Holmlund, E Ch Horwitz, Utrikeshandel, inflation och arbetsmarknad (Foreign Trade, Inflation and the Labor Market), IUI, Stockholm, 1979.

[2] See F R Førsund and L Hjalmarsson, Analysis of Industrial Structure: A Production Function Approach, forthcoming IUI study.

Figure 6. The change in the frontier and average production function through time

Combined time-series cross-section analysis. The production function cut with a vertical plane through the origin along a ray, $(\mu L^o, \mu K^o)$, L^o = 15 000 and K^o = 200 000.

$$x^{\alpha}e^{\beta x} = Ae^{\gamma_3 t}(\mu L^o)^{a_1-\gamma_1 t} \cdot (\mu K^o)^{a_2+\gamma_2 t}$$



Source: F R Førsund and L Hjalmarsson, "Technical Progress and Structural Efficiency of Swedish Dairy Plants", in Carlsson-Eliasson-Nadiri (eds), The Importance of Technology and the Permanence of Structure in Industrial Growth. IUI Conference Reports, 1972:2. IUI, Stockholm, 1978, p 170.

Another example is provided in Figure 7. It shows the development of average and best-practice capital productivity in Swedish hydroelectric power plants 1925-1975. Here, too, the difference between average practice (the lowest curve) and best practice (measured in several ways) has increased over time.

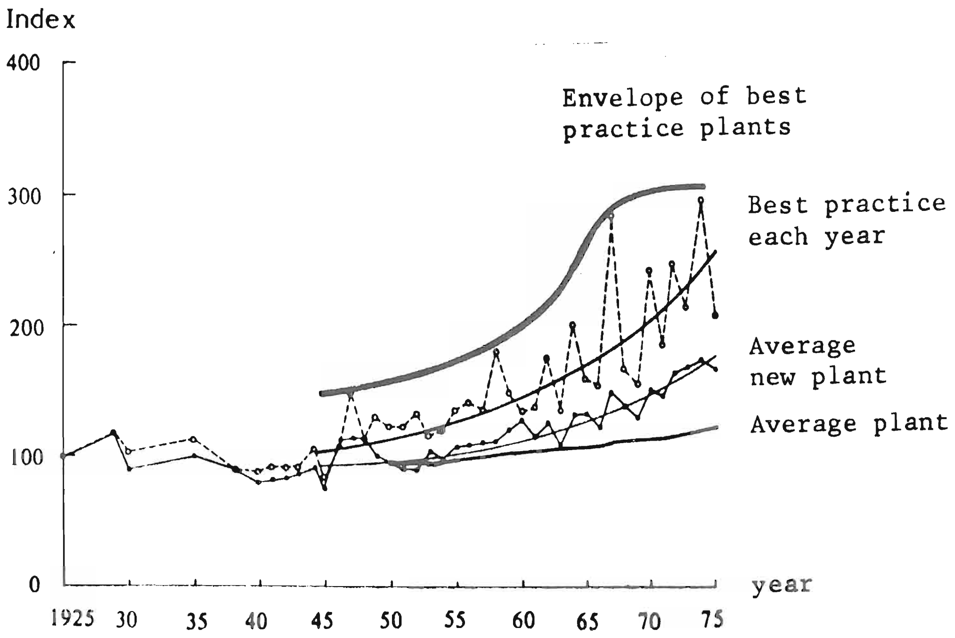
One implication of these findings is that slow demand growth in industries with rapid technical change (perhaps in the form of scale economies) leads to very great differences in competitiveness among firms within the industry. It is the average which determines the international competitiveness. If demand for the industry's products grows faster abroad than at home, chances are that foreign firms will be able to update their plant and equipment much faster than domestic firms. Thus, the international competitiveness of the domestic industry will diminish, making it more difficult to generate the funds necessary to build new capacity when old plants have to be phased out.

How big a problem this is in a given country depends on its composition of output and on its economic growth rate. A country that is heavily committed to a certain set of mature technologies may have difficulties until it can switch to new areas where technological progress is faster.

Some Further Aspects on the Relationship between Output Growth and Productivity

In this section, two examples are given, illustrating the possibilities of raising productivity that arise when output volume grows as well as the difficulties one encounters in maintaining productivity growth when demand fails to increase.

Figure 7. Capital productivity in the Swedish hydropower sector 1925-1975
Index 1925 = 100



Source: A Grufman, Teknisk utveckling och produktivitet i energiomvandlingssektorn. (Technical Change and Productivity in the Energy Conversion Sector; with English summary). IUI, Stockholm 1978, p 117.

The first example is an illustration of how productivity may increase as output grows even without capital investment. It is taken from the Swedish iron and steel industry.[1]

In a hot strip mill built in 1952 there were no investments made, other than replacements of worn-out equipment, over the whole period 1953-1977. In spite of this, labor productivity increased by an average of 3.7% per year. This result resembles very closely that reported by Erik Lundberg for the steelworks at Horndal, commonly referred to as the "Horndal effect".[2]

How was it possible to double the output per working hour over 17-18 years without any new investment?

The most important explanatory factor has to do with economies of scale. When production was originally started up in the new plant, only a fraction of the total capacity was used.[3] As the demand grew, more and more of the installed capacity was utilized. Thus, it was possible to increase production without increasing either the labor force or the invested capital. Each production batch simply grew larger.

In addition to the increase in output which in itself had beneficial effects on productivity, other measures were taken. One such measure was a concentration of the product assortment to certain dimensions and qualities of products. Another measure was

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1 This example is based on a study by Lars Vinell which was summarized in B Carlsson _et al_, _op cit_, pp 131-2. A more complete report is forthcoming.

2 See E Lundberg, _Produktivitet och räntabilitet_ (Productivity and Profitability). SNS, Stockholm 1961.

3 Cf the situation shown in Figure 5 after each expansion of ethylene oxide production capacity.

standardization of the products which further reduced the assortment. Through actions of this type, the production runs were lengthened, making it possible to increase the weight of the semis to be processed. This meant that the number of rolling operations was reduced for a certain tonnage of finished products, lowering capital and labor as well as energy inputs per ton of output. It is difficult to imagine the productivity increase in this case without a substantial increase in output.

Another example of the interrelatedness of productivity increase and output growth is provided by another recent IUI study,[1] which examines the transition from a functional layout of a particular plant producing small electrical components, contactors, along with many other products, to an integrated product layout designed for only contactors. In the original plant, each step in the production process was carried out at a specialized station (one for welding, one for drilling, etc) which performed the same function for all products. In the new organization, all operations pertaining to the production of contactors were broken out of this functional scheme and put in a separate plant. In connection with this change, many of the operations were mechanized or automated and connected via an automatic transport system of the assembly line type. This vastly reduced the need for interior stocks, thus reducing the capital tied up in the process, even though the purchase of new automatic machinery involved substantial investments. The amount of paperwork was also greatly reduced along with many manual operations, thus reducing the labor force and increasing productivity.

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1 S Nilsson, Förändrad tillverkningsorganisation och dess återverkningar på kapitalbindningen: En studie vid ASEA (Changing Organization of Production and its Impact on Capital Inputs: A Study at ASEA); mimeo. IUI, Stockholm 1980.

However, it is important to note that these changes could be carried out only after the production volume reached a certain level. Similar attempts to re-organize production and increase productivity have been made in other departments but have been severely held back by insufficient production volumes over which the investment costs could be spread. The company has also pointed out (1) that the success or failure of a re-organization such as this is very largely determined by whether or not the projected output levels are reached, and (2) that a fully integrated product-oriented plant is highly inflexible; it cannot be used for any other activity than that for which it was designed without very large adjustment costs.

Conclusion

The results of the present micro-based study seem to be consistent with the loose but highly suggestive results of earlier, more macro-oriented studies. The present results emphasize the negative impact on productivity of a slow-down in economic growth. This mechanism was pointed out e g in a 1954 study by Svennilson.[1] However, this is not to deny that there is also a reverse relationship, i e that productivity influences growth; this is clearly a two-way street. The slowdown of economic growth that has occurred since the mid-1960's throughout the industrialized world can be attributed to a number of factors (slower progress in trade liberalization, exhaustion of the most obvious potentials for resource re-allocation in connection with increased international division of labor, the breakdown of the Bretton Woods system of fixed exchange rates, the exhaustion of cheap energy and of labor reserves in agriculture, etc).[2]

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[1] I Svennilson, Growth and Stagnation in the European Economy, ECE, United Nations, Geneva, 1954, p 57.

[2] See e g B Carlsson and E Waldenström, op cit.

A stalemate in the development of basic inventions as suggested by Mensch and others may also have occurred. The results of the present study at least do not contradict that hypothesis. There seems to have been a fairly steady flow of relatively minor innovations (both new products and new processes) but few major or basic innovations in the areas studied in this paper. An important aspect of the technical improvement that has taken place is that economies of scale seem to have increased in virtually all areas studied. Scale economies seem generally to have outpaced the rate of growth of demand, leading to global overcapacity, greater specialization, and a higher degree of concentration in many industries. This has forced many businesses into putting great emphasis on increasing the volume of production as a means of survival. When demand fails or fluctuates, the firms are in trouble, because the very scale economies that make them competitive also make them highly inflexible and therefore vulnerable.

These phenomena are probably not restricted to a small economy such as Sweden but are rather more general. However, Sweden may be harder hit than other industrial economies, for two reasons: (1) Due to its comparative advantage in raw material processing, Swedish industry is heavily oriented towards industries where scale economies continue well beyond the size of the national market. Thus, in order to take advantage of scale economies in the future, Swedish firms may have to gain market shares from other competitors. (2) The international demand for raw materials generally increases more slowly than that for other products.[1] This means that these industries generate less dynamic force in the economy than other industries. Thus, even if technological change takes place in these industries at the same rate as

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[1] See e g Horwitz, op cit.

in other sectors of the economy, the impact will be smaller on the economy as a whole. (3) If it is true, as was hypothesized earlier, that technological progress is faster in new areas not covered in this paper than in traditional ones, the orientation of Swedish industry may render Sweden less able than other countries to take advantage of new technologies in those new areas of economic activity.

What, then can be done to deal with increasing economies of scale? One obvious response is to specialize in areas where scale economies are exhausted at a relatively small scale. However, the present paper indicates that these areas may not be very numerous. Another strategy is to organize production in such a way that scale economies can be reached by designing multi-purpose components that can be produced in large series. Many Swedish firms seem to be successful at this. Yet another possibility is to try to combine automation (which requires large scale) with a high degree of built-in flexibility. This requires new ideas in the organization of production, in product design, in programming machinery and process control equipment, etc. Progress in this area seems to have been slow so far.

Of course, an obvious solution to the present difficulties would be if a sudden burst of innovations were to occur. Could the electronics revolution break the impasse? Many people think so. Others fear its impact on employment. How far will the process of Schumpeterian "creative destruction" take us? These are topics that are dealt with in another paper.[1]

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[1] G Eliasson, Electronics, Technical Change and Total Economic Performance, IUI Research Report no 9, 1980.