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The evolution of manufacturing technology and its impact on industrial structure: An international study — Source link

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This is a preliminary paper. Comments are welcome.

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THE EVOLUTION OF MANUFACTURING TECHNOLOGY AND ITS IMPACT ON INDUSTRIAL STRUCTURE: AN INTERNATIONAL STUDY

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ABSTRACT

This paper shows that plant and firm size in manufacturing, and especially in engineering industry, in several Western industrial countries has declined since the early 1970s. Two hypotheses explaining the decline are advanced. One is "de-glomeration" or specialization: the divestiture of non-core businesses in order to free up scarce resources (particularly management time) to defend and nurture core business activities. The second hypothesis is that the emergence of new computer-based technology has improved the quality and productivity of small and medium scale production relative to standardized mass-production techniques which dominated previously.

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I. INTRODUCTION

Given the emphasis placed in the economics literature in recent years on economies of scale, and observing the current merger mania that is sweeping through a large part of the industrial world, one should expect to find firms and their production facilities (plants) becoming larger and larger. But, surprising as it may be, that is exactly opposite of the truth. In fact, the average plant and firm size in metalworking (engineering) industries -- as well as in manufacturing as a whole -- in the United States has been shrinking for well over a decade.[1] Nor is this phenomenon restricted to the United States; other countries such as Japan, West Germany, the United Kingdom, Italy, Finland, and Denmark appear to have shared the same experience. Among the countries included in this study, Sweden is the sole deviant from this rule.

The purpose of this paper is (1) to present the statistical evidence on the development of plant and firm size in manufacturing, and especially in engineering industry, in several Western industrial countries, and (2) to suggest some plausible explanations for the observed patterns.

The paper is organized as follows. In section II, the changes in plant and firm size in U.S. engineering industries are outlined. In section III, an international comparison is made. Section IV presents related evidence on the same theme. In section V, two hypotheses are formulated which are likely to explain the observed behavior. Section VI spells out the implications for both theory and policy.

II. STRUCTURAL CHANGE IN U.S. ENGINEERING INDUSTRIES 1972-82

Table 1 presents some data on United States engineering industries (SIC 34-38) at the 4-digit level. The data refer to changes which occurred between 1972 and 1982. Establishment size as measured by average employment declined in no fewer than 79 out of 106 4-digit metalworking industries. For all metalworking industries as a whole, the average establishment size declined by 12.3 %. As indicated in Figure 1, establishment size declined by more than 50 % in 10 industries, by between 50 and 25 % in 25 industries, and by between 25 and zero % in 44 industries. Similarly, Table 1 shows that company size declined in 78 industries. As can be seen in the Table, the changes in company size were virtually the same as those in establishment size. The average company size in engineering industries as a whole declined by 13.4 %.

The decline in plant and company size cannot be attributed to shrinking employment: on the contrary, employment in these industries increased by 11.3 %. In fact, total employment increased in all but 49 industries. At the same time, value added (in current prices) increased on the average by 160 %. If this figure is deflated by the producer price index for capital equipment, the increase in real output is still found to be about 11 % over the whole period 1972-82.

Perhaps even more interesting is the fact that the decline in establishment size appears to be related to an increase in the number of establishments and firms. In metalworking industries as a whole, the number of establishments increased by 27.5 % over the period; it increased in 86 out of the 106 4-digit industries. The number of companies increased in 81 industries and was unchanged in two. The total number of companies in the whole engineering industry rose by 28.6 %.

As shown in the correlation matrix (Table 2), the change in establishment size is strongly and negatively correlated with the change in the number of establishments and with the number of companies but positively correlated with all other variables included in the table. The correlation between the changes in the number of establishments and the number of companies is 0.97.

III. INTERNATIONAL COMPARISON

Is the U.S. experience an isolated phenomenon, or can similar changes be observed in other countries as well? The answer is that the observed U.S. behavior is clearly representative of an international pattern. As shown in Table 3, establishment size has declined in all the countries studied here, except in Sweden. This is true for both metalworking industry and for manufacturing as a whole. Besides Sweden, the only exception to this is that the average plant size increased slightly in the manufacturing sector in West Germany. The decline in establishment size in metalworking industry was very large (-41.4 %) in the United Kingdom, somewhat smaller in Finland, Denmark and Japan (-29.8 %, -25.1 % and -17.0 %, respectively), and modest in the United States (-12.7 %), West Germany (-10.3 %), and Italy (-1.0 %). In Sweden, the average establishment size increased by 4.2 %.

A decline is noted for all industries <u>within</u> the engineering sector in all of the countries with the exception of the Transport equipment industry in West Germany and Electrical machinery, Transport equipment, and Professional goods in Sweden. Thus, the decline cannot be attributed merely to a shift among industries; it is too widespread a phenomenon.

As shown in Table 4, the number of persons engaged in engineering industries declined in all of the countries except Finland, Japan and the United States, while the number of establishments increased everywhere except in Italy and Sweden. In Finland, the number of establishments in metalworking industry increased by 60 %, while employment increased by 12 %. The development in the United Kingdom is particularly intriguing; there the number of engineering establishments increased by nearly 15 %, even though employment declined by nearly 33 %.

A word of caution is in order, however, in interpreting these numbers. The minimum number of persons engaged in each establishment required for inclusion in the country's industrial statistics varies from country to country. In the United States, the minimum number of persons engaged is 1; in Japan 4, Sweden and Finland 5, Denmark 6, and in Italy, United Kingdom, and West Germany 20. Since most new establishments are initially quite small, this presumably means that the number of new establishments (and therefore also employment) is underreported in the countries with higher limits compared to those with lower limits. For example, in the United States there were a total of 312,671 establishments in manufacturing in 1972, while there were only 109,950 with 20 employees or more. This points to a topic for further research in a subsequent study: an international comparison of the size distribution of plants by various size classes.

IV. FURTHER EVIDENCE

While these findings may be surprising, and especially their consistency across both several countries and a wide spectrum of industries, they seem to fit well with some observations made in previous literature. Recent research on the United States indicates that most new jobs in the economy are generated in small firms (Birch, 1981; Acs & Audretsch, 1987 and 1988). Similarly, Duche and Savey (1987) have shown that small and medium-scale firms in the less developed regions of France have grown fast in the last decade, while larger firms in the more highly industrialized regions have declined in size. They also cite studies by Leclerc (1984) for Japan and Gudgin (1984) for the U.K. East Midlands indicating employment gains in small firms and declines in large firms.

In addition, Shepherd (1982) has found evidence suggesting that the minimum efficient scale is decreasing in American industry, and Piore & Sable (1984) have argued that the United States is currently in a period of transition from mass production to "flexible specialization." The hypothesis that U.S. trade performance in engineering products is better in industries characterized by flexible technology than in industries oriented towards mass production was successfully tested empirically by Carlsson (1987).

V. TOWARDS A NEW THEORY OF INDUSTRIAL DEVELOPMENT: TWO HYPOTHESES

What are the explanations for the observed behavior, i.e. the simultaneous increase in the number of plants (and firms) in most industries and the decrease in average plant size? This appears to be happening regardless of whether output and employment in the industry is increasing or decreasing.

Some recent research on related topics has led me to two major (interrelated) hypotheses explaining the phenomena under study here. These hypotheses will be formulated below.

V.1. "De-glomeration" (Creative Destruction)

The relationship between the growth rate of value added and the rate of growth of the number of establishments in the 106 U.S. engineering industries is depicted in Figure 2. While it is evident that there is a positive relationship between these two variables (cf. the correlation matrix presented above), it is also clear that many new establishments (and firms) have entered even in industries where the output growth rate is very low or even negative (in real terms).

This is not as mysterious as it may first appear. If one takes a look at U.S. manufacturing firms, it becomes apparent that many of them have shrunk considerably in terms of employment in

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recent years. Table 5 shows that the total number of employees in the largest 500 industrial companies in the United States (the "Fortune 500") has declined since 1979. However, as a share of total manufacturing employment, their share has declined since 1975, from 79 to 72 percent. What is perhaps even more surprising is that the Fortune 500 share in total manufacturing shipments has declined from 89 percent in 1980 to 77 percent in 1985.

What appears to have happened is that many firms have divested themselves of activities or businesses which they do not consider to be part of their "core" business. Whereas in an earlier era (especially during the 1960s and early 1970s) there was a tendency for firms to swallow up even businesses which were only remotely related to the core business, there has clearly been a reversal of this trend within the last ten years.[2] The business environment is now often perceived as considerably tougher than a few years ago, partly because of increased competition from abroad--the result of internationalization of business, globalization of competition, and increased rate of technology transfer via multinational firms. The same kinds of changes which were visible in Europe ten years ago are now occurring in America. (For an account of how the business climate changed in Sweden in the course of the 1970s and how this affected corporate strategies, see Carlsson, Dahmen, Grufman, Josefsson & Örtengren, 1979: 155-175.)

The mood now is to prune back the proliferation of businesses in order to protect and nurture more crucial lines of business.

The key constraint appears to be bounded rationality in the form of limited managerial ability and time; if a problem occurs in a non-crucial business activity, it simply takes too much managerial talent away from core businesses. Therefore, rather than taking the risk of losing more essential businesses, many firms have elected to divest themselves of non-essential business units.

The fact that the merger wave of the 1960s and early 1970s overreached the limits of management capability is clearly shown by Scherer:

> With few exceptions, the diversifying acquisitions of the 1960s and 1970s were much less than a resounding success. For acquired lines surviving long enough to be included inn the 1975-77 Line of Business surveys, profitability fell sharply on average relative to premerger levels. Moreover, Ravenscraft and I estimate conservatively that by 1981, one-third of the units acquired had been sold off. On average, lines that were fully divested had <u>negative</u> operating income in the year before sell-off commenced--a clear sign of failure. Fifteen case studies acquired-an-then-divested units revealed that sell-off was often precipitated by managerial control loss and incentive breakdowns. These in turn had roots in the more complex organizational structures into which the acquired units were thrust,, knowledge lacunae that impaired the conglomerat paretn's ability to solve emerging problems, and the inability of top management to develop

incentives stimulating sustained, vigorous performance by unit operating heads. (Scherer, 1988: 76-77)

Other reasons for divestiture, investigated by Scherer (1988) and Ravenscraft & Scherer (1987), are that acquiring firms often need to retire loans incurred in making takeovers, and a belief that the individual parts of acquired firms are worth more than the whole.

There are three possible outcomes of such divestitures: 1) elimination; 2) the business unit is established as a new firm, often selling its products or services to the original owner but now under separate ownership and management. In both of these cases, the average firm and plant size in the industry declines. 3) A third possibility is that the business unit is purchased by another firm which can provide a better "fit" for it (i.e. find more synergies in one dimension or another, such as marketing, manufacturing, or technical development, therefore absorbing less management time or other resources). The immediate result would then be an increase in firm size, but the impact on average establishment size would depend on whether the plant involved is larger or smaller than the average in the industries in which the buying and selling firms are classified. But what often seems to happen is that the newly purchased unit is consolidated with existing units (this "rationalization" perhaps being the main rationale for the merger), eventually reducing plant size (at least in terms of employment). If the buying firm is itself engaged in divesting non-essential businesses while buying up others in core areas, the impact on firm size is indeterminate. But table 5 indicates that at least recently, the main impact has been shrinkage of the largest firms in terms of both employment and sales.

The net result of this is at least twofold: (1) a substantial reduction in the number of middle managers. They are simply no longer needed; they are replaced by the invisible hand of the market. Recent events at General Electric, Standard Oil of Ohio (now BP America), and TRW, to name just a few, provide ample evidence of this. (2) To the extent that the sold-off units are providing services rather than manufactured goods, it may appear that output and employment in manufacturing are shrinking, even though in fact exactly the same activities go on as before. The difference is that the "new" establishments show up as service establishments rather than as manufacturing establishments.

Thus, the hypothesis advanced here is that there is a process of creative destruction going on which takes the form of de-glomeration (specialization), or concentration on core businesses. The question now is, what evidence is there that would confirm this hypothesis beyond the indication given in Table 5? There is plenty of evidence in the popular business press, as any reader of The Wall Street Journal, Business Week, or Fortune can testify. But what about more "hardcore" statistical evidence?

If the hypothesis is correct, it should show up in the form of larger purchases of more highly fabricated inputs relative to the gross value of output. In other words, the ratio of value added to the value of shipments should decline.

Such ratios have been calculated for the metalworking industries in the United States. See Table 6. It turns out that in no fewer than 88 out of the 106 metalworking industries did the value added/shipments ratio decline between 1972 and 1982. The frequency distribution is shown in Figure 3. A similar analysis of Swedish data shows that the value added/sales ratio declined in 38 of 47 engineering industries during the period 1975-1985.

These findings are corroborated in various other studies. For example, Altshuler et al. (1984, p. 189) conclude that in the automobile industry "[t]he evolving role for the final assembler is as the coordinator of the increasingly intricate production system and the manager of large distribution systems. Final assemblers are now purchasing more componentry, reducing vertical integration." Table 6 indicates that this is a widespread phenomenon throughout engineering industries, but it probably extends far beyond, to the economy as a whole.

In the automobile industry, a system (network) of supplier relationships and cooperative ventures even among rival firms is emerging. (Altshuler et al., 1984; Grant & Gadde, 1983; and Rosegger, 1986). Such systems replace the earlier combination of a high degree of vertical integration and purchases from multiple suppliers via the open market. But such networks are by no means restricted to the auto industry; as Imai (1987) has shown, networks of firms have replaced earlier, more vertically integrated systems in Japan.

In view of these findings, I find it difficult to reject the hypothesis that de-glomeration (and sometimes vertical disintegration) is one of the major reasons for the decline in plant size concurrent with the increase in the number of establishments and firms.

V.2. The Nature of Technological Change in Metalworking

As I have pointed out in a previous paper (Carlsson, 1984), there seems to have been a fundamental change in the nature of production in the metalworking industries in the last few decades relative to earlier periods. From the time of the Industrial Revolution until the early post-World War II period, i.e., for more than 150 years, most of the changes in production technology favored large-scale manufacturing relative to small-scale production. But clearly, the changes were not confined to the production side; they were closely intertwined with changes in product characteristics as well. Metal products became more standardized and commodity-like, while metalworking machinery improved in speed, precision, and degree of mechanization. It started as early as with the introduction of the so-called

"American System" of manufacture of interchangeable parts in gun making around 1800. Mechanization and mass production methods then diffused to a wide spectrum of industries in the United States, eventually giving America the technological lead over the previously dominating Great Britain which had pioneered in more handicraft-oriented methods.

During the course of the 19th century, machine tools became larger, heavier, more robust, and capable of much higher degree of precision than earlier. Some machine tools were designed for very high production rates, and there were many examples of mechanized feeding of individual machines.

In connection with the introduction of the moving assembly line in 1913 by Henry Ford, the demands of the automobile industry generated challenges to machine tool builders of an entirely new order of magnitude. Vast improvements were necessary in the speed and accuracy of machine tools in order to supply auto parts at rates many times higher than before. Because of the rapid expansion of the automobile market once these cost-saving devices reduced prices, the impact was enormous on both manufacturing technology in general and the whole economy.

The 1930s saw the introduction of so-called transfer machines. These consist of a number of machines or work stations, each for a separate operation such as drilling or milling, organized to work together in such a fashion that a workpiece is automatically put in place at one work station, operated on there, then transferred automatically to the next work station, etc. Work is performed simultaneously at all work stations, and several operations may be performed simultaneously at each work station. Transfer machines were first introduced in the automobile industry and then spread rapidly to appliance manufacturing, electrical parts production, etc. But because of the low level of economic activity during the Depression, the major impact of the new technology did not come until the build-up of military production in the United States during World War II.

The conversion to war production in connection with the War had a tremendous and lasting impact on manufacturing technology in the United States. For one thing, it forced the introduction of transfer technology far beyond the automobile industry into a large number of new applications. Another effect was that American manufacturing industry became equipped with new machinery for high-volume production to an extent which gave America a substantial lead over her overseas competitors in this type of technology.

When the war ended and manufacturing industries returned to civilian production, the production methods and tools used during the war were applied to civilian products. Another important development was increased use of mechanization. In 1950, the Ford Motor Co. introduced "automation," i.e. mechanical handling devices between transfer machines in its Cleveland engine plant, thus tying together several separate transfer machines into a continuous system. Even though the plant was far from automatic -- it employed more than 4,500 people -- and even though it had few feedback mechanisms and no automatic assembly, it inspired the diffusion to other auto plants of the technology known as "Detroit automation": the application of mechanical devices for handling the transfer of workpieces from one machine or work station to the next, along with improved control mechanisms. It was to become the standard technology for high-volume production throughout the engineering industry in all industrial countries.

But with the application of computers to machine tools in the form of numerical control (NC) in the late 1940s, the seeds of technological revolution were sown. While there have been improvements in the speed, accuracy, and degree of mechanization of transfer machines since the mid-1950s, there is little doubt that the main thrust in the development of metalworking technology in the last thirty years has occurred in an entirely different direction. Whereas the previous trend involved improving and extending mass production methods, the new development which began in the late 1940s and has gained momentum ever since involves the application of numerical control and the shift from mechanical to electronic control devices. For the first time, the major development of machine tools has been at low and medium scale (batch-type) production and has favored the manufacture of complex, non-standardized parts rather than simple, standardized parts in mass-production systems.

This change is reflected also in the proliferation in the number of varieties of products marketed. This can be seen in many product areas. For example, food distributors claim, and the everyday shopper can verify it, that the average supermarket store today in the United States stocks roughly twice as many items on its shelves as it did ten years ago. The story is similar in the auto industry. Whereas the number of models offered by U.S. car manufacturers in the American market increased from 205 in 1949 to 375 in 1970, the number fell to 247 in 1979 as the number of cars per model per year increased. (White, 1982: 159.) More recently, however, the number of models produced has again increased, reaching 313 in 1986. (Rosegger, 1986: 10.) The experience in Japan has been similar: whereas in 1980 the Japanese producers sold 46 separate models under 21 nameplates, by 1985 they had increased these numbers to 74 models and 34 nameplates. (Ibid.)

This development means that unless real output grows faster than the number of items produced--and that clearly has not been the case in recent years--the number of each item produced is shrinking. This means that it becomes more and more difficult to keep highly dedicated (specialized) equipment, such as transfer machines, operating at full capacity. Given the high capital costs involved in such systems, their profitability is very sensitive to variations in capacity utilization. They are also inherently difficult (costly) to change. It is therefore often cheaper to build a new, more flexible line in order to accommodate demand for new product varieties and more flexible production than to change existing lines.

What happens to plant size in connection with this development? If the old lines are left in place and operated more sporadically while new, more flexible lines are built in the same facility, plant size may increase. However, this is not likely to happen, for several reasons: 1) The type of organization needed for more flexible operation is fundamentally different from that involved in mass production (see Carlsson, 1988). 2) The types of labor skills required may be quite different from those released from the old line. 3) The space requirements for the new line may be difficult to handle in an existing plant. Work rules, seniority, wage and benefit costs in older facilities may also induce relocation of production to new (often greenfield) plants.

An example of the type of development discussed here is the following:

> New production hardware is already lowering the minimum efficient annual manufacturing scale for individual product lines in the auto industry and will lower it further in the future. For example, final-assembly plants were formerly most efficient when producing one model on a two-shift work schedule at a total volume of about 240,000 units <u>per year</u>. In the future, however, the increasing use of flexible automation able to assemble a wide range of products on the same line will mean that a plant may be highly efficient if

the cumulative volume spread over several models is around 240,000. (Altshuler et al., 1984: 182; italics added.)

The result is that restructuring of this sort is likely to lead to the establishment of new plants with more flexibility and lower total employment, at the same time as employment is reduced in older facilities. Thus, this mechanism can help to explain both the increase in the number of plants and the decline in average plant size.

Some evidence supporting this hypothesis is provided in a recent paper by Acs, Audretsch & Carlsson (1988). They show that in metalworking industries characterized by flexible production technology, the role of small firms increases and that of large firms decreases. The opposite is true in industries characterized by mass production technology. Also, Mills & Schumann (1985) have shown that there is an inverse relationship between firm size and flexibility.

The increasing importance of flexible technology is reflected in the increasing share of numerically controlled (NC) machine tools in the total investment in machine tools in various countries. See Table 7. While NC machine tools have been available in the market since the early 1950s, they began to have a major impact only in the 1970s. As can be seen in the Table, numerically controlled machine tools now dominate over other (conventional) types of machine tools in several of the major industrial countries, most notably in some West European countries and in Japan. It is interesting, and indicative, that the share is much lower in the United States. This undoubtedly reflects the substantially greater reliance on mass-production technology in the U.S. than elsewhere. Also of interest is the high share of NC machine tools in the United Kingdom recently. This in conjunction with the increasing number of establishments in the engineering industry may portend the long-awaited rejuvenation of British industry.

When it comes to the diffusion of the more sophisticated "cousins" of NC machine tools, namely industrial robots and flexible manufacturing systems (FMS), the British performance turns out to be distinctly less impressive. See Table 8. Japan and Sweden, with a great deal of small and medium scale, batch-type processes and emphasis on flexibility, turn out to be far ahead of other countries in the density of flexible technologies.

VI. CONCLUSION

The basic argument in this paper is that there are two major reasons for the observed decline in plant and firm size in most industrial countries in the last decade or so. One is what I have referred to as "de-glomeration" or specialization: the selling off or disinvestment of non-core businesses in order to free up scarce resources (particularly management time) to defend and nurture core business activities. The perception of a tougher and more uncertain business climate after the mid-1970s than during the 1960s and early 1970s is an important motive. The "back-to-basics" movement can also be viewed as a result of the recognition that the conglomerate merger wave of the earlier decades had simply gone too far. There are also more purely financial motives involved.

The second reason is the emergence of new computer-based technology which improves the quality and productivity of small or medium scale production relative to standardized mass-production techniques which dominated for the previous 150 years.

In my 1984 article, I raised the following question: "Are scale economies becoming less significant and the cost consequences of flexibility more important?" (Carlsson, 1984: 108.) In light of the evidence and the argument presented here, the answer is clearly yes.

What, then, are the implications? The most obvious implication is that the hypotheses put forward here need to be subjected to more thorough empirical analysis. If the hypotheses hold up under such scrutiny, there are further implications:

(1) It seems that the treatment of "market structure" needs to be both broadened and deepened. "Market structure" is usually understood to refer to the relative size distribution of firms in an industry as reflected in various measures of concentration in a particular market. The results of the present research suggest

that industrial organization economists need to concern themselves more than they currently do with understanding the mechanisms which generate the absolute sizes of firms and plants in various industries, why the absolute size differs among countries, and what the implications are for international competitiveness. "Market structure" needs to be analyzed in an international as distinct from a purely national context.

(2) The role and nature of new business formation, of small enterprises, and of entrepreneurship in general need to be better understood and integrated with existing theory so as to make it more dynamic.

Policy-wise, one of the main implications would seem to be that government policy should be more oriented towards promoting new and small businesses than towards preserving the status quo. Another implication is that the results of the current merger activity need to be studied with respect to their impact not only on "market power" but also on competitiveness in a more dynamic sense.

FOOTNOTES

1 The terms "engineering industries" and "metalworking industries" will be used interchangeably in this paper.

2 "The (mostly voluntary) merger wave of the 1960s and early 1970s was preponderantly conglomerate, more than doubling the number of lines in which the average Line of Business survey company operated. By contrast, the 1980s have seen a high incidence of 'bust up' takeovers--that is, acquisitions followed by the sell-off of numerous target company divisions." (Scherer, 1988: 76)

BIBLIOGRAPHY

Acs, Zoltan J. and David B. Audretsch (1987), "Innovation, Market Structure, and Firm Size," Review of Economics and Statistics, 69 (November), 567-575.

Acs, Zoltan J. and David B. Audretsch (1988), "Employment Generation and Firm Size in the U.S. and West Germany." Discussion Paper, Wissenschaftszentrum Berlin.

Acs, Zoltan J., David B. Audretsch, and Bo Carlsson (1988), "Flexible Technology and Firm Size," RPIE Working Paper 1988:x, Case Western Reserve University, March.

Altshuler, Alan et al. (1984), The Future of the Automobile. The Report of MIT's International Automobile Program. Cambridge, MA: The MIT Press.

Birch, David L. (1981), "Who Creates Jobs?" The Public Interest, 65 (Fall), 3-14.

Carlsson, Bo (1984), "The Development and Use of Machine Tools in Historical Perspective," Journal of Economic Behavior and Organization, 5, 91-114.

Carlsson, Bo (1987), "Flexible Manufacturing and U.S. Trade Performance," Paper presented to the European Association for Research in Industrial Economics (EARIE) Conference, Madrid, August. Case Western Reserve University, Research Program in Industrial Economics (RPIE) Working Paper.

Carlsson, Bo (1988), "Flexibility and the Theory of the Firm," Case Western Reserve University, Research Program in Industrial Economics Working Paper, forthcoming in the International Journal of Industrial Organization.

Carlsson, Bo; Erik Dahmen; Anders Grufman; Mårtha Josefsson; and Johan Örtengren (1979), Teknik och Industristruktur - 70-talets ekonomiska kris i historisk belysning (Technology and Industrial Structure - the Economic Crisis of the 70s in Historical Perspective). Stockholm: Industrial Institute for Economic and Social Research (IUI) and Royal Swedish Academy of Engineering Sciences (IVA).

Duché, Genevieve and Suzane Savey (1987), "The Rising Importance of Small and Medium-Sized Firms: Towards a New Industrial System?" in F.E.I. Hamilton (ed.), Industrial Change in Advanced Economies. London: Croom Helm.

Edquist, Charles and Staffan Jacobsson (1987), "The Diffusion of Industrial Robots in the OECD Countries and the Impact Thereof," Robotics, 3 (March), 23-32.

Edquist, Charles and Staffan Jacobsson (1988), Flexible Automation. The Global Diffusion of New Technology in the Engineering Industry. London: Blasil Blackwell.

Grant, Bruce and Lars-Erik Gadde (1983), Automotive Component Supply Strategies. Gothenburg: Chalmers University of Technology.

Gudgin, G. (1984), "P.M.E. et creations d'emplois. Le cas exemplaire dy Royaume-Uni," in Les P.M.E. creent-elles des emplois? Paris: Economica.

Hicks, Donald A. (1986), Automation Technology and Industrial Renewal. Adjustment Dynamics in the U.S. Metalworking Sector. Washington, D.C.: American Enterprise Institute.

Imai, Ken-ichi (1987), "Network Industrial Organization in Japan". Paper presented at the International Workshop on New Issues in Industrial Economics, Case Western Reserve University, June.

Leclerc, E. (1984), "Modernisation des P.M.I. japonaises et mutations des structures productives," in Les P.M.I. creent-elles des emplois? Paris: Economica.

Mills, David E. and Laurence Schumann (1985), "Industry Structure with Fluctuating Demand," American Economic Review, 75 (September), 758-767.

Piore, Michael J. and Charles F. Sabel (1984), The Second Industrial Divide: Possibilities for Prosperity. New York: Basic Books.

Ravenscraft, David J. and F.M. Scherer (1987), "Life after Takeover," Journal of Industrial Economics, XXXVI (December), 147-156.

Rosegger, Gerhard (1986), "International Rivalry and Cooperation: The Case of the U.S. Automobile Industry," Case Western Reserve University, Research Program in Industrial Economics Working Paper.

Scherer, F.M. (1988), "Corporate Takeovers: The Efficiency Arguments," Journal of Economic Perspectives, 2 (Winter), 69-82.

Shepherd, William G. (1982), "Causes of Increased Competition in the Economy, 1939-1980," Review of Economics and Statistics, 64, 613-626.

White, Lawrence J. (1982), "The Automobile Industry," in Walter Adams (ed.), The Structure of American Industry, sixth edition. New York: Macmillan Publishing Co., Inc.

Table 1. Changes in establishment and company size, number of establishments and companies, employment, and value added in U.S. metalworking industries, 1972-82, %

Industry	Establ. Size	Company Size	No. of Establ.	No. of Companies	Employ-ment	Value Added
Metal cans, barrels, drums & pails	-26.9	-38.6	2.4	22.0	-25.2	121.6
Cutlery	-1.5	-3.0	-1.5	0.0	-3.0	112.1
Hand and edge tools, n.e.c.	-18.1	-14.9	25.6	20.8	2.8	126.4
Handsaws and saw blades	-24.0	-22.3	49.5	46.3	13.6	100.0
Hardware, n.e.c.	-28.6	-28.5	12.5	12.4	-19.6	64.0
Plumbing fittings & brass goods	-3.9	.0	-19.5	-22.6	-22.6	85.8
Heating equipment, exc. electric	-59.8	-60.1	109.5	110.7	-15.9	85.7
Fabricated structural metal products	-8.7	-12.8	15.8	21.3	5.8	127.6
Fabricated platework	-14.5	-14.1	29.7	29.2	11.0	135.4
Screw machine products	-13.8	-12.4	8.4	6.7	-6.6	141.6
Iron and steel forgings	-33.8	-32.6	36.1	33.7	-9.9	104.4
Automotive stampings	-50.2	-49.7	47.5	45.9	-26.6	54.4
Crowns and closures	-31.5	-27.6	20.8	14.3	-17.3	123.4
Ammunition	-44.0	-44.8	-10.3	-9.0	-49.7	73.4
Small arms, ordnance & access., n.e.c.	-16.2	-17.3	31.6	33.3	10.3	183.1
Steel springs	-50.3	-50.8	44.4	45.9	-28.3	63.5
Valves and pipe fittings	-17.9	-16.6	48.8	46.5	22.2	198.1
Misc. fabricated wire products	13.7	15.7	-2.5	-4.2	10.8	131.0
Metal foil and leaf	31.3	36.7	52.4	46.3	100.0	422.2
Fabricated metal products, n.e.c.	-14.4	-14.5	23.4	23.7	5.7	129.1
Turbines & turbine generator sets	-40.2	-41.7	17.3	20.3	-29.9	75.8
Internal combustion engines, n.e.c.	-19.2	-17.5	40.8	37.9	13.7	140.8
Farm machinery & equipment	-25.4	-24.7	23.0	21.9	-8.2	131.3
Lawn & garden equipment	-45.9	-43.1	59.1	51.0	-14.0	108.6
Construction, mining & oil field mach.	-29.8	-29.3	77.9	76.5	24.9	204.4
Elevators & moving stairways	-19.1	-20.9	7.1	9.6	-13.3	90.0
Conveyors & conveying equipment	-5.3	-5.2	41.3	41.1	33.8	171.4
Hoists, cranes & monorails	-42.7	-42.0	46.8	44.9	-16.0	93.7
Industrial trucks & tractors	-27.7	-27.1	28.7	27.5	-7.0	37.7
Machine tools, metal cutting types	5.0	9.8	5.4	0.8	10.7	183.4
Oth. machine tools & metalworking mach.	-7.9	-5.3	15.7	12.6	6.6	134.5
Special dies, tools, jigs & fixtures	-4.1	-3.9	9.7	9.5	5.2	110.4
Machine tool accessories	-10.3	-9.1	31.6	29.7	18.0	146.9
Power driven hand tools	-59.5	-61.0	130.7	140.0	-6.5	116.4
Rolling mill machinery	-63.4	-66.2	34.0	45.0	-51.0	33.9
Textile machinery	-37.7	-38.0	-4.8	-4.3	-40.7	31.5
Woodworking machinery	-38.6	-39.3	15.3	16.6	-29.2	35.9
Paper industries machinery	0.2	2.7	16.1	13.3	16.3	200.2
Printing trades machinery	18.8	21.7	-0.7	-3.1	18.0	144.6
Food products mach., industr mach. nec	-0.4	3.2	39.5	34.6	38.9	164.1
Pumps and pumping equipment	10.2	20.6	12.0	2.4	23.4	204.5
Ball and roller bearings	-28.0	-20.6	19.3	8.1	-14.1	97.5
Air and gas compressors	-58.2	-67.7	235.7	334.5	40.2	214.7

Table 1 (continued)

Industry	Establ. Size	Company Size	No. of Establ.	No. of Companies	Employ- ment	Value Added
Industrial patterns	18.2	18.0	-2.4	-2.3	15.3	115.9
Speed changers, drives, and gears	19.2	23.8	-11.3	-14.5	5.8	147.2
Industrial furnaces and ovens	-8.8	-4.7	33.1	27.3	21.3	164.5
Power transmission equipment, n.e.c.	-48.4	-49.7	89.7	94.4	-2.2	112.0
Electronic computing equipment	-19.4	-20.7	187.9	192.7	132.1	459.1
Office machines, n.e.c.	1.6	7.9	2.0	-3.9	3.7	127.6
Scales & balances, exc. laboratory	-22.7	-20.7	31.3	27.9	1.5	108.5
Automatic merchandising machines	-4.2	-7.1	-26.4	-24.1	-29.5	17.2
Refrigeration and heating equipment	-28.5	-28.4	11.8	11.6	-20.1	72.0
Measuring and dispensing pumps	5.1	4.7	7.0	7.4	12.5	172.3
Transformers	-38.6	-42.6	35.6	45.2	-16.7	90.0
Switchgear and switchboard apparatus	-16.1	-13.8	13.7	10.6	-4.6	140.4
Motors and generators	-15.8	-13.0	10.6	7.1	-6.9	132.8
Industrial controls	-19.3	-20.0	55.4	56.8	25.4	186.8
Welding apparatus, electric	-11.7	-9.1	9.6	6.5	-3.2	93.6
Carbon and graphite products	-15.3	-12.5	26.4	22.4	7.1	155.2
Household cooking equipment	-5.2	3.1	7.3	-1.4	1.7	128.5
Household refrigerators & freezers	-52.7	-49.5	38.9	30.0	-34.3	30.6
Commercial & household laundry equip.	-9.4	-11.3	-17.6	-15.8	-25.4	49.3
Electric housewares and fans	-14.2	-14.5	-12.0	-11.7	-24.6	67.4
Household vacuum cleaners	-12.9	-12.1	-13.9	-14.7	-25.0	54.8
Sewing machines	-14.5	-13.1	21.3	19.4	3.8	35.5
Household appliances, n.e.c.	3.9	1.4	-2.4	0.0	1.4	97.4
Electric light bulbs	-31.8	-36.9	4.2	12.7	-28.9	77.3
Current-carrying wiring devices	-14.7	-10.5	3.5	-1.4	-11.7	84.8
Noncurrent-carrying wiring devices	-18.9	-18.5	26.3	25.5	2.3	148.4
Lighting fixtures & equipment	13.1	54.2	41.5	3.8	60.1	260.1
Radio & TV receiving sets	-54.6	-55.8	23.1	26.5	-44.0	11.2
Phonograph records & prerecorded tapes	-16.8	-17.3	1.2	1.9	-15.8	216.8
Telephone and telegraph apparatus	-38.1	-38.0	64.0	63.9	1.6	168.7
Radio & TV communication equipment	8.0	6.1	34.6	37.0	45.4	264.9
Electron tubes	13.1	17.9	-33.3	-36.1	-24.6	51.6
Semiconductors & related devices	-27.6	-28.3	135.7	137.8	70.6	381.7
Electronic capacitors	-9.0	-11.1	15.0	17.7	4.7	143.9
Electronic resistors	-25.5	-22.3	19.8	14.9	-10.7	98.9
Electronic coils and transformers	-36.8	-39.6	56.9	64.2	-0.8	151.3
Electronic connectors	1.9	11.2	115.2	97.3	119.3	372.8
Electronic components, n.e.c.	-0.8	-87.8	103.8	1562.8	102.2	415.3
Storage batteries	9.3	10.8	-5.2	-6.5	3.6	151.8
Primary batteries, dry & wet	21.6	16.1	14.6	20.0	39.3	152.3
X-ray & electromedical apparatus	57.1	73.4	151.0	127.4	294.2	776.6
Engine electrical equipment	-50.4	-50.0	49.3	48.3	-25.9	52.7
Electrical equipment & supplies, n.e.c.	49.3	52.1	-25.1	-26.4	11.9	144.6
Motor vehicles, parts & accessories	-30.0	-30.6	17.2	18.2	-18.0	85.1
Aircraft	20.2	22.3	-1.2	-2.8	18.8	209.2

Table 1 (continued)

Industry	Establ. Size	Company Size	No. of Establ.	No. of Companies	Employ-ment	Value Added
Aircraft engines & parts	-11.2	-12.4	39.8	41.7	24.1	264.1
Aircraft equipment, n.e.c.	-6.3	-7.0	39.2	40.2	30.4	203.2
Shipbuilding and repair	-23.9	-22.2	51.6	48.4	15.4	239.5
Boat building and repair	-10.9	-11.4	5.6	6.2	-5.9	117.3
Railroad equipment	-44.7	-45.4	22.7	24.4	-32.1	34.0
Motorcycles, bicycles & parts	-39.9	-39.9	23.0	22.8	-26.1	27.7
Guided missiles & space vehicles	103.1	15.7	-58.6	-27.3	-15.9	138.3
Space vehicle equipment, n.e.c.	0.3	2.4	2.1	0.0	2.4	152.4
Trailers, campers, transport eq. n.e.c.	-23.0	-25.0	-40.2	-38.6	-53.9	14.4
Tanks & tank components	57.0	49.2	95.5	105.6	206.8	933.1
Engineering & scientific instruments	-9.2	-9.5	45.2	45.7	31.9	140.7
Instruments to measure electricity	38.5	47.6	18.7	11.4	64.4	311.6
Optical instruments & lenses	107.5	118.3	30.0	23.6	169.7	527.4
Surgical & medical instruments	-2.8	-2.6	69.8	69.3	64.9	357.9
Surgical & dental equipmt & supplies	5.2	5.0	42.4	42.7	49.7	243.7
Ophthalmic goods	20.6	13.1	-18.0	-12.6	-1.1	112.9
Photographic equipment & supplies	-2.0	-4.8	26.8	30.5	24.3	165.7
Watches, clocks & watchcases	-53.5	-55.8	17.3	23.4	-45.5	3.8
Metalworking industry, total	-12.7	-13.44	27.5	28.6	11.3	160.3

Source: U.S. Department of Commerce, Bureau of the Census, Census of Manufactures, 1972 and 1982.

Table 2. Correlation Matrix

	Change in: No. of establ.	No. of companies	Establ. Size	Company size	Gross output	Value added
Change in # establ.	1.000					
Change in # companies	0.971	1.000				
Change in est. size	-0.248	-0.267	1.000			
Change in company size	-0.192	-0.263	0.940	1.000		
Change in gross output	0.525	0.448	0.537	0.589	1.000	
Change in value added	0.521	0.448	0.555	0.594	0.938	1.000

Table 3. Establishment Size in Metalworking Industries in Various Countries, ca. 1973 and 1983

		Denmark		Finland		Italy		Japan	
ISIC	INDUSTRY	1983	1973	1983	1973	1982	1975	1983	1972
381	Metal products	43.0	51.1	43.8	61.8	79.9	82.1	9.4	11.7
382	Machinery n.e.c.	61.2	76.1	75.6	109.8	116.9	118.5	16.8	22.3
3825	Office, computing, etc	77.3	80.0	60.3	35.7			40.2	45.2
383	Electrical machinery	84.3	162.0	131.8	181.6	261.8	281.2	39.8	47.4
3832	Radio, TV, etc.	104.9	169.2	160.7	248.6			52.4	62.6
384	Transport equipment	98.9	152.0	134.2	169.0	477.8	530.8	39.5	46.5
3841	Shipbuilding, repair	131.1	239.5	217.0	289.4			26.3	42.4
3843	Motor vehicles	46.3	57.6	63.8	92.6			45.5	51.3
385	Professional goods	85.1	87.8	50.0	76.2	170.1	179.6	21.8	24.7
38	Metalworking industry	64.0	85.5	76.9	109.5	173.8	175.6	20.0	24.1
3	Manufacturing, total	55.7	64.9	68.5	80.3	121.3	128.0	14.6	16.8

		Sweden		United Kingdom		United States		West Germany	
ISIC	INDUSTRY	1983	1973	1983	1972	1982	1972	1983	1973
381	Metal products	45.0	44.1	32.9	53.2	45.5	57.3	106.0	115.6
382	Machinery n.e.c.	87.7	95.8	41.5	70.4	40.9	45.0	189.5	206.4
3825	Office, computing, etc	134.0	200.0	114.6	329.2	186.3	210.5	577.2	658.3
383	Electrical machinery	178.5	154.1	97.0	197.1	117.0	136.0	271.8	328.4
3832	Radio, TV, etc.	392.2	353.5	109.4	230.7	128.4	155.0		
384	Transport equipment	214.1	207.0	153.6	265.5	159.3	172.7	799.2	701.8
3841	Shipbuilding, repair	194.1	265.9	84.1	154.5	79.9	82.9	438.0	493.2
3843	Motor vehicles	241.0	192.4	132.2	252.4	201.2	245.3		
385	Professional goods	65.6	54.8	34.2	84.9	77.6	75.9	97.8	158.1
38	Metalworking industry	96.0	92.1	58.9	100.4	64.4	73.8	209.4	233.5
3	Manufacturing, total	82.8	72.0	50.3	87.9	51.7	57.7	155.0	150.2

Sources: United Nations, Industrial Statistics Yearbook, 1974, Vol. I, General Industrial Statistics. (New York: United Nations, 1976.)

United Nations, Industrial Statistics Yearbook, 1984, Vol. I, General Industrial Statistics. (New York: United Nations, 1986.)

U.S. Department of Commerce, Census of Manufactures, 1972 and 1982.

Table 4. Number of Establishments and Number of Persons Engaged in Metalworking Industries in Various Countries, ca. 1973 and 1983

ISIC	INDUSTRY	DENMARK Number of establishments 1983	1973	Number of persons engaged 1983	1973	FINLAND Number of establishments 1983	1973	Number of persons engaged 1983	1973
381	Metal products	714	658	30.7	33.6	808	458	35.4	28.3
382	Machinery n.e.c.	853	752	52.2	57.2	810	549	61.2	60.3
3825	Office, computing, etc	22	20	1.7	1.6	58	28	3.5	1.0
383	Electrical machinery	274	187	23.1	30.3	223	147	29.4	26.7
3832	Radio, TV, etc.	103	78	10.8	13.2	56	35	9.0	8.7
384	Transport equipment	267	229	26.4	34.8	316	210	42.4	35.5
3841	Shipbuilding, repair	151	114	19.8	27.3	112	66	24.3	19.1
3843	Motor vehicles	95	92	4.4	5.3	149	95	9.5	8.8
385	Professional goods	114	82	9.7	7.2	92	42	4.6	3.2
38	Metalworking industry	2222	1908	142.1	163.1	2249	1406	173.0	154.0
3	Manufacturing, total	6491	6616	361.6	429.7	7493	6371	513.2	511.7

ISIC	INDUSTRY	ITALY Number of enterprises 1983	1973	Number of persons engaged 1983	1973	JAPAN Number of establishments 1983	1973	Number of persons engaged 1983	1973
381	Metal products	2202	2669	176	219	95609	81323	901	950
382	Machinery n.e.c.	2420	2615	283	310	75787	55761	1276	1246
3825	Office, computing, etc					5197	2853	209	129
383	Electrical machinery	1127	1252	295	352	40048	28208	1592	1336
3832	Radio, TV, etc.					17591	11032	921	691
384	Transport equipment	810	746	387	396	22936	19935	905	926
3841	Shipbuilding, repair					4865	5748	128	244
3843	Motor vehicles					15603	11835	710	607
385	Professional goods	341	401	58	72	11096	8722	242	215
38	Metalworking industry	6900	7683	1199	1349	245476	193949	4916	4673
3	Manufacturing, total	24939	28310	3025	3624	780837	703138	11364	11827

Table 4 (continued)

ISIC	INDUSTRY	SWEDEN Number of establishments 1983	1973	Number of persons engaged 1983	1973	UNITED KINGDOM Number of establishments 1983	1973	Number of persons engaged 1983	1973
381	Metal products	1546	1900	69.6	83.8	10948	11119	360	592
382	Machinery n.e.c.	1167	1308	102.3	125.3	14934	12589	620	886
3825	Office, computing, etc	47	54	6.3	10.8	349	161	40	53
383	Electrical machinery	419	471	74.8	72.6	5628	3760	546	741
3832	Radio, TV, etc.	90	101	35.3	35.7	2358	1621	258	374
384	Transport equipment	496	545	106.2	112.8	4082	3476	627	923
3841	Shipbuilding, repair	85	129	16.5	34.3	1189	1126	100	174
3843	Motor vehicles	268	278	64.6	53.5	2285	1886	302	476
385	Professional goods	154	146	10.1	8	2367	2178	81	185
38	Metalworking industry	3782	4370	363	402.5	37959	33122	2234	3327
3	Manufacturing, total	9220	12419	763	894	101563	86954	5105	7647

ISIC	INDUSTRY	UNITED STATES Number of establishments 1983	1973	Number of persons engaged 1983	1973	WEST GERMANY Number of establishments 1983	1973	Number of persons engaged 1983	1973
381	Metal products	29225	24341	1331	1394	5338	5102	566	590
382	Machinery n.e.c.	52635	39882	2151	1796	5472	5674	1037	1171
3825	Office, computing, etc	2158	993	402	209	123	120	71	79
383	Electrical machinery	16671	12114	1951	1647	3205	3316	871	1089
3832	Radio, TV, etc.	9207	5780	1182	896				
384	Transport equipment	8488	7898	1352	1364	1051	1100	840	772
3841	Shipbuilding, repair	2566	2232	205	185	121	146	53	72
3843	Motor vehicles	4885	3995	983	980				
385	Professional goods	8045	5983	624	454	1432	993	140	157
38	Metalworking industry	115064	90218	7409	6655	16498	16185	3454	3779
3	Manufacturing, total	336728	312671	17399	18034	42431	53719	6576	8069

Sources: United Nations, Industrial Statistics Yearbook, 1974, Vol. I General Industrial Statistics. (New York: United Nations, 1976.)

United Nations, Industrial Statistics Yearbook, 1984, Vol. I General Industrial Statistics. (New York: United Nations, 1986.)

U.S. Department of Commerce, Census of Manufactures, 1972 and 1982.

Table 5. Employment and Sales in Fortune 500 Industrial Companies and Total Manufacturing Industry, 1975-1986 (current prices)

	Fortune 500 Industrial Companies		Total Manufacturing Industry		Fortune 500 Share in Total Manufacturing	
	No. of Employees (Million)	Gross Sales (Billions)	No. of Employees (Million)	Shipments (Billions)	No. of Employees %	Shipments %
1975	14.4	865.2	18.3	1039.4	78.7	83.2
1976	14.8	971.1	18.8	1185.6	78.7	81.9
1977	15.3	1086.6	19.6	1358.4	78.1	80.0
1978	15.8	1218.7	20.5	1522.9	77.1	80.0
1979	16.2	1445.3	21.0	1727.2	77.1	83.7
1980	15.9	1650.2	20.6	1852.7	77.2	89.1
1981	15.6	1773.4	20.3	2017.5	76.8	87.9
1982	14.4	1672.2	19.1	1908.3	75.4	87.6
1983	14.1	1686.7	18.7	2045.3	75.4	82.5
1984	14.2	1758.7	19.1	2274.9	74.3	77.3
1985	14.0	1807.1	19.3	2341.2	72.5	77.2
1986	13.4	1723.4				

SOURCES: Fortune, various issues
Statistical Abstract of the United States, various issues

Table 6. Value added ratios in U.S. metalworking industries, 1972 and 1982

Industry	Value Added/Shipments 1972	1982	Diff.
1 Metal cans, barrels, drums & pails	0.403	0.365	-0.038
2 Cutlery	0.754	0.729	-0.025
3 Hand and edge tools, n.e.c.	0.633	0.609	-0.023
4 Hand saws and saw blades	0.656	0.512	-0.144
5 Hardware, n.e.c.	0.625	0.578	-0.046
6 Plumbing fittings & brass goods	0.511	0.517	0.006
7 Heating equipment, exc. electric	0.531	0.501	-0.030
8 Fabricated structural metal products	0.460	0.425	-0.035
9 Fabricated plate work	0.527	0.503	-0.024
10 Screw machine products	0.597	0.764	0.167
11 Iron and steel forgings	0.467	0.458	-0.009
12 Automotive stampings	0.504	0.469	-0.035
13 Crowns and closures	0.485	0.463	-0.023
14 Ammunition	0.735	0.643	-0.093
15 Small arms, ordnance & access., n.e.c.	0.714	0.737	0.023
16 Steel springs	0.520	0.528	0.008
17 Valves and pipe fittings	0.592	0.577	-0.015
18 Misc. fabricated wire products	0.526	0.494	-0.031
19 Metal foil and leaf	0.449	0.361	-0.088
20 Fabricated metal products, n.e.c.	0.540	0.516	-0.024
21 Turbines & turbine generator sets	0.560	0.586	0.026
22 Internal combustion engines, n.e.c.	0.489	0.418	-0.071
23 Farm machinery & equipment	0.496	0.484	-0.012
24 Lawn & garden equipment	0.428	0.400	-0.028
25 Construction, mining & oil field mach.	0.534	0.526	-0.008
26 Elevators & moving stairways	0.641	0.526	-0.116
27 Conveyors & conveying equipment	0.558	0.499	-0.059
28 Hoists, cranes & monorails	0.521	0.490	-0.031
29 Industrial trucks & tractors	0.507	0.376	-0.131
30 Machine tools, metal cutting types	0.636	0.575	-0.060
31 Oth. machine tools & metalworking mach.	0.610	0.554	-0.056
32 Special dies, tools, jigs & fixtures	0.741	0.703	-0.038
33 Machine tool accessories	0.705	0.684	-0.021
34 Power driven hand tools	0.595	0.524	-0.071
35 Rolling mill machinery	0.630	0.550	-0.080
36 Textile machinery	0.592	0.606	0.013
37 Woodworking machinery	0.576	0.530	-0.046
38 Paper industries machinery	0.567	0.550	-0.017
39 Printing trades machinery	0.612	0.546	-0.066
40 Food products mach., industr mach. nec	0.628	0.576	-0.051
41 Pumps and pumping equipment	0.572	0.538	-0.033
42 Ball and roller bearings	0.608	0.586	-0.022
43 Air and gas compressors	0.545	0.450	-0.095
44 Industrial patterns	0.813	0.769	-0.045
45 Speed changers, drives, and gears	0.646	0.624	-0.023
46 Industrial furnaces and ovens	0.551	0.571	0.021
47 Power transmission equipment, n.e.c.	0.621	0.595	-0.027

Table 6 (continued)

Industry	Value Added/Shipments 1972	1982	Diff.
48 Electronic computing equipment	0.540	0.533	-0.008
49 Office machines, n.e.c.	0.683	0.523	-0.160
50 Scales & balances, exc. laboratory	0.647	0.543	-0.104
51 Automatic merchandising machines	0.565	0.448	-0.117
52 Refrigeration and heating equipment	0.496	0.488	-0.008
53 Measuring and dispensing pumps	0.577	0.540	-0.037
54 Transformers	0.518	0.493	-0.025
55 Switchgear and switchboard apparatus	0.613	0.606	-0.008
56 Motors and generators	0.590	0.567	-0.023
57 Industrial controls	0.638	0.601	-0.036
58 Welding apparatus, electric	0.536	0.506	-0.030
59 Carbon and graphite products	0.576	0.566	-0.010
60 Household cooking equipment	0.438	0.390	-0.049
61 Household refrigerators & freezers	0.460	0.418	-0.042
62 Commercial & household laundry equip.	0.511	0.472	-0.038
63 Electric housewares and fans	0.570	0.488	-0.082
64 Household vacuum cleaners	0.640	0.598	-0.043
65 Sewing machines	0.781	0.563	-0.217
66 Household appliances, n.e.c.	0.501	0.471	-0.030
67 Electric light bulbs	0.661	0.619	-0.042
68 Current-carrying wiring devices	0.631	0.583	-0.047
69 Noncurrent carrying wiring devices	0.554	0.508	-0.046
70 Lighting fixtures & equipment	0.528	0.419	-0.109
71 Radio & TV receiving sets	0.407	0.332	-0.076
72 Phonograph records & prerecorded tapes	0.662	0.673	0.011
73 Telephone and telegraph apparatus	0.586	0.532	-0.054
74 Radio & TV communication equipment	0.635	0.641	0.006
75 Electron tubes	0.613	0.568	-0.045
76 Semiconductors & related devices	0.641	0.672	0.031
77 Electronic capacitors	0.670	0.613	-0.057
78 Electronic resistors	0.708	0.684	-0.024
79 Electronic coils and transformers	0.604	0.623	0.019
80 Electronic connectors	0.715	0.637	-0.078
81 Electronic components, n.e.c.	0.518	0.564	0.047
82 Storage batteries	0.484	0.495	0.011
83 Primary batteries, dry & wet	0.637	0.507	-0.129
84 X-ray & electromedical apparatus	0.702	0.640	-0.061
85 Engine electrical equipment	0.596	0.535	-0.061
86 Electrical equipment & supplies, n.e.c.	0.526	0.507	-0.018
87 Motor vehicle parts & accessories	0.501	0.465	-0.036
88 Aircraft	0.579	0.560	-0.019
89 Aircraft engines & parts	0.574	0.568	-0.006
90 Aircraft equipment, n.e.c.	0.676	0.608	-0.068
91 Shipbuilding and repair	0.573	0.582	0.008
92 Boat building and repair	0.493	0.478	-0.015
93 Railroad equipment	0.455	0.431	-0.024
94 Motorcycles, bicycles & parts	0.478	0.300	-0.178
95 Guided missiles & space vehicles	0.715	0.688	-0.027
96 Space vehicle equipment, n.e.c.	0.652	0.662	0.010
97 Trailers, campers, transport eq. n.e.c.	0.357	0.376	0.019
98 Tanks & tank components	0.410	0.492	0.082

Table 6 (continued)

	Industry	Value Added/Shipments 1972	1982	Diff.
99	Engineering & scientific instruments	0.913	0.674	-0.240
100	Instruments to measure electricity	0.679	0.703	0.025
101	Optical instruments & lenses	0.714	0.632	-0.081
102	Surgical & medical instruments	1.364	0.706	-0.658
103	Surgical & dental equipmt & supplies	0.640	0.604	-0.036
104	Ophthalmic goods	0.733	0.689	-0.044
105	Photographic equipment & supplies	0.727	0.637	-0.089
106	Watches, clocks & watchcases	0.497	0.407	-0.090
	Metalworking industry, total	0.593	0.547	-0.046

Source: U.S. Department of Commerce, Bureau of the Census, Census of Manufactures, 1972 and 1982

Table 7. Share of Numerically Controlled (NC) Machine Tools in Total Investment in Machine Tools in Japan, Sweden, the United Kingdom, and the United States, 1978-1984. (Percent, current prices)

Year	Japan	Sweden	United Kingdom	United States
1978	15.6	26.0	19.0	n.a.
1979	27.2	31.1	22.5	n.a.
1980	28.3	28.6	30.9	27.8
1981	29.3	30.6	44.9	30.2
1982	38.8	31.4	40.8	38.1
1983	47.5	55.0	54.6	43.8
1984	54.3	59.4	62.4	40.1

*) Refers to metal-cutting machine tools only; information on metal-forming machine tools is not available for Japan and unavailable for Sweden for 1978-1982.

Source: Jacobsson & Edquist (1988): 25.

Table 8. Number of Industrial Robots and Flexible Manufacturing Systems (FMS) in Various Countries, 1984.

(per 100,000 employees in engineering industries)

Country	Number of Robots	Number of FMS
Japan	1225.7	1.9
Sweden	701.1	5.5
Belgium	281.0	. .
Italy	271.6	. .
West Germany	161.7	0.6
United States	147.5	0.7
France	146.9	. .
United Kingdom	84.6	0.3

<u>Source</u>: C. Edquist and S. Jacobsson (1987)

Figure 1.

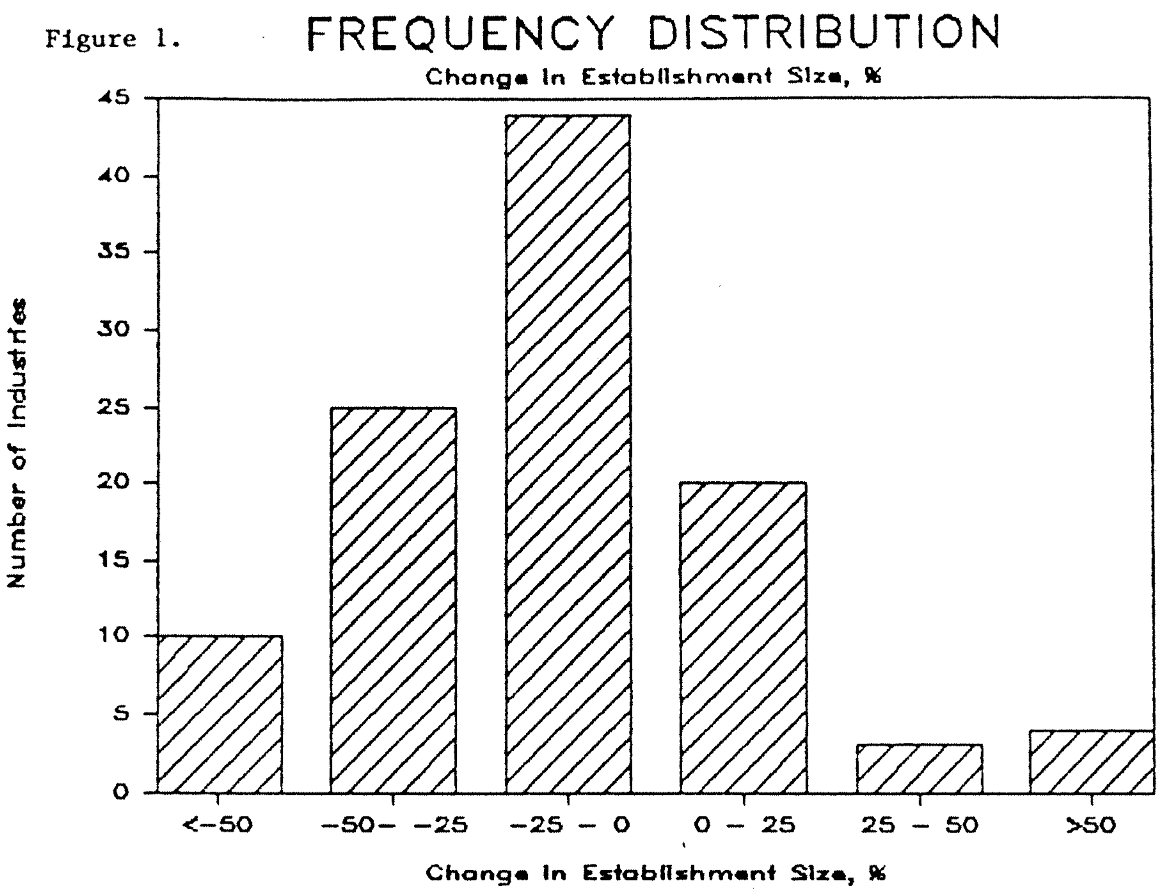
FREQUENCY DISTRIBUTION
Change in Establishment Size, %
Number of Industries
45
40
35
30
25
20
15
10
5
0
<-50
-50- -25
-25 - 0
0 - 25
25 - 50
>50
Change in Establishment Size, %

Figure 3.

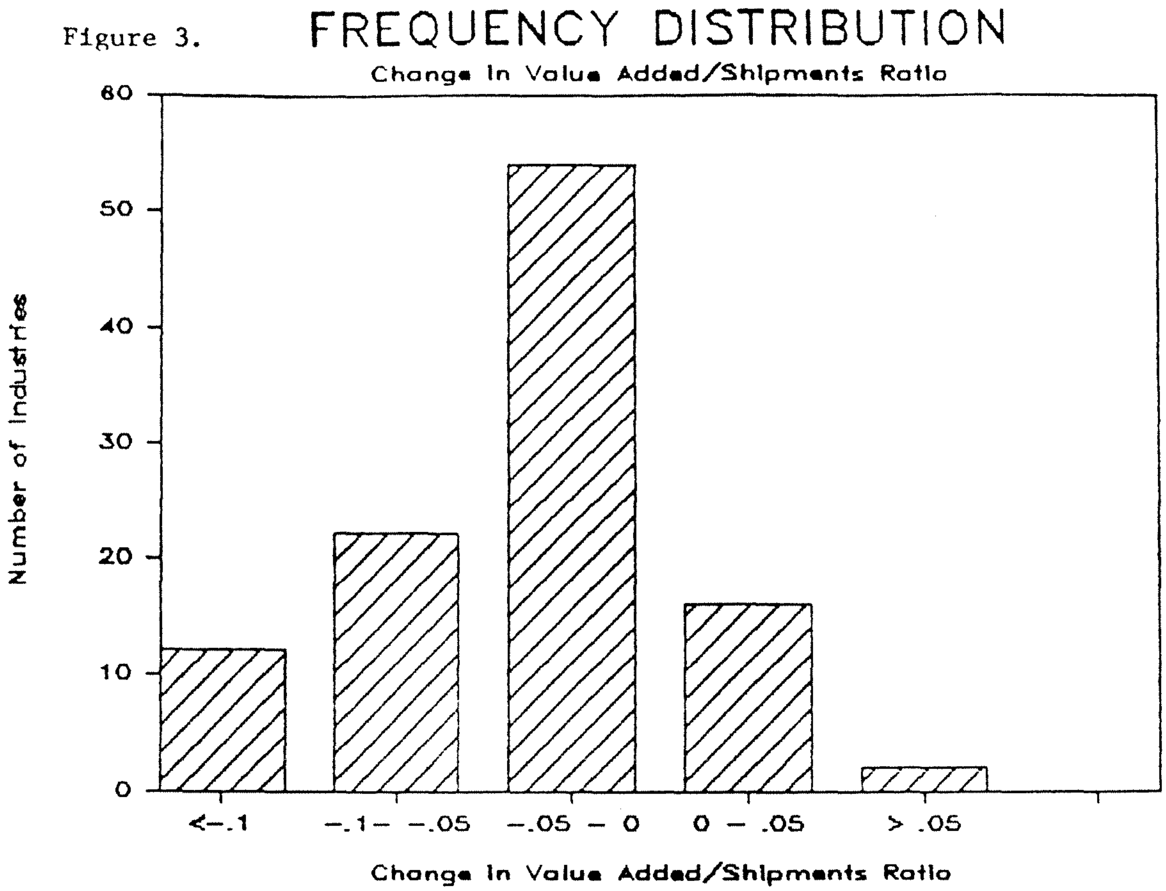
FREQUENCY DISTRIBUTION
Change In Value Added/Shipments Ratio
Number of Industries
0
10
20
30
40
50
60
<-.1
-.1- -.05
-.05 - 0
0 - .05
> .05
Change In Value Added/Shipments Ratio

Figure 2. Relationship between Change in Number of Plants and Output Growth in U.S. engineering Industries, 1972-1982.