Small Business and the Economics of Flexible Manufacturing

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ABSTRACT. The impact that flexible manufacturing has had on the structure of international trade is examined. By introducing an analysis of the economics of flexible manufacturing, it is concluded that flexible technology is more conducive to small rather than large firms. This shift in the size distribution of firms is the result of a new emerging techno-economic paradigm.

1. Introduction

A major industrial transformation took place in the international economy after the Second World War. The U.S., with its economic strength, stable dollar, technological lead and military power, provided the necessary direction and stability to the international economic order. For the fifties and sixties, the economies of the westernized industrial societies operated close to full employment, their wage rates and per capita income grew steadily while the prices remained stable. These were the decades of affluence, peace and prosperity. Compared with such economic performance, the decades of the seventies and eighties provide a spectre of crisis. In all of these countries, per capita incomes have stagnated while inflation and/or unemployment have remained high. The feelings among the writers in the U.S. are that there is a growing market globalization in which U.S. industries are losing its competitive edge.[1]

There is now a major debate underway about the nature of the crises and the competitive strength of the U.S. economy in general and industry in particular. There are various points of view. There are the usual believers of the status-quo who deny the very existence of such crises. Their arguments are based on special situations or factors and inappropriate policies, such as 'increases in the price of oil,' high wage rates in the U.S., an overvalued U.S. dollar, unfair trade practices by other partners, 'over-regulation,' and, of course, the catch-all 'wrong' monetary and fiscal policies.[2]

There is the other school of thought that accepts the proposition that the changes in the recent two decades are serious and structural. This school spans a number of different theories which have some common elements. One discerns three different arguments in the literature: (i) business cycle theorists suggest that these economies are now operating in the declining part of the 'Kondratiev Cycle.'[3] (ii) Recently a paradigm based on 'regimes of regulation' has been proposed mostly by French economists and historians.[4] (iii) Those who consider that technical change provides an important dimension in economic analysis seek explanation in a 'techno-economic paradigm.'[5]

This paper assumes that rapidly changing technology is influencing the structure of the international economic order and supports the growing consensus about the declining U.S. competitive strength.[6] It is based on the vision and proposition eloquently expressed by National Research Council[7] that the future of U.S. manufacturing lies in the broadly defined concept of high-tech in which flexible manufacturing[8] is one of the basic forms. It analyses the economic implications of flexible manufacturing and argues that small businesses are its main conduits.

2. U.S. competitive position: the role of high tech

As the structure of the international economy has changed, the U.S. has moved from a more or less closed to an open economy, so that trade increas-

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TABLE I
Trade balance in manufacturing (billions of U.S. dollars)

Year	US	Japan	West Germany
1970	3.4	12.5	13.3
1975	19.9	41.7	38.7
1980	18.8	93.7	63.1
1984	−107.5	107.7	59.5

Source: U.S. Department of Commerce, Bureau of Economic Analysis 1983 and International Trade Administration 1986.

ingly matters. The changes in the composition and patterns of world trade caused a good deal of structural change in the U.S. economy. This is best reflected in the U.S. trade balance in manufacturing. As Table I shows, the U.S. trade balance in manufacturing has moved from a surplus of $19.9 billion in 1975 to a deficit of $107.5 billion in 1985. By contrast, the trade balance of Japan and Germany have further improved; their surplus rose from $41.7 and $38.7 billion in 1975 to $107.7 and $59.5 billion in 1985. The composition of manufacturing in the U.S. is also changing. The share of high tech in manufacturing has been growing. As Table II confirms, the share of high tech in manufacturing has increased over the past 15 years, from 20.3 percent of output in 1967 to 26.3 percent in 1982, and from 21 percent of employment in 1967 to 23.3 percent in 1982. Indeed, the high tech sector has contributed heavily to exports. As Table III points out, high tech has helped the trade balance. In 1975 when there was a surplus of $19.9 billion, high tech contributed as much as $16.4 billion. Five years later in 1980, the high tech trade surplus of $30.5 billion changed the total manufacturing trade balance from a deficit to surplus. The competition in high tech industries is also heating up. In 1985, even though high tech exports inched up a little, high tech imports grew heavily so that the surplus was only $6.7 billion, too small to save the continuously eroding trade situation in total manufacturers.[9]

TABLE II
Importance of high tech in U.S. manufacturing

Year	High tech output as % of total manufacturing	High tech employment as % of total manufacturing
1967	20.3	21.0
1972	19.5	18.9
1978	20.3	20.4
1982	26.3	23.3

Source: U.S. Census of Manufacturers and Annual Survey of Manufacturers.
Note: The definition of High Tech here is rather stringent. It is discussed in Diwan and Vandyopadhyaya (1987).

A number of analysts have argued that as a result of the competition from Japan, West Germany and from the newly industrialized countries like Hong Kong, Korea and Singapore, a number of 'smokestack' industries in the U.S. have shown signs of a continuous decline. Thus, automobiles, steel, plastics, and the mechanical engineering industries are losing profits, employment and market share. These industries are being shifted to third world economies to reduce labor costs by making use of the lower wage rates in these economies.

TABLE III
U.S. trade balance in manufacturing and high technology industries (billions of current dollars)

Year	Total manufacturing			High technology		
	Exports	Imports	Balance	Exports	Imports	Balance
1965	17.1	10.6	6.4	6.2	1.8	4.6
1970	29.7	25.9	3.4	12.2	5.0	7.3
1975	71.0	51.1	19.9	27.8	11.6	16.4
1980	163.9	131.5	12.5	63.3	32.8	30.5
1985	178.6	286.8	−111.2	66.6	59.9	6.7

Source: U.S. Department of Commerce, International Trade Administration.

The trade situation presented above makes one point abundantly clear. As the international economy develops a global market, the world trade is becoming increasingly high tech oriented. In U.S. manufacturing too, high tech is becoming more and more important, far more important than the statistical percentages show. This trend is bound to continue.[10] This trend is driven by the 'rise of information technology.'[11] In manufacturing literature and circles, computer aided design (CAD), computer aided manufacturing (CAM), computer integrated manufacturing (CIM), computer aided engineering (CAE) are now commonly used acronyms.

3. Flexible manufacturing is the basic form of high tech

Even though the production structure is undergoing a structural change with the advent of high technology industries, the prevalent production system in the U.S. still remains preoccupied with the standardization of production where standardized goods are produced in mass scale.[12] High technologies are different. The core of high technology may be defined by flexible manufacturing, henceforth (FM). A meaningful distinction can be made between FM and standardized production systems. There are at least three sets of goods whose characteristics are fundamentally different from those of the standardized high volume goods. These are: (i) precision production that involve precision engineering, computer testing and sophisticated scientific maintenance. (ii) custom tailored goods produced in small batches that address consumer/buyers specific needs. (iii) technology driven products. These are the high R&D intensity goods incorporating new innovations. Even though these goods have been classified into 3 categories, they have lots of common elements.[13] They are highly information intensive and use extensive computer aid technologies.

We have called these flexible manufacturing because they are fundamental parts of manufacturing and their special characteristic is flexibility.[14] Some of the engineering terms, such as CAD, CAM, CIM, FMS, involve computers in an essential way. FM is a larger concept and involves all of these processes but is greater than any one of them.

'Flexibility' follows from two sources. The affluent consumer in high income industrialized countries desires to be different and demands goods that satisfy this desire. The market, therefore, promotes quality and product diversification. On the supply side, the new developments in science and technology make it possible for the producers to satisfy the consumer's demand for diversity and quality.

Diversity involves both complexity of tasks and the need to integrate various tasks and functions. The majority of the diversified and quality products are technology-intensive. Their production involves process technologies that can operate at high levels of precision. This implies precision machines and high skilled operators. The need for diversity also encourages and implies a continuous stream of innovations.

FM, then, must cope with market instability, high product quality and diversity, high rates of innovative activity, an extensive use of precision tools and machines, highly skilled operators and workers, a high capacity of organizers to motivate and integrate these functions efficiently, etc. Some of the old industries that are part of the FM are precision castings, speciality steel, special chemicals, control devices, sensor services, etc. In addition there are a whole host of new industries spanned by information, biology and space technologies.

In view of the quality and diversity of products, FM defines a production process in which variations in the characteristics of products can be regularly introduced, the goods are produced in small batches and efficiency is consistent with variety. In other words, the total output Q is now a vector; $Q = [Q_1, \ldots, Q_n]$ where Q_i and Q_j have some similarities and some differences. FM allows the same producing units to produce all the various Q_is. By contrast, in the standardized mass-volume production the production unit produces exactly the same good, i.e., $Q_i = Q_j$. In FM, the information-intensive technologies enable the producing unit to make changes in the design of the product, so that $Q_i \neq Q_j$, and produce the differently designed products.

An interesting question at this stage is: what is the nature of products in the Q vector? Economic theory looks at this question through the concept of a multiproduct firm. Generally, the products in a multiproduct firm are considered to be 'joint products,' i.e., the products are jointly produced. Theoretically, the concept of a multiproduct firm is more general and contains the 'joint product' as a special case. The 'joint product' is that particular case where the production unit is geared to produce a particular product Q_i and other product(s) Q_j follows from production. Generally Q_i and Q_j do not belong to the same vector Q. The classical example is that of 'wool and mutton.' The sheep are raised to produce either wool or mutton; the other just follows.

There are two ways to deal with the issue of the difference between Q_i and Q_j, both within the same vector Q. First, Q_i and Q_j may be considered as a part of the quality continuum. As one moves on this quality axis, at some point the quality differences become sufficiently pronounced so as to be identified separately as a different product; i.e., Q_i is different from Q_j.[15] The differences may be pronounced enough so as to need variations in the production process. FM can handle such variations in the production processes without involving a new production set up. Second, a product may be defined as a bundle of characteristics.[16] Diversity then follows from one or both of the following: (a) the composition of different characteristics and (b) different weightings of the same characteristics.

It may be useful, certainly for analytical purposes, to conceptualize a market for the whole vector Q. Q_i, Q_j will, then, relate to the various components or segments of this market for Q. These segments are far more sensitive to changes in technical change, income, and other exogeneous variables. The F in FM enables it to respond to and deal with the changes, instabilities and uncertainties of these sensitive market segments.

4. Towards an economics of flexible manufacturing

The principles of standard economic theory can be applied to a particular industry or a set of industries or manufacturing. In the last analysis an industry is defined by a product classification; e.g., SIC codes. The economic questions deal with the supply and demand of these industries. By and large, the demand is determined exogeneously that is based on the assumption of well behaved utility functions given by tastes. The industrial economic question then concentrates on the issue of supply. How can supply be generated to determine market equilibrium which in turn determines the price and output. In the case of standardized mass products, it is generally assumed that technology can be represented by a production function that is given or static. Another assumption is made about the nature of industrial organization that can manage output at the frontiers of the production function. To do so, it is further assumed that the factor market is perfect so that factors can be easily obtained and that economic agents are maximizers under relevant constraints. Given such an equilibrium, the standard theory formulates adjustment mechanisms that do clear the relevant markets so that the equilibrium is stable.

The question that arises is: how do the principles of standard economic theory operate in the case of FM? Is it possible to derive equilibrium conditions and their resulting welfare effects? Is FM viable in the long run? Since FM is fundamentally different from standardized mass production, the economics of FM is liable to be quite different. To develop an economics of FM, it is necessary to analyze the various assumptions suggested above in the context of FM. Our object in this paper is not to formulate the economics of FM and derive the theorems of cost and production. Instead we outline some of the steps in this effort and look into some of the implications that follow from FM.

As we have pointed out above, FM spans a whole vector of output Q and not an individual element in it. Analytically, SIC codes, certainly at a 7 digit level, attempt to define Q_i. As one moves from 7 digit to 4 to 2 digit levels, a number of different Q_is are joined together. An empirical question arises. Is the vector of FM equivalent to or different from two-three digit SIC code? If they are equivalent, empirical work on the SIC codes may be consistent with FM. If Q and SIC codes are different, the empirical work based on SIC codes may not be very useful for an analysis of FM.

Since FM responds to product quality and variety, analysis of quality becomes an important issue. Economic theory has made little attempt to separate quality from quantity. Whatever efforts have been made, the researchers have found it to be a tricky issue.[17] In producing standardized goods, quality appears in a discrete form. In FM we have suggested a quality continuum. All the same, quality in FM enters in an essential way. Research on the integration of quality will have a useful influence in many other areas of research.

The standard theory assumes that tastes are given so that the consumer can have well behaved utility functions. The standard theory is that the consumer knows what he/she wants and the producer produces those products. On the other hand, FM assumes a consumer who desires to be different and is not fully conversant what products are there. In FM, F means that the FM can provide a variety of goods; some of which will satisfy the consumer demand. Examined from another angle, the demand for Q is given but its segmentation by Q_i is not. The segmentation depends upon the capacity of FM itself. In other words, FM does influence the market segmentation simply because the product variety is, to a considerable extent, determined by the nature and rate of technical change. Utility functions, market segmentation and FM form an interactive process; hopefully a virtuous cycle.[18]

Economic theory uses the conceptual framework of a production function to incorporate technology. The production function does take into consideration both embodied and unembodied technical change. In the standardized mass production system, however, the technology is given and an increase in demand is met by the scaling up of the production process. Economies of scale, then, is one of the important concepts. Much of the advantages of the large sized production units have been found in their economies of scale. FM does not have scale economies since production is a vector Q with Q_i being different varieties. There are, however, similar types of economies in FM also. These follow from the fact that the machines, robots, CAD, CAM, CIM, etc. have a good amount of 'flexibility' so as to be able to produce different varieties of products. The relevant concept here is 'economies of scope'[19] which follows from shared inputs. Shared inputs must have the flexibility. In other words, the capital is not highly specialized in use as in most assembly lines; i.e., no horizontal constraints on capital. However, economies of scope have not yet been incorporated into economic analysis.

Like the utility function, production function is a major pillar in neo-classical economics. By and large, a production function is a relationship between output and inputs. Even though inputs are many, output is a single variable. In FM output Q is a vector. Therefore, the production function concept needs to be extended so that both output and inputs are vectors.[20] A simple extension like this has large implications in terms of production and cost theory. Since the output vector Q has many elements, one needs to develop some sort of a substitution concept in order to formulate decision rules and derive equilibrium levels of the outputs of various elements of the Q vector. The economist's tool box has the marginal rate of substitution between commodities. A relevant question is if this concept can be applied to FM.

The production function in standard economic theory is a representative of technology. One of the arguments in this production function is capital. For analytical purposes, it is generally assumed that the production process, or the firm, operates at the frontiers of the isoquant so that all of the capital and other relevant inputs are fully used. FM, on the other hand, requires that the inputs have not only alternative uses but also can be easily shifted to produce a different variety of the product. This characteristic may raise some serious questions about the 'capacity of capital' concept. The overriding concern in FM is the 'flexibility' by which inputs can be shifted/used to produce a different product. Some amount of 'flexibility' may be obtained from the 'unused capacity.'[21] Does FM always imply 'unused capacity?' What is the relation between 'unused capacity' and 'flexibility?'

The major propositions of production theory are defined by, and in terms of, the factor substitutions and complimentarity. The interaction terms between output and inputs are generally nonexistent. FM deals with complexity of production and introduces the complexities of an enormous number of interaction terms that have to be related to the complimentarity and substitutional relations. Economic analysis and models have to take into consideration much larger number of such effects.

5. Small firms and flexible manufacturing

One of the objectives of this paper is to analyze the implications of FM in terms of the size distribution of firms. As we have argued, FM is fundamentally different from the high volume, standardized, mass-produced manufacturing. The difference is consistent with the hypothesis about the emergence of a new 'techno-economic paradigm' and a 'technological trajectory.'[22] We, therefore, hypothesize that FM trajectory is a part of a new emerging techno-economic paradigm.

On the basis of the above hypothesis, one may argue that the high volume, standardized, mass-produced manufacturing defines a trajectory in a different techno-economic paradigm. This paradigm is based on the large advantages of 'economies of scale.' Economies of scale are generated by the breaking up and standardization of tasks and the scaling up of production units. This leads to the growth in the size of the producing firms. The size distribution in these industries, therefore, is effected by a small number of very large number of firms that account for a major part of the total production. The rest of the output is produced by small firms. The structure of production implies high concentration ratios. There is now ample empirical evidence confirming this thesis. Depending upon the industry and its evolution, 60 to 90 percent of the total output in virtually every manufacturing industry has been produced by 5—10 of the largest firms.

Growth in the size of the firm and the scale of production units has generally been obtained by heavy investments in highly specialized machines and tools that perform only specialized tasks. As the tasks have been routinized, the labor employed has been unskilled since it is cheaper. The organization of production is hierarchical in that it promotes bureaucracy and a 'business culture' of conflict between management and employees requiring an army of supervisory staff and resulting in an unmotivated — if not alienated — workforce. Even when R&D expenditures are large, the bulk of R&D has gone to processes that develop further economies of scale by specializing, refining and routinizing tasks, even products.[23]

With the shift in the techno-economic paradigm in favor of the FM trajectory, the large size firms are at a great disadvantage because the FM scale does not provide any useful economies. On the contrary, there is a major trade-off between scale and 'flexibility;'[24] the larger the scale, the lower the flexibility. The large scale firms suffer from inflexibility. To switch over to FM has a high cost to the firm since it may involve writing off investment, changing business culture, reorganizing production and training the work force. There are costs of not only reorganization but also of unlearning. The short term interests of the large firm, therefore, are to stay on the old technological trajectory.

The question is: what advantages do small firms have to get on the FM trajectory? It is argued that since the large firms satisfy a major part of the demand, the small firms can exist only if they have some special advantages. These advantages range from the familiarity with a special and small segment of the market to flexibility of production in order to meet such demand. The ability of the small firms to try new ideas and innovations as well as their intimate relations with the customer provides them with a special 'niche' and makes them viable. The existence of the small firms along with the very large ones is in itself an empirical fact and confirmation of the special advantages of the small firms.

In addition, there is ample evidence about the strengths of the small firms. Comparing the innovative capacity of small and large firms, Scherer finds in favor of a lower degree of innovativeness of the larger firms and higher degree of innovativeness of the small firms.[25] In a recent study, Acs and Audretsch (1988) find that small firms are more innovative. In their own language, "this (the regression results) suggests that, *ceteris paribus*, the greater extent to which an industry is composed of large firms, the greater will be the innovative activity, but that increased innovative activity will tend to emanate more from the small firms than from the large firms."[26] They also cite other studies that provide further evidence on this thesis.[27] They also find other interesting evidence to the effect that "innovation activity of small firms is high relative to the industry level in industries in which there is only a small share of small firms and in which *skilled labor* plays an important role"[28] (emphasis added).

In view of the major strength in their innovativeness, the new techno-economic paradigm and the FM trajectory provide an important new opportunity to the small firms. Perez and Soete (1988) have argued, persuasively, that entry into the new technological trajectories do not depend solely on traditional costs and price: "It is clear that there is no single price tag for production technologies nor is it solely determined by the supplier. Furthermore, the absolute threshold level is not limited to the price of technology. It includes minimum levels of scientific and technical knowledge, practical experience and locational advantages."[29] The entry costs of a firm into a new technological trajectory are determined by four factors:

(i) the traditional investment costs;
(ii) scientific and technological knowledge;
(iii) skills and experience;
(iv) locational advantage.

The threshold levels for all these four factors are quite different. As far as FM trajectory is concerned, the threshold levels of investment costs are comparatively low. This is partly due to the fact that major FM technologies involve information/computer aided technologies. The price of information technologies has been continuously declining. Similarly, the threshold level of skills and experience is somewhat lower insofar as technologies are new and all are starting from a similar base. Both these factors make it possible for the small firms to enter the industry relatively easily. The other two factors, scientific and technological level and locational advantage are basically macro level variables depending more on the economy, its public R&D and educational institutions. These two factors are more or less equal for both the large and small firms. Since FM requires that production is in small batches and because customer satisfaction is quite important, small firms have a distinct advantage. On the other hand, large sized firms have a clear disadvantage insofar as they have to write off the cost of existing capital and unlearn the old habits and ways of organizing production.

There is now some empirical evidence on the above propositions. Considering that FM technologies are of recent vintage, a decade or two old, there are only a few empirical studies. The evidence comes in two forms: (a) the decline in the mean firm size and (ii) increases in the number of small firms. Carlsson (1989) has analyzed the engineering (metal working) industry. He observes, "in fact, the average plant and firm size in metal working (engineering) industries — as well as manufacturing as a whole — in the United States has been shrinking for well over a decade. Nor is this phenomena 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."[30] The reason for this decline is 'vertical disintegration' and the emergence of FM trajectories.

Acs, Audretsch and Carlsson (1988) have analyzed the relationship between firm size and numerically controlled machines: "We find that the implementation of numerically controlled machine tools is related to an increased relative presence of small firm overtime."[31]

It seems reasonable to conclude that as the FM trajectory expands further, it will help, and be helped by, the size distribution in favor of the small firms for quite some time.

Notes

[1] Quite a large number of books have been published on this thesis in the past 10 years. For illustrative purposes one may refer to Hayes and Wheelwright (1984), Lawrence (1984), Reich (1983), Starr (1988) and Vogel (1979).

[2] This school of thought is well represented by policy makers and their statements regularly reported in daily and weekly newspapers.

[3] 'Kondratiev Cycle' is deeply embedded in the literature on the business cycle. This cycle is brought out as and when needed even though not much empirical work has been done on this cycle.

[4] Robert Boyer is the best exponent of this paradigm. "The regulation approach is an attempt to elaborate a *continuum of concepts* from the more abstract ones (for example, that of production modes) to the observed regularities in the behavior of economic agents (as part of the 'regulation' mechanisms). Some of these intermediate notions are accumulation regime, structural or institutional form, wage-labor nexus, and so on." (Boyer, 1988, p. 70.)

[5] The changes defined in techno-economic paradigm "have such widespread consequences for all sectors of the economy that their diffusion is accompanied by a major structural crisis of adjustment, in which social and institutional changes are necessary to bring about a better 'match' between the new technology and the system of social management of the economy." (Freeman and Perez, 1988, p. 38.)

[6] A more recent articulation of this consensus is evidenced in Starr (1988); particularly Duffey (1988), Lamm (1988), Starr and Ullman (1988) and Tyson (1988a, b).

[7] National Research Council (1986) provides a synthesis and

a description of the consensus among diverse groups of the economy.

[8] It may be pointed out that 'flexible manufacturing' as discussed in this paper is different from Flexible Manufacturing Systems (FMS).

[9] U.S. Congress' Joint Economic Committee (1986) arrived at the same conclusion about the U.S. trade competitive position in high tech industries.

[10] "In the future, U.S. manufacturing will be increasingly high technology in both basic industries ... and in the high-tech industries themselves." (Tyson *et al.*, 1988, pp. 35—36.) This is so because these 'sun-rise' industries are 'strategic.' There is now a large number of studies defining high technology industries and arguing about their importance. See also Aho and Rosen (1981), Carlsson (1988a), Cohen and Zysman (1987), Davis (1982), Diwan and Chakraborti (1988), Diwan and Vandyopadhyaya (1987), Kallianpur and Jang (1987), Kelly (1977), Magaziner and Reich (1983), Markusen *et al.* (1986), Naisbitt (1982), Steedman and Wagner (1988), Tomer (1987), Vinson and Harrington (1979).

[11] Freeman and Perez (1988) argue that the 'techno-economic paradigm' of these decades is defined by the 'rise of information technology' and the continual decline in the price of information.

[12] Willinger and Zuscovitch (1988) articulate it eloquently: "The keystone of the technical system which is still dominant today is the *standardization of production.* It relies upon a process of technical and organizational changes in order to scale up operations and to satisfy a growing demand" (p. 254).

[13] "They require the traditionally separate business functions (research, design, engineering, purchasing, manufacturing, distribution, marketing, sales) to be merged into highly integrated systems that can respond quickly to new opportunities." (Reich, 1983, pp. 129—130.)

[14] 'Flexible system' in Reich (1983) and 'information-intensive production system' of Willinger and Zuscovitch (1988) are parallel concepts to 'flexible manufacturing'.

[15] This argument can be analyzed through the concepts of 'piece-to-piece substitution' and a threshold level. Just as there is a quality continuum, one can also conceive of a substitution continuum. At some point this substitution reaches a level that may be considered a threshold so that there is meaningful change in the product. Willinger and Zuscovitch (1988) use these concepts to analyze the diffusion process.

[16] Lancaster (1979) formulated this argument.

[17] Triplett (1988) surveys some of the research to analyze quality due to technical change in computers. This is a problem researchers face all the time in updating indices.

[18] There are very few economic analyses and models that assume such a relationship between the producer and consumer. This interaction does raise questions about the well-behaved utility functions and therefore the maximizing behavior of the economic agent in the demand part of the market.

[19] Panzar and Willig (1981) have defined the concept of 'economies of scope' and compared it to scale economies.

[20] The translog cost and production functions are sufficiently general being the 2nd order expansion of a Taylor Series. This extension implies that the standard translog function will have to be extended further.

[21] In the world of computers and computer aided units, the 'memory' or capacity is always larger than it is needed in any one particular activity.

[22] Dosi (1988) analyses these trajectories/paradigms in terms of the process of innovation.

[23] An interesting example is the research that attempts to produce a hard tomatoe that is amenable to large scale handling and therefore easy to transport and store.

[24] Dosi (1988, pp. 1153—1155) analyses some of the implications of this trade-off.

[25] Scherer (1986). Acs and Audretsch (1988) refer to a similar argument advanced by Scherer (note 11, p. 687).

[26] Acs and Audretsch (1988, p. 687).

[27] See also Thurik and van der Hoeven (1988).

[28] Acs and Audretsch (1988, pp. 687—88).

[29] Perez and Soete (1988, p. 470).

[30] Carlsson (1989). This is new phenomena now being defined by "downsizing" of the companies.

[31] Acs *et al.* (1988, p. 22). They also develop a similar analysis for 'programmable robots' and obtain results favorable to large firms. This is not surprising because the 'robots' are not yet a standard production technology.

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