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INFORMATION TECHNOLOGY, CAPITAL STRUCTURE AND THE NATURE OF TECHNICAL CHANGE

by

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FOURTH DRAFT

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Abstract

This paper presents statistical evidence on (1) the importance of "soft" capital spending items like marketing and R&D investments, and (2) the dominant service content of production in the modern manufacturing firm. It pictures the firm as a dominantly information processing entity that has been gradually shifting its competitive base from process cost efficiency toward a product technology. The paper, hence, argues (3) that during the post-war period technical change has been gradually pivoting in a relatively more (hardware) capital saving direction.

The growing service content of manufacturing production consists of various forms of information gathering and using activities, product development, marketing and management being the most important items, using up more than half of the resources in the largest Swedish manufacturing firms. Rather than competing with simple products and lower prices the advanced manufacturing firms are based in sophisticated customer markets and compete with improved product qualities, to a large extent through extensive marketing networks located in foreign countries. Sometimes the information gathering and using activities take place within the administrative framework of the firm and are statistically measured as a manufacturing activity, sometimes the activities are run through separate agents, and are statistically observed as private services. The institutional delimitations are becoming increasingly unstable.

(This development suggests that the current concern with the employment consequences of information technology in automation of factory production is a misdirection of attention. Far more significant developments are occurring in other dimensions. It also makes the notion of price elastic export functions, commonly used in international trade models and macroeconometric models, somewhat suspect.)

1 From a Process toward a Product-Based Industrial Technology

A large body of literature conventionally assumes that technical change has been, and still is predominantly labor saving. These results come out of standard production function analysis, the bulk of which is from econometric analysis of macro time series data. (This quality of technical change is sometimes thought to have permanent consequences for employment, see Eliasson 1985c).

The econometric studies practically always see capital as consisting of machinery and constructions to be used in factories. Occasionally, goods in process inventories are included. The notion of a firm from this (macroeconomic) perspective is that of a factory.

The argument in this paper is that this kind of analysis fails to capture the evolution of the modern manufacturing firm. Statistical data as a rule do not exhibit the large "soft" part of investment spending, devoted to product development (almost all R&D), marketing and knowledge accumulation in general. Lacking, or disregarding, this information, we do not understand the change in the nature of technical progress that has taken place gradually, from a process efficiency ("cost cutting") based industry toward a product-based ("value added increasing") industrial technology oriented toward specialized customer markets.

Internal data on production activities in a modern firm used for analysis in several IUI studies suggest that technical change has been gradually shifting in the direction of relatively more capital saving technical change. With capital we then mean machinery, constructions and possibly inventories, or the data that usually enter macro production function analysis. New coordination and information management techniques work in that direction and the higher share of interest costs in total costs during the 70s has provided an economic incentive to adjust faster to what has been technically feasible.

This change in the nature of capital invested in industry also mirrors a parallel shift in technology in which economies of scale in processing is diminishing in importance, while significant economies of scale in marketing and finance are emerging, forcing the organization and institutional delimitation of the modern firm to change (Eliasson 1985a, b).

This paper broadens the concept of capital to include all inventories, accounts receivable, and all other assets appearing on the active side of a balance sheet, as well as a spectrum of debt categories directly linked to the ongoing production process. This is exactly where capital saving technology is predominantly applied, in the non-hardware production process, which appears to be a major part of value added creation within a modern business entity.

If the analysis is extended to cover all external, institutionalized information and distribution activities that are directly related to manufacturing goods production and the carrying of the goods to the final users, this conclusion as to technical change would no doubt be further reinforced. And the notion of a shrinking "manufacturing sector" in a modern industrial society would most likely be falsified as a statistical artifact, based on badly designed statistical taxonomies.

The point of my argument is that if we continue to stick with the old notion of capital in industry as being machinery and construction capital directly linked to the process side of production, and think that this is all that matters, we are being deceptive to ourselves and our readers.

This paper will present some recent statistical and qualitative evidence on the nature of capital accumulation in Swedish manufacturing to support this view.

2 The Modern Manufacturing Firm - a Knowledge-Using and Information Processing Entity

Most of capital invested in a modern manufacturing firm applies to the non-hardware side of production. Take human capital away and the same conclusion probably still holds. Practically all non-hardware capital and much hardware capital (computers being a case in point) are related to the gathering, analyzing and use of information in various forms, or information handling in general. The following set of Tables 2, derived from Swedish firms, illustrate this. Sweden seems to be one of the few places where such data are systematically gathered.[1] The data are neither representative for all Swedish manufacturing firms, nor for average industry in the advanced industrialized countries. However, the data should be indicative of the direction in which manufacturing in advanced industrial nations will eventually be heading.

The basic information technology in the sophisticated fringe of large Swedish firms is devoted to developing the right products and moving the products to the right customers around the world. In the early 80s these firms employed some 50 percent of the industrial labor force in Sweden. Their product development and marketing competence have been the vehicle for making them competitive during the 70s, thus displacing basic industries to second rank in the hierarchy of size, performance and as competitive exporters. (Table 3 lists all Swedish large companies by size as exporters

[1] At the Industrial Institute for Economic and Social Research (IUI) as part of the database project associated with the micro-to-macro model project (see Eliasson 1978, 1984, Lindberg-Pousette 1985) code named MOSES Database.

in 1965, 1978 and 1981).[1] Those firms carry a special interest as indicators of the future structure of industry. The tables show that at least half of "measurable" capital spending has been invested in marketing and R&D. The bulk of marketing capital is invested abroad, and even if it is largely of a goodwill nature associated with the development of new markets, it is still "physically" or geographically tied to these markets. R&D capital has largely been invested domestically in Sweden as is also the case with the bulk of process installations.

A conclusion drawn elsewhere (Eliasson 1984b) is that market and R&D capital are decisive for the competitive situation of the entire corporation. Capital for marketing and R&D defines the unique knowledge base of the firm, and explains whatever profitability that can be derived from process activities. A supplementary indication of this is that practically all statistically measured R&D spending in Swedish industry goes into new product development (see Table 4) and that new product changes usually initiate and carry major productivity advances in ongoing process activities (see next section).

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[1] A supplementary conclusion of this paper is that the existence of this technology washes away the importance for medium-term employment of the crisis industries (accounting for more than 10 percent of manufacturing employment in the mid-70s) and the enormous industrial subsidies during the crisis years of the 70s, spent to save employment. In the longer term these subsidies appear insignificant or perhaps even worthless. I would even argue for a sizable negative value, since industrial subsidies probably stimulated substantial domestic factor cost overshooting and retarded output growth in the frontier firms, see Eliasson-Lindberg (1981), Eliasson (1984) and Carlsson-Bergholm-Lindberg (1982).

With at least half of capital spending devoted to development and improvement of products for specialized customer markets and to move them to these customers, the bulk of the latter investment being located outside the country, the whole notion of estimating traditional macro export functions and export price elasticities for industry sectors in advanced OECD countries is becoming increasingly irrelevant.

Since the competitive edge of these firms is only secondarily based on process knowledge one can safely conclude that further investments will shift capital structures in the direction of relatively more non-process, product and market investments, and away from plant and equipment installations. If any part of the entire operation will perish for economic and technical reasons it will be the manufacturing process part. This is already evident from a firm by firm and sector comparison. Hardware intensive firms, producing simple goods and selling them through external traders, like basic industries, iron and metal manufacturing and parts of intermediate goods and heavy engineering industries constitute a relatively declining industrial base. These firms live on process cost performance and the cost efficient technology is relatively easy to imitate, in, for instance, the newly developed industrial countries. Technical innovative activities are oriented toward process improvements, where the payoffs from R&D spending appear not to be as large as in R&D investments closer to the product. While R&D intensive production seems to be competitive through exports from Sweden, more simple, process dependent production, like textiles, seems to be more prone to be allocated abroad, away from a high wage economy like Sweden.

The change in aggregate capital structures thus observed has mainly come about through a generally faster growth of those firms, whose competitive edge was based on new product creation to begin with, rather than on cost efficient production. Technological and market development, however, has made marketing and product development (R&D investment) relatively more profitable than new process installations (Eliasson-Bergholm-Horwitz-Jagrén 1985). Hence, also within firms, one can observe a shifting in emphasis toward upgrading product qualities through R&D spending and marketing investments. This is typical of the industries in the upper left hand corner of Figure 1.

Swedish manufacturing industry was heavily based on process performance through skilled workers by the late 60s. For instance, internal budgeting and control procedures in Swedish firms appeared to be relatively more biased toward cost and process control than the pronounced product and market orientation of similar management procedures observed in U.S. firms (Eliasson 1976, p. 227). The process-based industries in Western industrialized countries suffered heavily in the post oil crisis years of the 70s. Perhaps as much as 20 percent of manufacturing capacity in Sweden, almost all of it in the unsophisticated basic industry firms,[1] in practice went bankrupt with little advanced notice, and the bulk of remaining industries went into a reshape period. (Only some of the already R&D, product and marketing oriented firms weathered the 70s more or less unscathed. Some firms went for process rationalization of existing

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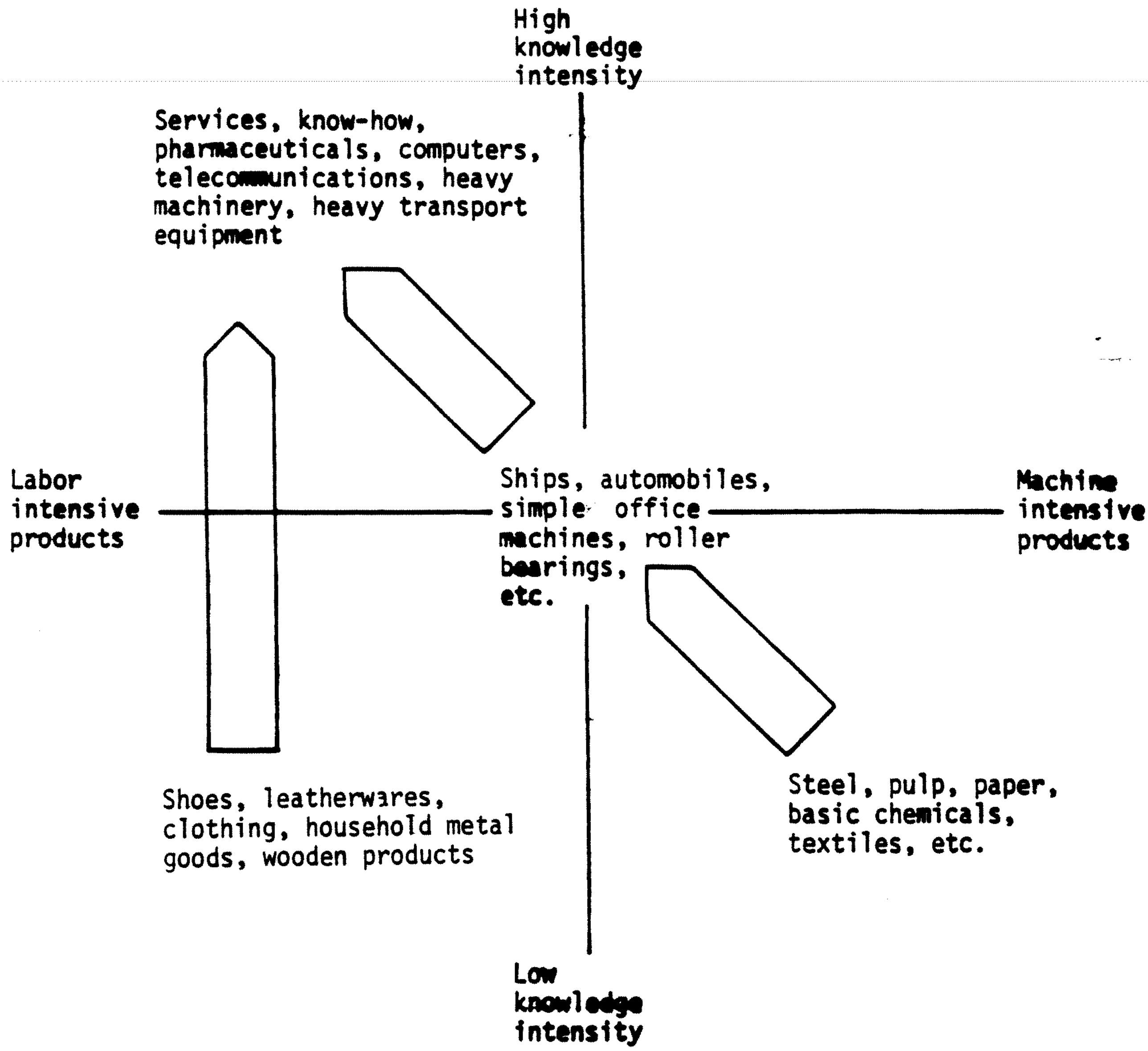
[1] This figure comes on top of a normal share of distressed industries. See Chapter 10, Section 6.6 in Eliasson-Carlsson-Ysander et al. (1979).

Figure 1 From a process cost efficient toward a product-based industrial technology



lines, with not so successful outcomes. Others pulled ahead, restructuring their organizations, emphasizing product and knowledge-based activities, and closing unsophisticated product lines, emerging, if successful, at the top of Table 3. These reorganizations would probably not have been possible without a prior build up of the necessary knowledge and competence base. To understand the nature of, and the prerequisites for a successful reorganization of a firm a much more profound and comprehensive knowledge is needed of the interior activities of an industrial firm than economics currently has. This in particular holds for the accumulation and transmission of knowledge within a firm (Item 10 in Table 1. Also see Eliasson 1985b).

To serve as a systematic background for understanding the content of ongoing activities within a modern firm, Table 1 lists the important functions. The equations below is a break-down of costs allocated on the functions in Table 1. They have been used to calculate Tables 2B and 2C. The argument above is that the performance of the materials processing function is no longer the critically important one, and will be even less so in the future in the more advanced industrial economies. Non-processing[x)] activities are mainly oriented toward innovating and coordinating the entire business entity. Such stocks of knowledge we do not measure well, but the rough estimates presented in the table suggest that they are sizable and at least comparable to machinery, equipment and buildings on a reproduction value basis. The coordination activities require sizable capi-

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x) all other items than (6) in Table 1.

Table 1 Main operational tasks of a large manufacturing firm

1) Innovative
2) Internal reorganization

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3) Product development
4) Investment (bank) allocation
5) Commercial bank (cash management)
6) Insurance, risk reduction
7) Materials processing (the hardware function)
8) Purchasing
9) Marketing and distribution

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10) Education and knowledge accumulation

tal stocks to keep the flow performance of the firm efficient. Ingoing, intermediate and outgoing inventories of the process stage is one well-known example.

To measure the input content of total value added let us decompose total costs (TC) of a division or a firm into:

$$TC \equiv \sum^{n} w \cdot L + \sum^{n} p^{I} \cdot I + \sum^{n} (r + \rho - \frac{\Delta p^{K}}{p^{K}}) p^{K} \cdot \bar{K} \quad (1)$$

n lists the number of tasks or functions (i.e. n = 10 in Table 1).

The first item to the right is labor costs (w=wage, L=labor input). The second item adds up purchases (p^I(= price), times I (= volumes)).

The third item is the standard definition of capital costs associated with each function. The price of the service of a unit of capital is p^k (the price of a unit of capital) multiplied by the sum (within brackets) of the interest rate, the depreciation rate and the change (with negative sign) of the capital goods price index. The latter measures the capital gain or K, which has to be subtracted from the capital service charge.

Define

$\varepsilon = R - r$

where R is the nominal rate of return on capital (K) and r is the nominal loan rate. Then the sales value (= S) of the firm can be expressed as

$S = TC + \varepsilon \cdot K$

If the return to capacity is equal to the loan rate then $\varepsilon = 0$ and total sales equal total costs, if properly measured. From an analytical point of view it is interesting to know how the various functions n (that draw labor, materials and capital costs) contribute to the overall return to capital, measured by ε. We argue in this paper that the major contributions to a positive ε in the 70s have been R&D spending on product development (item 3) and marketing (item 9) in Table 1. We would also argue that items 1, 2 and 10 have been critical in developing the product and marketing skills although it is close to impossible to pinpoint these activities in statistical terms. In Tables 2B and 2C we have disregarded the ε item in dividing total costs, and in Table 2B we have disregarded all costs but labor costs when distributing costs on functions 3, 9 and everything else.

Table 2A Investments[a] in the 5 and the 37 largest Swedish manufacturing groups, 1978

Firms have been ranked by foreign employment

Percent

	The 5 largest groups		The 37 largest groups	
	All group	Foreign subsidiaries only	All group	Foreign subsidiaries only
R&D	25	10	21	6
Machinery and buildings	45	41	52	42
Marketing	30	49	27	52
TOTAL	100	100	100	100

[a] Investments in Marketing and R&D have been estimated from cost data.

Table 2B Wage and salary costs in different spending categories in the 5 and the 20 largest Swedish groups, 1978

Percent

	The 5 largest groups		The 20 largest groups	
	All group	Foreign subsidiaries only	All group	Foreign subsidiaries only
R&D	7	3	7	2
Processing and other	63	52	70	58
Marketing and distribution	30	45	23	40
TOTAL	100	100	100	100

Note that we have been unable to separate out administrative costs etc. from production process cost data and that wages and salaries in marketing and distribution probably are underestimated. The "other" item should be in the neighborhood of 15 percent of total costs according to preliminary data from an ongoing IUI study.

Source: Eliasson, G., De utlandsetablerade företagen och den svenska ekonomin, IUI Research Report No. 26, Stockholm 1984.

Table 2C Total costs distributed over different activities in a large Swedish engineering firm, 1981 (Swedish operations only)

Percent

(1)	R&D, design and technical documentation	17
(2)	Work scheduling	15
(3)	Production	44
(4)	Marketing and distribution	9
(5)	Finance and administration	5
(6)	Other	10
	TOTAL	100

Source: Fries, H., "The Firm, Productivity and the Emerging Technology", in *Microeconometrics*, IUI yearbook 1982/83, Stockholm 1983.

Table 3 The largest Swedish (manufacturing) exporters, 1965, 1978 and 1981

Name of firm	Rank by size of exports 1981	1978	1965	1965 Exports from Sweden in percent of total Swedish goods exports	1965 Percentage of total employment in foreign subsidiaries	1978 Exports from Sweden in percent of total Swedish goods exports	1978 Percentage of total employment in foreign subsidiaries	1981 Exports from Sweden in percent of total Swedish goods exports	Year of Establishment	Type of activity
Volvo	1	1	1	5.0	Percentage	9.2	Percentage	10.6	1926	Automobiles, trucks etc
ASEA	2	4	5	2.6	share for	3.4	share for	5.2	1883	Heavy electrical, robots
Saab-Scania	3	3	13	1.6	group 1-5	3.8	group 1-5	4.2	1937/1891	Trucks, automobiles, aircraft
Electrolux[a]	4	6	25	0.8	13.0	2.3	29.3	3.6	1910	Whitewares etc.
Sandvik	5	5	9	2.2		2.6		2.6	1862	Hardcore metal, tools
Ericsson	6	2	8	2.3	Percentage	4.0	Percentage	2.5	1876	Telecommunications
SCA	7	8	3	3.0	share for	2.1	share for	2.3	1929	Paper & pulp
Boliden[b]	8	19	18	1.4	group 6-10	1.2	group 6-10	1.8	1925	Metal & mining
SKF [a]	9	15	6	2.5	48.8	1.5	31.3	1.6	1907	Ball bearings etc.
Alfa Laval	10	11	20	1.1		1.6		1.5	1878	Dairy systems, centrifugal equipment
LKAB	11	10	2	4.6		1.8		1.5	1890	Iron ore
Stora Kopparberg	12	14	12	1.7		1.5		1.5	13th century	Copper mining, steel
Svenska Varv	13	7	-	-		2.1		1.5	(1977)	Ship building
Södra Skogsägarna	14	16	-	0.6		1.5		1.5	1943	Pulp & paper
SSAB	15	13	-	-	Percentage	1.5	Percentage	1.5	(1978)	Pulp & paper
MoDo	16	18	7	2.4	share for	1.3	share for	1.3	1873	Pulp & paper
Bofors	17	17	21	1.0	group 11-20	1.3	group 11-20	1.2	1873	Weapons, steel, electronics
Holmen	18	21	23	1.0	0.9	1.2	2.2	1.2	1609	Paper
Billerud	19	-	19	1.2		(1.0)		1.2	1883	Paper
Papyrus	20	-	-	0.3		0.9		1.1	1895	Paper

[a] Including large parts of Facit 1978 and for 1981 also Gränges.

[b] The reason for the large advance of Boliden in the export ranking is partly the rapid increase in relative raw materials prices 1978 to 1981 and partly an increase in trade activities.

Source: Eliasson, G., De utlandsetablerade företagen och den svenska ekonomin, IUI forskningsrapport nr 26, Stockholm 1984.

Table 4 Orientation of R&D investments in Swedish manufacturing 1981

Percent

1)	On general increases in knowledge	4
2)	On new products	19
3)	On products already in market but new to firm	26
4)	On improvements of existing products	36
5)	On improvements of existing processes	8
6)	On development of new processes	7
7)	TOTAL	100

Note: In 1977 18.2 percent of R&D spending in Swedish manufacturing went to process and systems improvements, 4.9 percent to general increases in knowledge. Remaining 76.9 percent of R&D spending was classified as directed toward product improvements, see Figure 2 in Bergholm-Jagrén, "Det utlandsinvesterande företaget - en empirisk studie" in Eliasson-Bergholm-Horwitz-Jagrén (1985).

Source: Swedish Central Bureau of Statistics, U1984:20.

The internal structure of the modern firm is such that each function listed in Table 1 has its own departmental domain well defined within the firm and in its cost account classification. To some extent, most of these "internal" activities can be made both cost and profit responsible, a circumstance that is illustrated by the fact that they are more or less internalized. Notably, in small firms the services of many of the non-processing activities are bought in the market. This highlights two important factors in productivity change, namely (1) <u>institutional or organizational change</u> as a result of recombinatorial activities within the firm; through acquisitions and through exits, and the floating concept of what we call a market, that I will return to later. For our immediate purposes, however, we also (2) observe that each of the 10 operational tasks and departments has its own capital endowment, that can sometimes be measured and isolated on an investment accrual basis, but not easily on a market basis. We can now rephrase our previous argument by saying that much of total factor productivity growth or improved profit performance of a firm can be traced to a changed allocation of resources on the various items in Table 1. (In Eliasson 1985c) I continue this argument about the content of productivity change in terms of the market dynamics of resource allocation between firms.)

3 Finance and Organization

Finance in its various manifestations has a much more significant impact on the real side of firm behavior than is generally recognized in the economic theory of the firm, a circumstance that makes it natural to view a firm as a financially defined entity. It is dominated and coordinated top down by the capital market and the owners, who set rate of return requirements, that also define the outer limits of the firm as an organization, namely when, on the margin, it begins to attract and/or leak external funds (Eliasson 1976, p. 256, 1984d).

Risk finance and ownership control is usually associated with high level recombinatorial decisions that fundamentally restructure the organization of the firm and that appear to be the main vehicle for large and fast advances in productivity (Eliasson 1984c). Venture capital is a special form of risk finance. The term is usually associated with new innovative entry activities, often thought of as "high tech" innovative entry (see Granstrand 1985). The long-run importance of such innovative entry activities for the macro economy appears to be very large. Much more theoretical and empirical research is, however, needed for this working hypothesis to be gainfully used in policy making (Eliasson 1984a, e). In addition, the bulk of innovative activity seems to take place within the large firms, financed through internal cash flow, which is the quantitatively most important form of risk capital.

In addition to supplying risk finance aiming for long-run economic performance, owners also exercise a short-term cost and rate of return control function. This is operated indirectly through top level management. Either owners sell out (vote with their feet) or apply pressure on, or change top management. Efficient profit control is partly a matter of being informed, partly a matter of taking action on the basis of information. Modern information technology is rapidly increasing the transparency of large corporations for owners and top management in terms of cost and profit performance allowing, as a consequence, more "flat" hierarchical organizations. However, access to information, control and the ability to take effective action fast have much to do with how the firm is organized. Divisionalization or the organization of the firm as a group of separate corporate entities owned and controlled by a financial holding company (the investment company function, item 4 in Table 1) began long ago, but is still in progress.

Finance buffers, furthermore, operate as a risk reducer that makes it possible to plan ahead and to smooth other activities over time, something that has been demonstrated over and over again to be productivity enhancing.

Of course, any firm that cannot efficiently finance its own trade is placed at a disadvantage, when it comes to the planning of production, distribution and marketing. The advantage of a large investment capital becomes even more important when allocating investment and in the carrying out of long-term, risky investment programs.

In addition to this - of growing significance because of the high interest rates during the 70s

- is the fact that large, idle financial balances, that are not profitably invested, are costly. That is one of the reasons why both the investment allocation, the commercial bank and the insurance function have been increasingly internalized and centralized in large firms in an effort to economize on the costs of finance, while preserving financial independence. Arguments resembling these have been used for including a "real balance" variable in macro production function analysis, for instance Fisher (1974), You (1981). In principle, there is a good point here, even though I doubt these are the effects that show up in macroeconometric production function analysis. [Jagrén (1984) demonstrates how productivity on the construction side of the OIII nuclear reactor in Sweden was deliberately lowered to complete the project ahead of schedule in order to reduce total costs and start an income stream earlier. Toward the completion of the project accumulated interest costs were much larger than total construction cost.]

Financial strength on the margin of course also defines the outer limits of the firm seen as a financial entity. If rates of return on some marginal activity within a firm are consistently below the market loan rate or the rate of return on some interior activities, strong pressures to sell off or close down that activity built up, or at least to deprive it of new resources. There are few factors that hold back efficient long-term planning as much as insufficient financial size and strength. It reduces the ability to take on risks. If firm management knows what it wants, inefficiency breeds if they cannot launch ahead on full scale, but have to take one cautious step at a time. This is particularly emphasized by the shifting of economies of scale during the post-war period, between the items in Table 1, away from factory production toward marketing in particular. The 10 largest firms in Table 3 have been devoting a rapidly growing share of their capital spending on international marketing efforts, investments that are extremely risky.

Pratten (1976) reports another intriguing and related result. In his comparison of matched Swedish and British firms he notices that Swedish firms were much smaller in financial size but larger if compared by process/factory scale of operations. Productivity in the latter sense in Swedish firms was much above the same measures in British firms, that also invested less and grew much more slowly, even though they exhibited a somewhat higher return to capital according to the three definitions used. These are data from the late 60s. They do, however, suggest that there may be financial factors at work both on the formation of firms as institutions and on the real, GNP contributing performance of manufacturing activities.

Financial durability is critical for longer term innovative ventures, where a positive cash flow may take years to show. A large and somewhat oversized financial base is therefore instrumental in running a large modern firm efficiently. The larger and more heterogeneous the the firm entity, however, the more complex it is to operate and the more easily internal inefficiencies develop. The firms may simply be too large to be efficiently run or the technology and competence to run them may be lacking. Rigidities and inefficiencies associated with big corporate bureaucracies have been increasingly discussed in the last decade (Dearden 1972, Eliasson 1976, Hayes-Abernathy 1982). As an introduction to the next section I venture to say that this competence (vested in items 1 through 6 and 10 in Table 1) may be a most fundamental industrial technology that defines the comparative advantages of firms in the advanced OECD nations. The efficient use of information is the critical matter.

4 Technical Change in a Modern Firm

From the macroeconometrics of production technology, the residual "after labor and capital", for a long time "explained" most of output growth among the industrialized countries as a measured time trend, or in a "mystic way". Technical change so measured faded away in the 70s (Åberg 1984). Denison (1967) removed part of the shift by redefining input volumes through ad hoc adjustments for quality. Griliches-Jorgensen removed much of the U.S. residual in the 50s and the 60s through appropriate adjustments of prices on factor inputs (see Eliasson 1985c). Why the residual came in the 50s and the 60s and why it went in the 70s, however, still remains a mystery to paraphrase Denison (1979).

When seen from a macroeconomic point of view, technical change can occur at roughly three levels of aggregation in the production process, and at a fourth level in terms of the market environment.

Table 5 Stages of technical change

1. Process
2. Product
3. Management (firm level)
4. Economic policy (macro level)

Items 3 and 4 separate the firm from its environment, or the market. It is significant in my view that much of measured productivity improvement at the macro production function level appears to lie in the intersection between 3 and 4, notably between the firm on the one hand, and the capital and equity markets on the other, suggesting that the dynamics of institutional recombination is important (see below).

The most widely "acknowledged level" of technical change on the other hand, again, is the first process stage, where (exactly defined it has to be) process techniques are improved so that the same products can be manufactured by the application of smaller inputs of one, several or all factors, or rather more interesting from the economic point of view, at lower total unit costs. In some industries, notably capital intensive, basic process industries, technical change oriented toward a more cost efficient production of simple products undoubtedly is very important. However, such improvements as a rule occur as a consequence of a redesign of production process flows associated with the installation of new capital goods (new products). In engineering industries, however, technical improvements of existing production lines appear to be the least important of the four types of technological improvement, even though it can be large and rapid at small, well-defined segments of the production process (Figure 1A illustrates this. Also see Eliasson 1980).

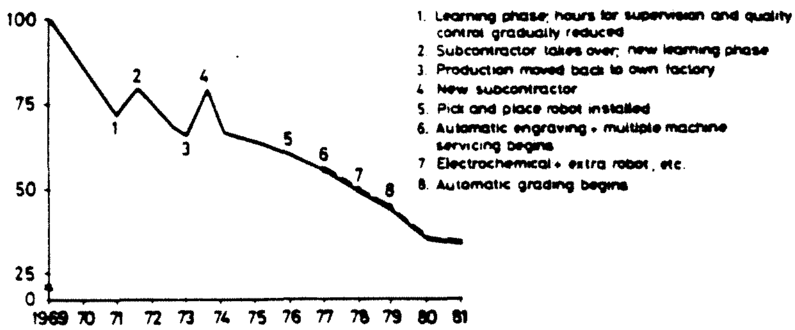
Major shifts in productivity at a production line in engineering industries normally occur simultaneously with a redefinition or a redesign of a product, like a new automobile model, or the high speed printer in Figure 1B. This redesign of the product and a simultaneous redesign of the production line, after the initial shift, often leaves ample scope for further piecemeal improvements. The major initial shift also seems to be dependent upon a reorganization of process activities that have been planned and thought of when designing the product, not necessarily with the installation of new, faster and more sophisticated machinery. The research carried out by the Swedish Computers and Electronics Committee (some of it by IUI) includes many examples of how a reorganization of existing machines to obtain a new flow pattern significantly improved aggregate productivity performance as measured. It is not by accident that recent engineering literature is so occupied with the optimal factory design and that the availability of engineers trained in "systems thinking" has been found to be insufficient in advanced industrial nations.

In fact, improved overview and better coordination of the entire factory process appear to be the major simple notion that is extremely conductive to productivity increase in a general sense. I will begin at the production line level and move upwards through the product design and process levels, including also distribution and finally reach stage 3 in Table 5 and the art of holding the firm together financially and optimizing productivity performance at that level. I will demonstrate by example that as you move up in level, non-process equipment begins to dominate and to become a large cost item in total costs and that overview of the entire system can significantly cut stock requirements needed to obtain flow efficiency.

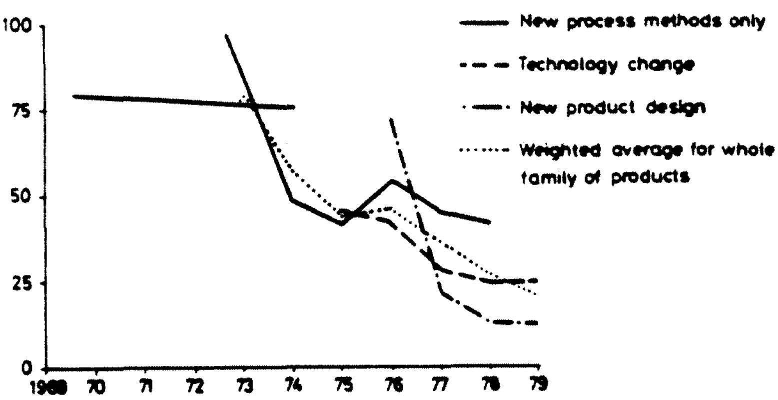
It is clear from much of the analysis carried out at IUI that the productivity potential of the so-

Figure 2 Change in productivity, 1969–81
Index

A - Labor productivity (the inverse) in the production of a particular part which remains identical over time



B - Total factor productivity change (the inverse) for a family of sophisticated engineering products



Note: The figures show the use of factor inputs (labor hours in A and a weighted index of all factors in B) per unit of output. Index = 100 initial year.

Source: Gunnar Eliasson, "Electronics, Economic Growth and Employment - Revolution or Evolution", in Giersch (ed.) Emerging Technologies, Consequences for Economic Growth, Structural Change and Employment, Tübingen 1982.

called new information technology lies in making the business organization more transparent and in the more efficient coordination that becomes possible. Improved, central profit control makes it technically possible to decentralize operational decisions and responsibilities (Eliasson 1984c, Fries 1984). Improvements begin to show already at the parts production stage where better overview and a faster flow allow savings in inventories at all stages. Positive systems effects, however, expand rapidly from there all the way to financial control at the firm level, although the higher up the more difficult they are to measure. Labor saving improvements may dominate at the lower process stages of production (numerically controlled machines, robots), but capital (costs) saving improvements escalate from there on.

Let us begin by seeing a <u>product</u> as a <u>particular constellation</u> of parts. Some parts may be standard parts while others are uniquely fashioned for the particular product. Competitiveness of a product of a particular producer lies in;

(1) the manufacture of parts (or purchasing of parts)
(2) the design of the combination of parts (product design)
(3) the design of new parts and new combinations of parts (and new product design)
(4) the assembling of parts to a product.

Competitiveness under (1) and (4) is normally based on process cost efficiency, under (2) and (3) on unique human skill endowments. Parts production employs most of the heavy machinery in a firm. (In the extreme case, where a bulk commodity like pulp or steel is the output and little assembling or combinatorial activity is needed, the entire process can be seen as "parts production".) Numerically guided machine tools, robots and automation (in process industries) have become increasingly important at this stage. The smaller the part the more labor saving such installations appear to be. The longer the parts production process, with several sequences of machine installations like in Figure 1A, or complete automation of a line (see Nilsson 1981), the more of machine capital saving is achieved through faster flows but also, and more importantly, the more of savings on stocks of goods in process are achieved.

It should be remembered, however, that a part in a product, is a product in itself, that may be the main (final) product of a subcontractor (for instance ball bearings in an automobile). The earlier in the production stage the simpler the product as a rule, and the more process-oriented production (steel, parts, automobile) the more of automated processes we find. However, also at this stage major innovative product design activity has been taking place recently. New materials are entering engineering industries making it possible to integrate, or rather cut across several production stages, using different technologies, i.e., to "shape" materials (casting and gluing rather than turning and grinding). It was noted already by Hicks (1977, p. 147 ff.) that the basic functions of machine tools used in engineering production are the same as those about 150 years ago. Plastics and composite materials are becoming increasingly superior to steel in standard products and - above all - as basic materials, in the new, advancing industries (aircraft, etc.). Entirely new tools to cut (for instance lasers) and to form and fasten are used, and costs are coming down rapidly. It is no wonder that the traditional machine tool makers are finding themselves in a competitive squeeze from two ends, new materials and distressed customers. (The frequent worries about robots and distressed machine tool manufacturers by industrial policy authorities may simply be beside the point. It is the combination of new materials and new types of tools that will reshape manufacturing in the advanced industrial countries and rapidly shift performance upwards.)

Capital costs increase in relative importance as we approach the later assembly stages of a given combination of parts (a given automobile). Automated equipment is still relatively rare at this stage, but technology is improving fast. The more comprehensive the production process, the more of stocks are needed to handle flow interruptions in order to keep up flow speeds. Information techniques, and designs to monitor the production flows to achieve overview of the production line become instrumental in the capital savings process. Hence, what we are observing is the substitution of one form of capital for the other used in the coordination of production and all activities of the firm. In the old type of decentralized operations, inventories are needed to prevent flow interruptions. Particular designs of the work-shop organization can reduce stock requirements. Better monitoring of flows and feedback adjustments cut stock, and also machine capacity requirements even further. The more in this direction we move, the more of information technology and accumulated human capital is, however, needed to achieve the observable capital savings.

The design and change of the product itself is the third competitive factor, and the decisive one in advanced industries. It is quite resource using in itself (see Tables 2 and 4). Electronics enters importantly in the product, replacing mechanical techniques. Major advances are currently on the way in design (service) production in the form of CAD and (even) CAD/CAM techniques linking parts inventory and parts production directly to product design. This is inventory saving, while labor inputs in the design stage may even increase. The important technical improvements, however, come with the interaction of product design with process organization and techniques. (In saying so I am thinking more of designing the product with the requirements of the process technique in mind than of actually integrating design work with work preparation and processing. The latter is the idea of CAD/CAM which is still (1985) in its embryonic stages, with few applications outside specific industries like chip manufacturing. The former is probably the major instrument behind currently observed productivity advances.)

Standard parts in the manufacturing of increasingly complex and variable product designs are becoming common. The automobile is a case in point, and the relative competitive superiority of small producers of design-based manufacturing is a double case in point.

CAD technologies coupled with flexible process designs make it possible to achieve more frequent product changes using standard parts all the time and without fundamentally new investments in factory equipment. All this is dominantly capital saving technical change. In addition to this the major advances in total factor productivity performance (see Figure 1B) are normally associated with major product design changes. Robotization, for instance, to be profitable normally requires a minimum product life. Hence, existing production lines for old products are not automated if the remaining lifelength of the product is short. When a new product is introduced and a new production line designed, new techniques, like robotization, can normally be planned in advance.

A division or a profit center of a firm can be seen as a bundle of products of the above type. At this stage the combination of products is truly what matters for competitiveness, and in some firms a division may be buying semi-manufactured products or the whole product, simply applying its own brand label, or maybe adding some design features to the product.

This is the situation in important areas for many of the world's leading firms, notably several in Table 3. The design, marketing, distributing and financing activities increase in importance. Overview, often global overview, becomes important and technical change at this level operates significantly on the capital (stock) requirement side. Global inventory control systems are easily recognizable illustrations of this, where large technological steps forward have already been taken, but these are not necessarily the potentially most important areas.

A <u>firm</u>, finally (we are now reaching stage 3 in Table 5), can be seen as a <u>bundle of divisions</u>. Technology now is almost entirely <u>management</u> or various forms of <u>coordination</u>. We can distinguish between four different categories

(1) cost control
(2) profit control (short term)
(3) investment allocation (medium term)
(4) organizational change (long term)

Cost control dominates the interior activities of the firm. Profit control enters at a level of aggregation when the firm opens up to both product and input markets, for instance, the division level. It is normally associated with the budgeting process (see Eliasson 1976a). In practice, this process is concerned with improving cost performance over a given divisional product structure, eliminating cyclical slack. Hence, budget profit control is closely related to the economists notion of static efficiency. The comprehensive budget process in a large firm means coordination through total cost control through the application of advanced, predominantly capital-saving information technology.

The problem of comprehensive profit control of course becomes even more important and difficult at higher decision levels in the firm. Investment allocation was closely related to the long-term planning process which was very popular during the late 60s. As a formal management procedure, however, it has not been successful (see Eliasson 1976a). Investment allocation is a typical corporate headquarter task. It means changing the composition of output through remixing a given bundle of products, through the varying of investment. Efficiency, here in the sense of equating the marginal product of capital to some chosen interest rate, is closely associated with the neoclassical notion of dynamic efficiency. Reweighing of output composition has been demonstrated to be a significant factor behind shifts in the macro production function (see Eliasson 1985c).

(Again, short-term profit control in the budget appears to be the important information technique currently used in achieving such results.)

What I prefer to call Schumpeterian dynamics (see Dahmén 1984) is dominated by the entrepreneurial, or the capitalist, ownership function. It enters under category (4). This time we are concerned with institutional change or reorganization within a firm defined as a financial entity (a group, a conglomerate) through entry, exit and internal recombinations at all levels. (Entry corresponds to the use of new, unique parts in a new product design.) Large step improvements in competitiveness and productivity, as we measure them at the firm level, are normally associated with such internal reorganizations.

This is not the place to present quantitative evidence on such structural changes. Very little, in fact, exists and research in that area has recently been started at IUI. However, a few observations should illustrate what I have in mind. Over the past 7-year period, for instance, Swedish Match has bought 40 subsidiary companies and sold off 45 companies.

Electrolux has acquired ca 325 producing units and sold off ca 30 firms since 1967. This is the kind of recombinatorial activity that can be observed rather easily. But if one looks deeper into the aggregates a much more lively recombinatorial activity appears. Parts of subsidiaries or divisions are purchased or sold. So far, we have only impressionistic evidence of this, even though IUI is currently doing a detailed study on a group of firms.

The overall purpose of these recombinatorial activities appears to be to concentrate and reduce the number of activities to a few rather than many knowledge bases and to achieve economies of scale both in product development, marketing and production. Interestingly enough the patterns that we think we have observed point in one direction. Some tentative conclusions could at least be put down on hypothesis form. Economies of scale in increasingly costly R&D spending require larger and larger volume shipments. To achieve larger volume shipments either new markets have to be developed or - which is more typical of mature product firms - market shares have to be increased, notably through increased marketing efforts in customer markets. Investments in marketing are both long term and expensive and increased competitiveness does harm to competitors. Marketing skills draw on a rather homogeneous, product-related knowledge base and a specific, market-dependent knowledge base that relates to many products in that same market. Furthermore, it is often less expensive - and much faster - to buy an existing market network than building it from scratch. Hence, one observes firms, in particular in the mature product markets, that expand their administrative control system to internalize also the significant value added created through marketing services, that was earlier often run through independent agents or sales agencies.

At least for Swedish firms, the bulk of foreign direct investments is related directly or indirectly to such extensions of directly (controlled) marketing networks in foreign markets (Eliasson-Bergholm-Horwitz-Jagrén, 1985).

Larger volumes bring larger production and economies of scale. Most firms want to concentrate processing of hardware production to a few places. It is typical and most economical for most Swedish multinational companies, as in all activities of any degree of sophistication, requiring skilled or educated workers, to concentrate goods processing to Sweden. Local markets, national trade policies and existing production facilities in purchased companies, however, do not always make this homeward production concentration possible, practical or economical.

However, at the other end, service production at earlier stages of production and R&D development demand a much larger variety of very specialized service activities.

As a rule it is not economical even for large firms to keep all these activities inhouse, at least as long as they are not vital for commercial product innovations or for reasons of commercial secrecy.

Hence, while manufacturing firms are integrating vertically downstream, closer and closer to the final consumer, the need for more and more specialized services at earlier stages of production has been spinning off a varied, institutional fragmentation and specialization. (In countries where taxes are high and labor markets are regulated, the economic incentives for this are also strong, since skilled, specialized and valuable talent normally does not fetch its right remuneration within a large organization.)

It is clearly so, that the organizational and interior institutional changes that we are discussing are decided at the very top of companies, at the highest executive level, at the board of directors and by the dominant owners.

Very little systematic research on the importance of the capitalist ownership function has been published. IUI has recently begun a large scale project with this ambition.

As it emerges from our analysis the major advances of productivity at the firm level seem to be associated with recombinatorial activities of the kind mentioned at the product and higher levels that are closely linked to the ownership function of a firm where risk finance and industrial competence enter a form of symbiosis. As I have demonstrated elsewhere, the next important step in the shifting of the macro production function appears to be the capital market allocation function between firms (see my second paper).

Technical change currently appears to be working against traditional economies of scale in factory production while at the same time an often neglected scale function has been on the advance for decades, and increasingly so during the disorderly 70s (see Eliasson-Sharefkin-Ysander 1983), i.e., financial scale, financial risk reduction being the key factor at work. Figure 3 summarizes these tendencies.

For one thing, the international market environment has become increasingly less predictable.

Figure 3 Tendencies

1 Uncertainty up and predictability down in international business environment

2 Product technology is becoming relatively more important for competitiveness than cost efficiency

3 Products are characterized by
- more complex technology and design
- longer development periods
- larger development costs
- larger demands for risk capital
- shorter life lengths

and hence

- higher risks

4 Competing technological development and higher business uncertainty together places a premium (ceteris paribus) on financial size.

Secondly, product technologies and continuous innovative product change have become key competitive edges for the advanced manufacturing firm.

New products, however, are characterized by longer gestation periods, larger development costs, larger requirements of internal risk finance. But once in the market product life cycles have shortened.

Together, this means a higher level of risk taking on the part of the firm. Even though this is not the most efficient organization of factory operations or coordination of all activities, disorderly market behavior and reduced environmental predictability mean that larger financial size, nevertheless, commands a premium. Risks can be spread over a larger number of activities, and most importantly by concentrating cash flows from many operations to one point at a time. The financing of high risk product developments can be internalized.

However, the larger and the more heterogenous the financial organizations under which all these activities are gathered, the more complex and the more information demanding the task of managing the system. This becomes obvious when we look again at, for instance, Electrolux Corporation, headquartered in Stockholm with ca 89 thousand employees, ca 270 subsidiaries and operating in ca 50 countries. The typical characteristics of such a company is that top level management has far from complete knowledge of what goes on below them. This is particularly true for <u>how</u> things are done. On the other hand, the top managerial staff of a well managed large company has a clear view of its objectives and a quite clear view of what, in terms of performance, can be demanded of the various subsidiary operations of the company (see Eliasson 1976).

The key top level managerial technology is to set the right targets and to device a reliable reporting and control system against these targets. Targets have to be close to what is feasible, only slightly above, to be taken seriously and to stimulate increased efforts. But if targets are set too low, performance invariably adjusts downwards. The art of remote control and guidance of a large business organization affects productivity performance of the entire organization and clearly is a matter of how to design an efficient information system.[1]

The art is moving in the direction of delegation of operations (how to do things) and increased centralized control (what to do). (See Eliasson 1984c.) This is exactly the opposite to automation which involves centralizing process knowledge (how) in enough detail to run a production process centrally. This orientation of modern business information and management systems also runs contrary to the "old" idea of scientific management, which was based on the naive idea of centralized management. The reason for the changed orientation was the clash with reality. Sheer (1) complexity of top management decisions and (2) built-in inconsistencies (see Table 1) between various functions

[1] See again Eliasson 1976 on MIP targeting (op. cit., pp. 236 ff., 258 f., 291 ff. MIP targeting characterizes the firm in the micro-to-macro model used for simulation experiments in Eliasson (1985c).

make centralized management techniques impracticable.

Table 6 illustrates that important parts of key elements of operations knowledge simply are not available at the top. The resolution of top level routine access to information rarely goes below the product group level (item (3) in Table 6) and the reasons are entirely practical, namely costs of designing and updating the database.

Table 6 Organizational and informational hierarchies in a large firm

Level of aggregation (1)	Organizational unit (2)	Activity (3)	Objective (criterion) (4)	Database (Measurement system) (5)	Market contract[a] (6)
1)	Group	Financial guidance and control	Return to equity	Profit & loss statement and balance sheet	I,L,P,K
2A)	Division	Financial & profit control	Return to to total capital	Profit & loss statement and partial balance sheet	I,L,P
2B)	Subsidiary	Profit control	Return to total capital	Ditto	I,L,P
3)	Product group	Factory production	Profit margin	Profit & loss statement	I,L,P
4)	Product	Process	Sum of cost elements	Cost accounts	I,L
5)	Component (part)	Process-stage	Cost element	Cost accounts	I,L

[a] I = Market for components, etc. (purchasing)
L = Labor market (hiring)
P = Product market (selling)
K = Credit market (borrowing

Source: Eliasson (1984c).

5 Why is Technical Change Shifting in a Capital Saving Direction?

A typical development of the modern firm that accompanied the post-war advancement of industrial technology in the Western world, has been the increased emphasis on product technology and a relative decrease in the importance of process techniques and cost efficiency as a basis for competitiveness. This development is witnessed by the emerging importance of engineering industries, while basic industries have been in relative decline, and in important places in distress. The relative growth of a white-collar, educated labor force in manufacturing tells a similar story.

Perhaps even more important in a future perspective is the so far neglected emergence of service production and information handling as the dominant production activity of a manufacturing firm. It is often more important to know how to design the product and the production process and to know where the right customers are, than to manufacture the product. A consequence of this has been a rapid institutional change, also in typically non-manufacturing sectors and a growing dependence of the manufacturing firm on human knowledge and skills.

A side effect of this development has been a rapid deterioration in the quality and relevance of official statistics, that so far has not been adequately taken into account in economic analysis. Above all, the delimitations of statistically defined sectors have become shifty and dependent upon the organization of firms. With a significant part of total resources in manufacturing devoted to service production that can be administered within the firm as a manufacturing activity or in a separate business unit (a consulting firm, a distribution or a sales agent, a firm devoted to technological innovative development work, etc.) statistically classified as private service, the information content of official national accounts statistics is on the decline. A traditional economic analysis of standard aggregates may make us believe in "deindustrialization", while a careful analysis may suggest that this is all nonsense.

All the factors mentioned appear to have combined to generate a relatively more (hardware) capital saving technical change as industrial structures are transformed toward more advanced industries. The first step is obvious. The relative decline of hardware-intensive, basic industries means a lower capital output ratio in macro aggregates. The second stage, the relative increase in information handling in total output, is more subtle. Service production in all its manifestations mentioned certainly is less hardware capital intensive. Thus, on the average, it is more intensive in its use of "software" capital that we do not measure well. If we did, the intensity of use of market R&D, marketing and general knowledge (human) capital may be even larger. Our argument in this paper is that as long as we don't know how much of, and how, such soft capital enters the production process, we should not carry on the traditional argument simply implying a broader concept of capital investment. The various capital items are not comparable. Especially their complementarity properties with hardware capital and labor have to be considered.

Industrial technology will probably push further in the direction of using relatively less hardware than software capital. And at least to judge from Swedish experience, the locus of manufacturing competence has already shifted toward product technology, where most of R&D spending goes, and marketing and distribution, which also - in fact - means a broadening of the product concept. Let me summarize some of this expected development. The enhanced product orientation has already demonstrated itself in

(1) more diversity and complexity in product offerings
(2) longer product gestation periods
(3) shorter product life cycles
(4) that successful manufacturing firms have their base in competitive customer markets in advanced industrial economies.

A direct consequence of the growing product orientation of manufacturing industry and the longer gestation period between product initiation and final delivery is (1) the growing importance in total value added of service production of various kinds and the increasing share of both (2) information and transaction costs and (3) capital costs in total costs. The accumulation and application of information is a common denominator of those activities. The development of a new product, preparing for its production, perhaps in a different country, making it known to customers, marketing it, distributing it and servicing it etc. are all reflections of the

(5) increased role of information use in manufacturing production.

These activities are not hardware capital intensive. They are based on people and human skills.[1] This development, however, at the same time increases the total risk exposure of the entire business entity. It takes longer before investments begin to generate a positive cash flow, and if mistakes are made, product lives in the market will be short and the whole firm may be in jeopardy. Such technical, commercial and market risks are normally carried within the company as a financial unit and by the owners, risk carrying being an important production activity of the modern firm. The increased exposure has already induced, and will continue to induce, the formation of larger multiproduct, multinational firms seen as financial units, that can absorb greater mistakes internally.

We have already observed from a number of studies that better coordination of factory processes and distribution networks has been a typical capital-saving technology based on new information techniques. This above mentioned development, hence, means that these monitoring and control techniques are now becoming even more important in coordinating the entire set of activities in even larger business units.

The techniques of overcoming organizational complexity grow in importance. Overview of structures, improved database design and coordination techniques become the critical process technology development both in factories and when it comes to

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[1] Information processing has also become more hardware intensive (see Barras' paper), for the simple reason that computers are replacing clerks with pens at desks. But this is beside the point in this context.

reigning in all activities of the entire organization. Better coordination of the entire organization means a faster flow of products (cf. global inventory control and is a typical capital-saving technological change.

6 Summing up

This paper does not present a strict econometric test of some well-defined hypotheses. The economic issue is much too complex for such simple empirical methods. We have rather brought together a wealth of scattered facts gathered during the course of ongoing IUI studies. This fragmented evidence has been merged with some - we believe - reasonable guesswork into a rather complex working hypothesis about the nature of, and change in technological progress in modern manufacturing industries. The following five statements make up our main conclusions.

First, total factor productivity as observed at sector or macro levels is mainly economic in nature, rather than technical, the dynamics of allocation of resources within firms ("management") and through markets, between firms being the vehicle for advance (this point is further elaborated in Eliasson 1985c).

Second, the focus of technical change, and the application of R&D spending are shifting from achievment of cost efficient processing towards product quality upgrading. This shifting of emphasis reflects the orientation towards customer markets and large and elaborate resource applications in marketing.

Third, points 1 and 2 highlight the modern manufacturing firm as a predominant "information processor". Exploiting new, emerging technologies for sophisticated product designs and intense marketing to find the right "paying" customers globally is a more profitable focussing of resource use than efficient production of simple hardware. The not very successful idea of a world car compared with the successful performance of specialized, customer-oriented automobile designs is a good example. This development will probably knit the advanced industrial OECD nations together economically even more, further alienating the group from the not so developed economies.

Fourth, this shifting of activities from hardware processing towards various forms of information processing appears to be pivoting the nature of technical change in a relatively more capital saving direction than was earlier the case.

Fifth, finally, even though the service content of manufacturing production may dominate, the services are still linked to a product that can be traded (Lindberg-Pousette 1985). It is rather so that the changing nature of manufacturing production and institutional reorganization brought about by both technological advance and other, economic factors are blurring our statistical observation instruments. We may wrongly believe to observe a process of "deindustrialization".

A proper scientific foundation of these results requires much more painstaking empirical research. But the evidence accumulated so far is quite suggestive. I believe industrial policy makers should take careful note of this movement of the industrial locus away from blue-collar factory production in order to avoid (Eliasson 1984a) continued mistaken policy designs.

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