Articles

The Content of Productivity Growth in Swedish Manufacturing

by Bo Carlsson

What role has technical change played in economic growth in Sweden? What are the major components of technical change? These are two of the main questions which motivated a study on the origin of the economic crisis of the 1970's which IUI conducted in collaboration with the Royal Swedish Academy of Engineering Sciences (IVA) with financial support from IVA and the State Board for Technical Development (STU). In this paper, an attempt will be made to summarize the results of this study with regard to the role and composition of productivity change in industrial growth in Sweden.

The Role of Technical Change in Industrial Growth

In a traditional production function approach to the measurement of economic growth it was found that increased inputs of labor (measured in man-hours) and capital (the stock of plant and equipment) account for only 57 % of the increase in Swedish non-residential business output over the period 1870-1964.[1] In this measurement, no adjustment was made for quality changes in inputs such as those associated with increased education of the labor force or improvements in capital equipment. Instead, such changes are included in the unexplained residual, often referred to as total factor productivity. By definition, the residual includes all changes in the volume of output which cannot be attributed to changes in the quantity of labor and capital. Thus, for the period 1870-1964, total factor productivity growth accounted for 43 % of the increase in non-residential business output in Sweden.

Åberg's calculations show that the contribution of total factor productivity growth to output growth has increased over time, namely from 42 % 1870-1913 to 59 % 1946-64. Table 1 shows the corresponding development during the postwar period for the manufacturing sector only. The rate of growth of total factor productivity reached a historical peak during the first half of the 1960's. The same is true for the rate of growth of industrial output. Since then the growth rates of both volume of output and total factor productivity have declined, but the *relative* contribution of total factor productivity growth has increased. During the last decade, almost the entire in-

[1] Y. Åberg, *Produktion och produktivitet i Sverige 1861-1965* (Production and Productivity in Sweden 1861-1965). IUI, Stockholm 1969.

crease (over 90 %) in the production volume can be attributed to total factor productivity growth. The increase in capital stock has been roughly sufficient to compensate for the decline in labor inputs (still measured in man-hours). Over the whole period 1950-76, 3/4 of the growth of output can be attributed to total factor productivity growth.

Table 1. *Production, factor inputs and total factor productivity in Swedish industry 1950-1976*

Period	*Pro-duction*	*No. of hours worked*	*Capital stock*	*Total factor produc-tivity*	*Percentage of output growth attributable to total factor productivity growth*
		Annual percentage			
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
1950-55	2.5	0	5.5	0.9	36
1955-60	4.8	—0.2	4.6	3.6	75
1960-65	6.9	0	5.4	5.3	77
1965-70	5.1	—1.8	4.8	4.9	96
1979-75	2.4	—1.8	4.6	2.2	92
1950-76	4.2	—0.8	5.0	3.2	76
United States non-residential business sector					
1948-73	*3.6*	*1.0*	*2.9*	*2.2*	*61*

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. 111.
The U.S. data have been computed from data presented by E. F. Denison, *Accounting for Slower Economic Growth, The United States in the 70's.* The Brookings Institution, Washington, D.C., 1979, esp. pp. 62-3.

For comparison, similar figures for the United States non-residential business sector 1947-73 are presented in Table 1. In this case, too, total factor productivity growth accounts for most of the increase in output, namely 61 %.

The Content of Total Factor Productivity Growth

What, then, are the major components of total factor productivity growth? The traditional methodology of growth accounting developed by Denison and others involves an attempt to break down the residual by taking into account changes at the macro level in labor force characteristics (age and sex composition and education), improved allocation of resources, changes in the legal and human environment, and economies of scale resulting from larger markets. The remaining residual is then attributed mainly to advances in knowledge.[1]

It is worth noting, however, that even after taking account of these factors, a very significant portion of total factor productivity change remains unexplained. Another drawback of this method of productivity accounting is that it focuses almost entirely on the macro level, ignoring changes that take place at lower levels of aggregation, i.e. within branches of industry, within firms, etc. More specifically, the method offers no possibility of analyzing the impact at the macro level of specific technical changes that occur at the micro level. If one believes (as I do) that a thorough understanding of productivity change must encompass the whole micro-to-macro chain, a different approach is called for. In what follows, an attempt will be made to outline a more micro-based approach and to report some preliminary measurements.

In a completely static world, i.e. a world without technical change, any increase in production would be explained by increases in inputs of labor and capital, assuming that no other factors are relevant and that there are no measurement errors. In such a world, total factor productivity growth would be zero. But as soon as any change occurs, e.g. in the form of a new product or a new production process, the output volume which can be obtained with given resources increases, i.e. productivity is raised.[1]

The same result can be obtained if a better way to organize production is found, in which case production rises as a result of better utilization of the available resources.

Thus, total factor productivity growth includes new and improved production processes, rationalization of existing production facilities, organizational changes in production, materials handling, etc., closing of old plants whose productivity is below average, and opening up new plants with higher than average productivity. Changes in product mix, improved marketing and storage systems, etc., are also important components.

Therefore, at the bottom of total factor productivity growth there is some kind of technical change. But it is apparent that "technical" here refers to a much wider concept than is normally understood by that word. It includes a

[1]See e.g. E. F. Denison, *op.cit.*, pp. 2—3.

[1]Ideally, new products should be included in productivity growth, but this is not usually done due to practical problems of valuation. In practice, therefore, entirely new products do not enter in at all; inputs devoted to their production are treated as if they were used in the production of already existing products. Quality improvements in existing products are included in the measure of production only to the extent that they are reflected in increased resource use. Thus, they do not influence measured productivity in the producing activity but may, of course, do so at the aggregate level if they lower resource use in other lines of production or change consumer tastes so that production expands in activities with high or rapidly increasing productivity. For further discussion, see e.g. E.F. Denison, *op.cit.*, pp 10—11 and 124.

large spectrum of activities which may more appropriately be referred to as "entrepreneurial activity" in a wide sense.[1]

In order to capture the role of technical change in productivity growth, a disaggregation procedure has been used, the essence of which is shown in Figure 6.

Part of total factor productivity growth is attributable to changes in the composition of output. If, for example, industries with high or rapidly growing total factor productivity grow faster than other industries, total factor productivity at the aggregate level (all manufacturing) is raised. The same is true at lower levels of aggregation, i.e. the sector composition of output within branches of industry and the commodity composition of output within firms, etc, influence total factor productivity. By sorting out such structural changes, it is possible in principle to capture "purely technical change" at the micro level, i.e. changes which cannot be attributed to changes in composition of output. "Purely technical change" in turn may be sub-divided into new or improved products and new or improved production processes.

Breakdown of Total Factor Productivity Growth: Methodology and Some Quantitative Results

An attempt has been made to quantify the relationships outlined in Figure 6. As indicated in the figure, about 1/3 of total factor productivity growth at the aggregate (manufacturing) level and at the branch level turned out in our measurements to be attributable to structural changes in output. In measurement at the firm level and below, approximately one-half of total factor productivity change was found to be due to structural changes.

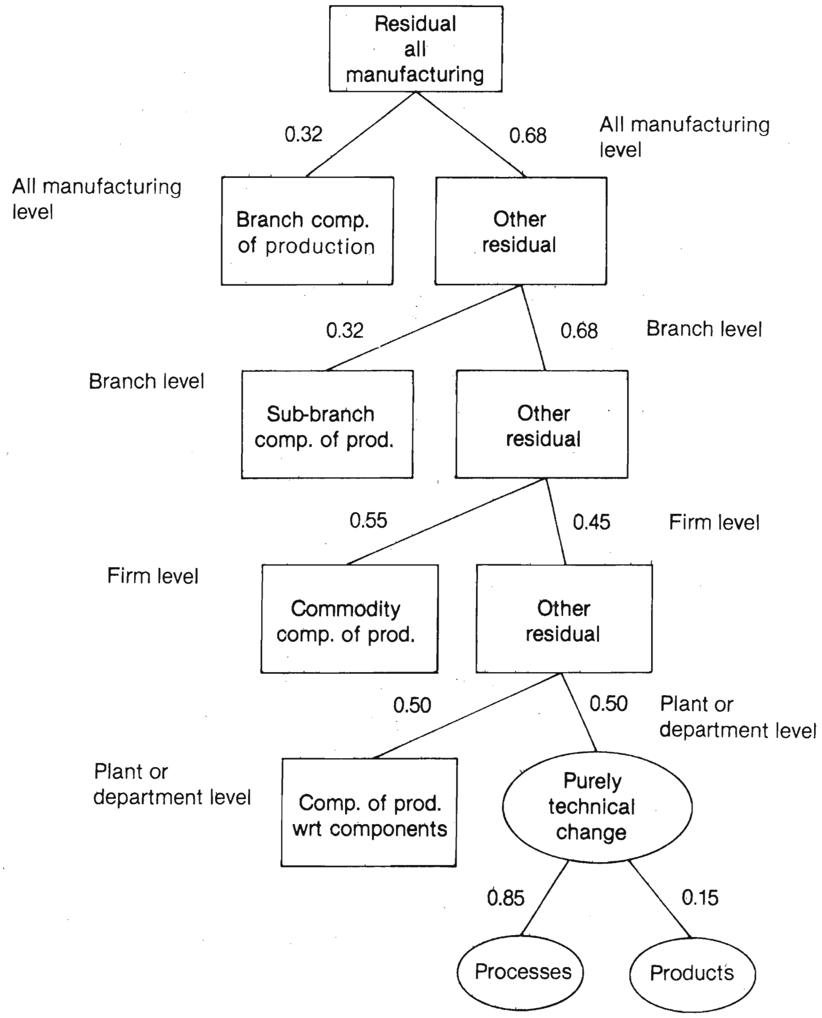
The breakdown of the residual (total factor productivity growth) at the aggregate level (i.e. all manufacturing) was done in the following way. The Swedish manufacturing sector was broken down into 13 industries. A production function of the Cobb-Douglas type but with variable elasticity of substitution was fitted to each industry, using data for the period 1950-74.[2] First, a hypothetical calculation was made in which the actual inputs of labor and capital in 1950 were augmented in each industry according to the actual rate of increase for each factor, respectively, in the entire manufacturing sector. Then these hypothetical values of labor and capital inputs were in-

[1] What is referred to here is the concept developed more fully in E. Dahmén, *Svensk industriell företagarverksamhet* (Entrepreneurial Activity in Swedish Industry in the Period 1919—1939). IUI, Stockholm 1950.

[2] For a more detailed description, see G. Eriksson, U. Jakobsson and L. Jansson, "Produktionsfunktioner och strukturomvandlingsanalys" (Production Functions and Analysis of Structural Change) in *IUI:s långtidsbedömning 1976, Bilagor* (Supplement to IUI's Medium-Term Survey 1976). IUI, Stockholm 1977.

troduced into the production function and the rates of change of the production volume, total factor productivity, and the contributions of capital and labor were computed and finally weighted together (using the shares of total output of each industry).

Figure 6. *Composition of the residual total factor productivity growth at various levels of aggregation*



Source: B. Carlsson et al, pp. 34 and 136.

The difference between the actual rate of growth of industrial production and that computed as described here (i.e. holding the relative shares of total inputs constant for each industry) reflects that part of the production increase which is attributable to changing resource allocation among industries. The actual rate of growth of output turned out to be considerably higher than the hypothetical one. The contribution of total factor productivity growth was also much lower in the hypothetical case. The difference between the hypothetical and actual total factor productivity growth, divided by the actual rate of growth of output, turned out to be 32 %. This is the figure used in Figure 6 as a measure of the part of the residual in total manufacturing industry attributable to changing allocation of resources among sectors.

It is obvious that if a further disaggregation of the entire manufacturing sector had been done (comprising, say, a hundred sub-sectors rather than 13), an even larger share of the residual at the macro level would have been accounted for. The figure given (32 %) is therefore somewhat arbitrary, and this should be borne in mind when interpreting the results. This point is amply illustrated as we proceed down through the lower levels in Figure 6. As we leave the total manufacturing level, the figures given represent only examples. For obvious reasons, it is not possible to calculate the total contribution from structural changes at all levels of the economy.

At the branch level we have chosen to study the production of town gas in Sweden 1960-73.[1] During this period, some gas works were closed, while the remaining ones changed from coal to oil based gas production (i.e. coke was eliminated as a by-product). It was found that 32 % of the change in labor productivity (used here as a proxy for total factor productivity) was attributable to the transition to the new process and to the closing down of old plants, while the remaining 68 % was due to rationalization of plants with given basic technology.

The estimates at the firm level in Figure 6 refer to a particular Swedish multinational firm, but the general order of magnitude of the estimates has been confirmed in investigations of other firms as well. In the particular firm studied here, the trade liberalization in Western Europe, reflected i.a. in the elimination of tariffs, necessitated a re-organization of production within the firm in order to take advantage of economies of scale. Rather than having several plants around Europe, each producing roughly the same assortment of products, it was found advantageous to reduce the number of plants and to specialize production in each plant on a narrower assortment. In the Swedish part of the firm, this change is roughly approximated by the transition from batch oriented (functional) organization to product oriented (line) organization. The latter turned out to have considerably higher productivity

[1]See A. Grufman, *Teknisk utveckling och produktivitet i energiomvandlingssektorn* (Technical Change and Productivity in the Energy Conversion Sector). IUI, Stockholm 1978, pp. 32—46.

than the batch technology, and this fact in combination with the increased share of line-oriented production explained 55 % of the total productivity change 1974-78. The remaining 45 % would be attributable to other productivity changes ("everyday productivity change") in both old and new plants.

Turning now to the lowest level of aggregation, the plant or department level, our results are based on detailed studies of several departments in a particular firm. For the departments concerned, we have obtained information on all changes affecting productivity during one year, namely 1977. A summary of the information given for one of these departments is provided in Table 2. It can be seen that in this case, about half of the productivity change was directly associated with the introduction of automatic machines as opposed to manually operated ones. However, the introduction of these machines also triggered a number of other changes which may be regarded as organizational but which were ultimately dependent on the new machines.

However, productivity changes need not depend on investments. In a classic example, provided by Erik Lundberg, labor productivity in the steelworks of Horndal was found to increase by almost 2 % per year for 15 years without any investment other than replacement of worn-out equipment.[1] Although Lundberg did not study the reasons for this increase in

Table 2. *Labor productivity change in one department of a Swedish multinational firm, 1977*

	Man-years saved on yearly basis	Labor productivity change %
Introduction of automatic lathes	8.4	4.6
Integration of earlier separate lathing operation with new machines	2.1	1.1
Elimination of control function	1.0	0.9
Integration of earlier separate stamping operation with new machines	1.4	0.9
Transfer of control function to operator	0.8	0.5
Increased No. of machines for maintenance personnel	0.9	0.5
Simplified routines for machine adjustment	1.0	0.5
Total	15.6	9.0

Source: B. Carlsson *et al.*, p. 126.

[1]E. Lundberg, *Produktivitet och räntabilitet* (Productivity and Profitability). Studieförbundet Näringsliv och Samhälle, Stockholm 1961, pp. 130—1.

detail, he attributed it in general terms to technical change, increased education of the labor force, increased willingness, interest, and ability to work thanks to improved working conditions, improved organization, possible effects of increased scale of production, better adjustment of production and sales to changing prices, etc. In other words, the "Horndal effect" is synonymous with total factor productivity growth.

More recently, the IUI has obtained access to detailed information on a similar case, also involving an iron works. The plant was built in 1952, and our data cover the period up to 1978. During this period, no net investment was made, only replacement of worn-out equipment. In spite of this, labor productivity increased by 3.7 % per year, i.e. production per man-hour more than doubled over the 26-year period. The reasons for this increase turned out to be the following. Through increased demand for the firm's products (probably due partly to the firm's own sales efforts) it became possible to utilize the installed capacity of the plant more fully without hiring more labor. The increased production facilitated an increase in the batch size for each product, the labor saving effect of which was further enhanced by a certain reduction in the product assortment (i.e. increased specialization) and by increased standardization of the products. Thus, in this case the Horndal effect is dissolved into increased economies of scale, better organization and "learning by doing".[1]

As pointed out earlier (see p. 35 above) new or improved products are not usually counted in our output measures. This means that insofar as measured productivity change involves "purely technical change", it reflects changes in production processes primarily and changes in products only in a very minor way. It is an open—and highly interesting—question to what extent the "true" productivity development is distorted by this. In our research on technical change and productivity at the Institute we have tried in at least one case to measure the relative contributions of product and process changes to productivity growth. In doing this, the measure of output is extended to include the value to the user of product improvement (which ideally should not be deflated away in measuring output). The activity studied involves the production of a certain type of machinery from 1950 to 1977. Through economies of scale involved in increasing the size of the machine and in the size of each order and increasing the speed (measured in R.P.M.) at which the machine operates (implying smaller physical dimensions for the machine with a given capacity), labor productivity increased by 6.5 % per year. At the same time, certain changes in product design led to an increase of machine capacity of approximately 1 % per year. Thus, if output is measured in terms of the capacity of machines produced, (rather than simply the number of units), labor productivity increased by 7.5 % per year. Thus, 1/7.5 or about 85 % of this was attributable to changes in the production

[1] An in-depth study of this material is in progress within the IUI.

process and the remaining 15 %, to improvements in product quality.

It is impossible to know whether or not this quantitative relationship between product and process technical change is representative for manufacturing in general. The same difficulty applies to most of the other measurements presented here as well. It is obvious, therefore, that this approach does not immediately offer an alternative to the conventional macro-oriented growth accounting method. However, it does seem to offer new insights, for example concerning the importance of structural change in productivity growth. The impression one gets from the results presented here is that about half of measured productivity growth at the firm level consists of changes in output mix in connection with increased specialization and increased utilization of scale economies. This implies that more than half of the measured productivity change at the sector level must be attributed to such structural changes, and at the macro level even more. Thus, the resource allocation aspect is heavily emphasized.

Another advantage of the method suggested here is that it indicates a way to conceptualize technical change at the micro level in a macro context. It shows that it is possible, at least in principle, to obtain a more thorough understanding of total factor productivity growth at all levels of aggregation. The Horndal effect need not remain a mystery.

However, a serious problem that still remains is that of developing a framework or model for analyzing technical change at the micro level *quantitatively* (not only qualitatively) in a macro context. Some considerable steps in this direction have already been taken in the Institute's micro-to-macro model.[1] In the next section, an attempt will be made to outline how this is done.

Micro-to Macro Analysis of Productivity Change

The micro-to-macro model uses individual firms as units of observation. Firms interact with each other in both factor and product markets. The productivity concept used at the firm level is that of labor productivity, rather than total factor productivity. Labor productivity in the firm is raised in connection with new investments. The size and allocation of investment at the firm level (as determined endogenously by the market mechanism in the model) influence aggregate productivity growth. Thus, to calculate labor productivity change at the macro level, one needs observations on labor productivity of new plant and equipment relative to old. This requires data on labor productivity in new (best practice) plants over time.

[1] See G. Eliasson (ed.), *A Micro-to-Macro Model of the Swedish Economy*. Papers on the Swedish Model from the Symposium on Micro Simulation Methods in Stockholm, Sept. 19—22, 1977. IUI Conference Reports 1978:1. Stockholm 1978. See also G. Eliasson, *Technical Change, Employment and Growth—Experiments on a Micro-to-Macro Simulation Model of the Swedish Economy*, IUI Research Report No. 7 1979.

In connection with the IUI-IVA study, such information was collected. 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.[1] Among other things, these persons were asked to supply data on the development of labor productivity in best-practice plants in their own field over time. The results are shown in Table 3.

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 higher in most cases than those in the second column.[2] The table shows, therefore, that the rate of labor productivity change measured in these terms has slowed down in many areas in the last decade relative to the earlier decade.

In the table, the examples have been grouped according to the industrial classification used in the Swedish micro-to-macro simulation 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 model indicate that the rate of increase of labor productivity in best-practice plants 1955-75 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.[3] The figures obtained in these simulations are given in parentheses in column 3 in Table 3. For all manufacturing the estimated rate of increase (a weighted

[1] 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.

[2] 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.

[3] B. Carlsson and G. Olavi, *op cit.*

Table 3. *Examples of labor productivity change in new plants 1955-1975*

Industry	Productivity Measure	Annual percentage change 1955-1965 (1)	1965-1975 (2)	1955-1975 (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. [b]Refers to 1960—1970.

Sources: B. Carlsson *et al,* 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 Report 1978:1, IUI, Stockholm 1978.

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.

Some Thoughts on the Slowdown in Productivity

In interpreting the table, several more 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 as reflected in labor productivity is slow in the beginning, fast during a certain period, and again slower as the technology matures) the slowing of technical progress in the last decade indicated in the table is only 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.

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, along with cheep energy supplies. This led to a decline in economic growth in the industrialized countries in general.

One implication of this slowdown in economic growth is that the rate of introduction of new technologies (i.e. innovation) has slowed down even if the rate of invention has not. The considerable fall in the investment rates in most industrial countries after 1973 would indicate that this has been true. But in addition to this, some of the findings in this paper suggest that many productivity changes are not linked directly to investment but are only indirectly triggered by them—e.g. organizational changes necessitated or facilitated by new investments. This would mean that the slowdown in investment may have led to a slowdown in other productivity increasing activities as well.

Also, the slowdown in economic growth may imply that it has not been

[1] B. Carlsson and E. Waldenström, "Technology, Structural Change, and Economic Growth in Sweden—A 100-Year Perspective", IUI, Stockholm 1980. (Paper presented to the OECD conference on Industrial Politics for the 80's. Madrid, Spain, May 1980).

possible to increase the scale of new plants at the same rate as earlier. A detailed investigation of some of the technical fields listed in Table 3 showed that economies of scale have increased at a much higher rate than domestic or even world demand for the products involved.[1] It seems to be true at least for many Swedish firms that while in the 1960's domestic demand was large enough to accomodate at least one plant of internationally competitive scale, that is often no longer the case.

Therefore, many Swedish firms have found it difficult to expand their production facilities to take advantage of increasing economies of scale. This has significantly reduced productivity growth. In addition, it appears that the lure of large scale economies in combination with overly optimistic demand forecasts in the early 1970's led to overinvestment and global overcapacity in several heavy industries—industries whose rates of productivity change appear to have been relatively high previously.

Conclusion

In his recent book *Accounting for Slower Economic Growth—The United States in the 1970's*, E. F. Denison came to the startling result that even after adjustments for input quality changes, economies of scale from larger markets, etc., the remaining unexplained residual ("Advances in knowledge and n. e. c.") for the period 1973-76 was not only smaller (by 2.1 percentage points) than during 1948-73 but was actually negative (-0.7). Having considered some seventeen hypotheses concerning the causes of this reversal he confessed that "what happened is, to be blunt, a mystery" (p. 4).

It would be misleading to suggest that the present paper offers a fully developed alternative to the conventional approach to productivity measurement. Nevertheless, in this paper I have tried to take a step in that direction by outlining a methodology which can at least complement the conventional approach and which is especially designed to open the way for micro analysis of productivity change without losing sight of the macro side.

Practical considerations concerning data availability constitute sufficient reason to start productivity analysis at the macro end and then try to reduce or eliminate the unexplained residual through various adjustments. However, in order to really understand the components of and forces behind productivity change, one needs to start at the micro end, even though this creates difficult data problems.

The first part of the paper is concerned with breaking down total factor productivity growth through disaggregation to lower and lower units of observation in order to separate out structural from "purely technical" changes. Some preliminary measurements indicate that more than half of the total factor productivity growth at the macro level is attributable to changes

[1] B. Carlsson, "Technical Change and Productivity in Swedish Industry in the Post-War Period", IUI Research Report No. 8. IUI, Stockholm 1980.

in composition of output at lower levels. In a few case studies the components of "purely technical" changes at the micro level are analyzed.

The second part of the paper is devoted to a framework for analyzing how productivity changes at the micro level can be aggregated to the macro level, using a micro-(firm-) based macro simulation model of the Swedish economy. The results emphasize the importance of economies of scale and suggest that one reason for the slowdown in productivity advance in the last decade is that scale economies have far outpaced the growth of firms' markets and made it difficult for them fully to take advantage of scale economies.

Thus, the approach presented here emphasizes the role of resource allocation in determining productivity and economic growth. A large part of the rapid productivity gains in the 1960's are attributable to large investments in connection with a re-orientation of the economy to international markets. To what extent the decline in productivity growth in the 1970's may be attributed to a relative exhaustion of the re-allocation potential or to interference with the market mechanisms influencing resource allocation still remains an open question, however.