Impact of Plant Size and Focus on Productivity: An Empirical Study

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Recent popular business literature has suggested that there is a significant trend in the United States for firms to decrease the size and increase the focus of manufacturing plants they operate, and that this leads to higher productivity. This paper tests empirically the validity of these claims. We analyze data on virtually the entire population of manufacturing plants in the United States and find that, contrary to the popular business literature, the average size of plants increased during the period 1972–1984. However, consistent with the popular notion, the rate of growth in plant size slowed considerably, and even turned negative for a category of large plants. Plant focus did increase during this period. We then investigate the relationship between productivity and plant characteristics including plant size and plant focus. Overall, our results do not support the popular argument that reduction in plant size results in productivity gains. However, we do find support for this argument in some two-digit SIC industries; also, scale economies in the entire population decreased over the period 1972–1982. We also find only limited support for the popular argument that plant focus increases productivity.
(*Focussed Factory; Plant Size; Scale; Plant Focus; Productivity; Manufacturing Strategy*)

Introduction

Recent popular business literature suggests that the size of manufacturing plants in the United States is shrinking (for example, *Industry Week* 1981, 1990). *Business Week* (1984) proclaims that a conventional manufacturing wisdom—the bigger a plant, the more efficient it is likely to be—is being seriously questioned. Numerous firms including AT&T, FMC, and General Electric "are replacing huge manufacturing complexes with new, smaller plants. And they are automating large existing factories in an attempt to turn them into 'small plants' in terms of number of employees." Peters and Waterman (1982) find that many of their excellent companies including Dana, Motorola, and Emerson Electric have consciously put caps on plant employment levels. *The Wall Street Journal* (1993) argues that U.S. manufacturers are opening small plants in an effort to compete with foreign rivals. There is much anecdotal evidence suggesting that plant size is shrinking in the United States, but there is virtually no rigorous empirical research demonstrating this trend. One of the objectives of this paper is to fill this gap.

The next logical question is that even if plant size is in fact shrinking in the United States, what impact does this trend have on plant level productivity? As opposed to the conventional wisdom in manufacturing that "big is better," the popular press nowadays suggests that "small is beautiful" (*Business Week* 1985). Small organizations are believed to be more entrepreneurial and quicker at meeting market needs than larger organizations (*Business Week* 1989, Peters 1992). A number of popular business press articles argue that manufacturing plants in the United States have become too large to be managed effectively, and that a shift towards small plants would improve performance. Peters (1992) states, on the basis of anecdotal evidence, that "economies of manufacturing scale can hardly be said to exist anymore." In less extreme terms, *The Economist* (1990)

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argues that "the newest technologies (flexible manufacturing, faster computers, and better telecommunications) have reduced the optimum size of many businesses . . . the odds are that they will reduce it even further." This paper empirically tests the impact of plant size on productivity.

The focused factory literature initiated by Skinner (1974a, 1974b) argues that factories that are focused have higher productivity than unfocused factories. Anecdotal evidence in the popular business press (for example, *Business Week* 1984) and in case studies (for example, March and Garvin 1986) suggests that corporate America has been moving towards focused factories. This paper empirically tests these claims regarding plant focus.

Size and focus are, of course, two distinct characteristics of a plant. It is possible for a large plant to be focused on a single product or process; conversely, a small plant could manufacture several different products and thus be unfocused. In our empirical work in this paper we will treat size and focus as two independent characteristics and study their individual impact on productivity. However, in the popular literature and often in practice, size and focus are intertwined. Skinner (1974b) criticizes the development of the "multi-product, do-all general purpose" or "white elephant" plant which in most cases is "unusually big and complex." Schmenner (1983) points out that multiple capacity expansions can result in a mix of process technologies, poor materials handling, no central control of operations, and much work-in process inventory. Similarly, in practice, a firm moving toward focused plants often simultaneously moves toward smaller plants.

The conceptual argument in favor of small plants is quite similar to that in favor of focused plants and is rooted in organizational theory. Organizational theory and the focused factory literature have consistent perspectives on why focused and/or smaller plants might enjoy greater productivity. Galbraith (1974) defines the problem of organizational design as integrating the specialized sub tasks of a large organization around the completion of a global task. One solution to this information processing problem is to create self-contained tasks which shift the basis of authority from "one based on input, resource, skill, or occupational categories to one based on output or geographical categories" (Galbraith 1974). The focused factory argument is that by organizing plants by output categories "on a limited, concise, manageable set of products, technologies, volumes and markets" (Skinner 1974a), the manufacturing task becomes explicitly linked to accomplishing the company's overall strategy or marketing objective. The focused factory proposed by Skinner is Galbraith's organizational design solution of "creating self-contained tasks" applied to the problem of large, complex manufacturing plants.

Organizational theory suggests that large organizations would tend to be more formalized, decentralized, and complex (horizontally and vertically) (Daft 1986, Kimberly 1976). Size grants some efficiencies in administration, and there is evidence that large firms tend to be early adopters of innovations (Tornatzky et al. 1990, Kelley and Brooks 1988, Levin et al. 1987), but the tradeoff is that all the various parts of the large organization are more distant from the object of the whole organization when the organization faces many different and sometimes conflicting demands. Large organizations may have the organizational slack that allows them to be more innovative but this is not the same as being entrepreneurial in the sense of being responsive to market demands. As organizations, if large plants are also more formalized, decentralized, and complex than small plants, this could in part explain why they would tend to be less focused on the manufacturing tasks necessary to achieve the strategic objectives of the company, as the focused factory literature also suggests (Skinner 1974a).

Schmenner (1983) argues that the problem with big plants is that they usually have "formidable bureaucratic structures" in which "relationships inevitably become formal, and the worker is separated from the top executives by many layers of management." Organizational problems arise as firms choose to overcome the problem of complexity and multiple demands of a variety of products or customers by adding people and staff groups. "It takes more effort in terms of inventory control, more personnel, labor specialists, more accountants and cost controllers and a great deal more paper work of all sorts to manage the large and complex multi-product, multi-market plant" (Skinner 1974b, p. 35).

According to the popular business literature, U.S. plants in the 1970s were unfocused and too large, and reductions in size and increases in focus would improve productivity. The examples from the popular press suggest that this adjustment has been occurring. Previous research has provided very little empirical validation of these claims; the objective of this paper is to fill this gap. We provide empirical answers to the questions: Has corporate America been moving toward smaller and more focused manufacturing plants? What is the impact of changes in plant size and focus on productivity? Have economies of scale been decreasing over time? How do the answers to these questions vary by industry?

Our analysis is based primarily on the data from the U.S. Census of Manufacturers, which covers all (approximately 345,000) manufacturing establishments in the United States, for the years 1972, 1977, and 1982 (the last year for which the data is now available). We find that, contrary to the popular literature, plant size, on the average, was still growing in the United States during the period 1972–1982. In partial support of the popular literature, we find that the growth rate in plant size declined during this period. Also consistent with the popular notion, we find that there was a trend for plants to become more focused in terms of product and process specialization. Contrary to the popular literature, we find that across the entire sample of plants in our study, there is a positive relationship between productivity and plant size, though this positive relationship declines significantly over the period 1972–1982. In addition, the relationship between size and productivity is negative in some two-digit SIC industries. We find limited support for a positive relationship between focus along the product dimension and productivity.

The rest of the paper is divided into five sections. The next section develops the research questions and derives hypotheses concerning the effects of scale and focus on productivity. The Model Development section derives a total factor productivity model which estimates scale effects while controlling for factor inputs. We then develop operational measures of the variables in the model. The next section reports the empirical results. The final section summarizes the conclusions and the limitations of our research.

Research Questions

Trends in Plant Size

We are here interested in how plant size is changing over time in the United States, and not how it should change or what is the optimal plant size; the issue is a purely descriptive one. The popular business literature (for example, *Business Week* 1984, *The Wall Street Journal* 1993) suggests that plant size is shrinking. All the evidence presented in such literature is anecdotal in nature. It thus leaves unanswered questions such as: How fast is plant size shrinking? Is this shrinkage uniform across all manufacturing industries? Is this shrinkage uniform across different sizes of plants? We will provide some answers to these questions.

There has been virtually no large-scale empirical research on trends in plant size in the fields of strategy, manufacturing strategy, or operations management. One notable exception is a study by Schmenner (1983), which surveys 410 manufacturers and finds that plants opened before 1970 were more than two and one half times as large as plants opened after 1970.

Research in industrial organization on census data has found a dominant trend toward increasing plant size through 1972 (Kaufman 1979). A second stream in economics is explicitly concerned with technological progress and economies of scale (see for example Hughes 1971, Levin 1971). The view here is that at any point in time there exists a "scale frontier" which defines the largest economically feasible plant that can be constructed. Technical progress over time shifts this frontier, resulting in larger plants. Lieberman (1987) analyzes the construction of new plants in the chemical products industry and finds a steady increase in plant size over time driven by technological progress. Studies documenting the shift in the scale frontier have been conducted for only a few industries, typically capital intensive industries. We agree with Lieberman (1987) that it would be useful to have comparative results covering a broader set of industries. In contrast to the inexorable rise in the scale frontier, Carlsson (1989) shows that between 1972 and 1982 establishment size as measured by average employment declined in 79 out of 106 four-digit SIC engineering/metalworking industries (SIC 34-38), resulting in an average decline of 12.3%. Carlsson believes that this is due to 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. A comprehensive review of these industries and others using the same methodology would help identify where the scale frontier continues to increase and where it does not.

Though it does not describe trends in plant size, operations research literature has investigated the determinants of plant size. In the classic capacity expansion model of Manne (1961), firms should build new plants with size proportional to the industry growth rate, subject to various assumptions including deterministic demand. The relationship between plant size and industry growth rate is even more pronounced if demand is modeled as being stochastic. Schmenner (1982) finds that as an industry matures, firms tend to use smaller facilities than they operated when they were growing rapidly which is consistent with Manne's model. Scherer et al. (1975, p. 122–126) expect and find the rate of increase in petroleum refinery sizes to be greater in markets where demand is growing more rapidly than in slowly growing markets. Lieberman (1987), however, finds that market growth rate is statistically insignificant in explaining size of new plants.

Trends in Plant Focus

There is much anecdotal evidence reported in the popular business literature (for example, *Business Week* 1984) and in case studies (for example, Harvard Business School 1978, March and Garvin 1986) that suggests that corporate America has been moving towards more focused factories. But there has been very little large sample empirical research on this issue. Pesch and Schroeder (1991) empirically investigate the determinants of plant focus using a sample of 24 plants. They find evidence that product lines and the number of processes are statistically related to their measure of plant focus while plant size and plant age are not.

Vertical integration represents a dimension of process focus because it often implies combining upstream and downstream processes within the same plant when these processes require different managerial tasks. Carlsson (1989) believes that there is a process of "deglomeration (and sometimes vertical disintegration)" underway within U.S. manufacturing which is partly due to increased competition from abroad and an increased rate of technology transfer via multinational firms. In this view, which is common among observers of the U.S. automobile industry, the traditional combination of vertical integration with purchases from multiple vendors on the open market for nonintegrated inputs has given way to a system (or network) of suppliers relationships (Womack et al. 1990). Carlsson (1989) predicts that this transition toward final assemblers as coordinators of the production of others with increased reliance on components from suppliers would result in a decline in vertical integration; he finds that vertical integration as measured by value added divided by shipments falls in 38 out of 47 engineering industries from 1975 to 1985.

Productivity Relationships

The popular business press argues that U.S. manufacturing plants are too large. The argument is not that there are never economies of scale, but rather that on the average U.S. manufacturing plants have exhausted the available economies of scale and are now characterized by diseconomies of scale. The proposition (which we will test) is that on the average U.S. plants have grown beyond the minimum point of the U-shaped long run average cost curve.

The above proposition naturally raises the question why would managers build plants that are too large and result in high cost production. The problem may be driven by both a pervasive expectation of economies of scale combined with a lack of recognition of the benefits of the focused factory. It is possible that economists and managers have overemphasized the engineering and technical factors that lead to advantages of large plants, and under-emphasized the organizational factors that lead to disadvantages of large plants (Galbraith 1974; Kimberly 1976; Skinner 1974a, 1974b). This argument is consistent with the prescriptions of Peters and Waterman (1982) and Peters (1992) and similar to an argument with respect to the learning curve (Abernathy and Wayne 1974). Managers may associate best practice with larger plants when in fact many other changes besides scale increases are required, such as changes in technology (Gold 1981). In addition managers may incorrectly project gains from scale in a given plant by extrapolating scale improvements without allowing for organizational costs (Schmenner 1976), or simply by expecting productivity gains from higher capacity in a given plant to be available in larger plants (Porter 1985, p. 71).

If the limitations of the concept of economies of scale were not as widely diffused as the concept itself, managers may have mistakenly expected cost reductions from increasingly larger plants (Gold 1981). We therefore expect that on the average managers have moved beyond the minimum cost position with respect to the scale of their plants. We conjecture that U.S. managers began to recognize the organizational costs of large plants in the seventies and eighties, in part due to articles such as Skinner (1974a) and in part due to the onsite practitioner recognition of the difficulties of managing complex manufacturing facilities. Our hypothesis is that there are decreasing returns to scale for U.S. plants, and that firms which reduce their plant size will improve their plant productivity.

H1A. *Reducing plant size improves plant productivity.*

This hypothesis contrasts sharply with the conventional analysis which finds economies of scale across many industries in U.S. manufacturing. For example, based on the sum of the output elasticities on inputs in a Cobb-Douglas production function, a study of 18 two-digit industries found increasing returns to scale in fifteen of these industries though the increasing returns were only significant in five industries (Moroney 1967). There is some counter evidence: Schmenner and Cook (1985) find that plant size relative to industry norms is not associated with plant productivity after controlling for other inputs. In another study, Caves and Ghemawat (1992) find a negative relation between plant size relative to a specific competitor and the proportional gross margin on sales of a respondent minus that of the same competitor. Conventional reasoning based on economies of scale would expect the opposite effect.

If we segment the population of plants in the United States by size, we expect that the larger the plant size, the more likely there will be benefits from a shift towards a smaller size. The degree to which managers have expanded plants beyond minimum cost with respect to scale would be greater for larger size plants. We therefore hypothesize the following:

H1B. *Reducing plant size improves productivity more in larger plants than in smaller plants.*

Whatever the current relationship between plant size and productivity may be, it is possible that this relationship is changing over time because of technical or organizational innovations. *The Economist* (1990) and *Business Week* (1994) argue that new technologies (such as computers and telecommunications) have reduced the optimum size of businesses. A set of studies investigates technical determinants of changes in plant size (Piore and Sabel 1984, Carlsson 1989, Acs et al. 1990) and hence a change in the structural relationship between plant size and productivity. Piore and Sabel (1984) believe that the rise of flexible production technologies may result in a shift in the firm-size distribution toward an increased presence of small firms. Acs et al. (1990) test the hypothesis of Piore and Sabel with a priori predictions about the relationship between a flexible technology (numerically controlled machine tools) and the share of sales accounted for by small firms in 36 engineering industries. They find a positive relation between the implementation of numerically controlled machine tools and the increased relative presence of small firms. The observation of a trend to smaller plants in the engineering industries in Carlsson (1989) is linked to technical change in those industries. This new technology allows for more flexible production of greater product variety in shorter production runs in contrast with high volume production typically associated with mass production. He speculates that this technology would not simply be added into larger plants because the organization, labor skills, and space requirements would be difficult to handle in an existing plant. New, small plants would be necessary to exploit the technology. If such changes were underway broadly in the economy, then one would expect the relationship between plant scale and productivity to become less positive (or more negative) over time.

H1C. *Economies of scale are diminishing over time.*

It can be argued that increased product variety in a plant will lead to economies of scope and some economies of scale resulting in lower costs and higher productivity (Kekre and Srinivasan 1990). The focused factory literature (for example, Skinner 1974a) argues to the contrary that a factory focusing on a narrow product mix for a particular market niche will outperform the conventional plant which attempts a broader, less well-defined mission. According to this perspective, plants should be focused on simpler tasks, and this results in less confusion and a stronger feedback connection between the strategic objectives of the plant and the operations of the plant. Less focused plants operate with reduced efficiency and plant management is less able to implement changes in operations to address new opportunities. Overhead costs may be higher with a broader product line (Johnson and Kaplan 1987, Miller and Vollmann 1985). Direct costs may be higher as well due to congestion in multiproduct batch manufacturing facilities. In these facilities parts spend relatively more time waiting in queues than being processed which drives up inventory and work-in-process costs (Karmarkar 1987). Plants can be focused along several dimensions including products, served markets, production volume, degree of customization, and process (Hayes and Wheelwright 1984); we examine here the dimensions of product and process focus. We expect that as the variety of products and manufacturing processes in a plant grows, the associated managerial complexity increases to the detriment of productivity. With regard to product focus, our hypothesis is the following:

H2. *Increasing product focus through product specialization improves plant level productivity.*

We operationalize process focus through plant level vertical integration. Vertical integration at the plant level is very different from vertical integration at the firm level; if a firm operates several plants which from a vertical chain, the firm will be highly integrated but each plant will have low vertical integration. For example, a plant which does only assembly will be both less integrated and more focused than one which makes the components and also does the assembly. In a more vertically integrated plant, management will be involved in more tasks that may have different or conflicting demands.

H3A. *Increasing process focus through reduced plant level vertical integration improves plant level productivity.*

Carlsson (1989) argues that alternative supplier relationships have arisen which make vertical integration a less attractive means of supplying downstream operations. The causes cited by Carlsson, increased global competition and technical transfer from multinational corporations, are both changes which are increasing through time. In addition, the development of these alternative supplier relationships requires a diffusion of common standards and approaches to quality through many different firms which also occurs through time (Womack et al. 1990). One implication of this theory is that whatever net benefits vs. costs exist for vertical integration, these net benefits vs. costs are diminishing and becoming less positive (or more negative) over time.

H3B. *The relationship between vertical integration and productivity is becoming less positive (or more negative) through time.*

There has been much discussion recently about "lean" manufacturing (Womack et al. 1990, Peters 1992), which reduces the specialization of supervisory workers, or eliminates the distinction between supervisory and production workers, by giving more responsibility to production workers. A prominent thesis of lean manufacturing is that by returning responsibility to solve problems to workers who are most directly able to observe the source of problems, there is a greater likelihood that many small improvements will be made.

Consistent with the thesis of lean production we argue that reducing layers of management and indirect workers in a plant leads to lower costs and higher productivity (Bolwijn and Kumpe 1990, De Meyer et al. 1989). It is also consistent with Skinner (1974a) that plants with a high proportion of supervisory workers are using those workers to manage complexity within the plant, the very antithesis of the focused factory. The contrary reasoning would be that these layers of management and indirect workers are necessary to effectively manage the plant and result in higher productivity. We hypothesize the following:

H4. *Reducing the ratio of supervisory to direct workers in a plant improves plant level productivity.*

Model Development

We estimate a total factor productivity model; to derive the model we start with a Cobb-Douglas production function at time 1 with output (Q), a constant term (c), capital (K), labor (L), materials (M), plant size (PS), supervisory overhead (SO), vertical integration (VI), product specialization (S), a control for capacity utilization (CU), and an error term represented by ϵ (Lieberman et al. 1990):

$$Q_1 = c_1 \cdot K_1^{\alpha 1} \cdot L_1^{\beta 1} \cdot M_1^{\gamma 1} \cdot PS_1^{\delta 1} \cdot SO_1^{\mu 1} \cdot VI^{\nu 1} \cdot S_1^{\tau 1} \cdot CU_1^{\rho 1} \cdot e^{\epsilon 1}. \quad (1)$$

Capacity utilization influences productivity for technical reasons that are independent of the economies of scale or plant focus issues investigated in this paper. To control for this effect on productivity we include capacity utilization as a control variable, and we expect a positive association with productivity.

Dividing Equation (1) by L_1 and substituting R_1 for K_1/L_1 yields Equation (2). This formulation has been widely estimated and can be shown to be functionally equivalent to Equation (1) (Kmenta 1986, p. 252–253). Dividing the total output by labor helps to address the potential problem of spurious regression resulting from a common time trend among the variables Q, L, and M (Davidson and MacKinnon 1993, p. 670–671; David 1970, p. 555; David 1975, p. 181):

$$\begin{aligned} Q_1/L_1 = {} & c_1 \cdot R_1^{\alpha 1} \cdot L_1^{\alpha 1+\beta 1-1} \cdot M_1^{\gamma 1} \cdot PS_1^{\delta 1} \cdot SO_1^{\mu 1} \\ & \cdot VI^{\nu 1} \cdot S_1^{\tau 1} \cdot CU_1^{\rho 1} \cdot e^{\epsilon 1}. \end{aligned} \quad (2)$$

Substituting P_1 (output per worker) for Q_1/L_1, creating an identical equation for time 2, and dividing the equation for time 2 by the equation for time 1, results in Equation (3). There are likely to be many unknown characteristics, that affect productivity, for a plant at time 2 that will be the same for that plant at time 1. By taking the ratio of the productivity Equation (2) for the same plant at two different times we control for those characteristics and hence derive a more efficient estimator of the coefficients:

$$\begin{aligned} P_2/P_1 = {} & c_2/c_1 \cdot R_2^{\alpha 2} \cdot R_1^{-\alpha 1} \cdot L_2^{\alpha 2+\beta 2-1} L_1^{-\alpha 1-\beta 1+1} \\ & \cdot M_2^{\gamma 2} \cdot M_1^{-\gamma 1} \cdot PS_2^{\delta 2} \cdot PS_1^{-\delta 1} \\ & \cdot SO_2^{\mu 2} \cdot SO_1^{-\mu 1} \cdot VI_2^{\nu 2} \cdot VI_1^{-\nu 1} \\ & \cdot S_2^{\tau 2} \cdot S_1^{-\tau 1} \cdot CU_2^{\rho 2} \cdot CU_1^{-\rho 1} \cdot e^{\epsilon 2} \cdot e^{-\epsilon 1}. \end{aligned} \quad (3)$$

In the next section, we estimate Equation (3) (after taking logs and dropping the disturbance term). We are interested in the effect of the shift terms for plant size (PS), supervisory overhead (SO), vertical integration (VI), and product specialization (S); capacity utilization is a control variable and is entered in the same functional form as the other shift terms. Thus we are interested primarily in the estimates for the parameters $\delta 1$, $\delta 2$, $\mu 1$, $\mu 2$, $\nu 1$, $\nu 2$, $\tau 1$, and $\tau 2$.

Aside from point estimates for the parameters, we are also interested in the changes over time in these parameters represented by $\delta 2 - \delta 1$, $\mu 2 - \mu 1$, $\nu 2 - \nu 1$, and $\tau 2 - \tau 1$. For this we estimate a different version of Equation (3). Through algebraic manipulation of Equation (3) and taking logs, we can derive Equation (4); we estimate this equation in the next section.

$$\begin{aligned} \ln P_2/P_1 = {} & \ln c_2/c_1 + \alpha 2 \ln(R_2/R_1) + (\alpha 2 - \alpha 1) \ln R_1 \\ & + (\alpha 2 - \alpha 1 + \beta 2 - \beta 1) \ln(L_2/L_1) \\ & + (\alpha 2 + \beta 2 - 1) \ln L_1 + \gamma 2 \ln(M_2/M_1) \\ & + (\gamma 2 - \gamma 1) \ln M_1 + \delta 2 \ln(PS_2/PS_1) \\ & + (\delta 2 - \delta 1) \ln PS_1 + \mu 2 \ln(SO_2/SO_1) \\ & + (\mu 2 - \mu 1) \ln SO_2 + \nu 2 \ln VI_2/VI_1 \\ & + (\nu 2 - \nu 1) \ln VI_1 + \tau 2 \ln S_2/S_1 \\ & + (\tau 2 - \tau 1) \ln S1 + \rho 2 \ln(CU_2/CU_1) \\ & + (\rho 2 - \rho 1) \ln CU_1 + \epsilon 2 - \epsilon 1. \end{aligned} \quad (4)$$

We will first estimate a model that pools all industries together to test our hypotheses for all U.S. manufacturing industries taken together. We will then also estimate the model separately for each two-digit SIC industry, which may provide better estimates for particular industries.

Measurement

Data

The analysis in this paper is based on the data from the Census of Manufacturers for the years 1972, 1977, and 1982. These data are compiled by the U.S. Department of Commerce every five years; unfortunately, there is a long lag after the census before data are available to

Table 1 **Changes In Industry Average Plant Characteristics: Median Percent Change Across All Manufacturing Industries**

	1972–1977	1977–1982	1972–1982
Plant Size			
by Employment	+11.5%	+7.1%	+19.4%
by Shipments	+12.3%	+6.0%	+17.5%
Vertical Integration	−4.7	−1.6	−5.9
Specialization	0.0	0.0	+1.1
Capital Intensity	+5.7	+10.6	+23.0
Supervisory Overhead	+0.9	+3.4	+4.2

researchers, and 1982 is the latest year for which the data are now available. The Census of Manufacturers is conducted on an establishment basis; a company is required to file a separate report for each location of its operations. The 1982 Census covers all (approximately 345,000) manufacturing establishments in the USA. While the data are not as timely as we would like it to be, they are the most comprehensive data collected at the disaggregate level of a plant. The published data, however, report only statistics aggregated above the level of individual plants (but below the level of an entire industry) to preserve confidentiality.

The Census data do not allow us to track individual plants, but they do permit us to track aggregations of plants of similar size. By classifying plants of similar size into groups and comparing changes over time we are still able to control for unknown characteristics which may be shared in common by plants of similar size. Most industries have a large number of very small plants, which would bias the central tendencies we are interested in; moreover, these "fringe" plants may follow different decision criteria with respect to choosing plant size and focus than other plants. Therefore, we eliminate the fringe plants from our study. (Other studies have also chosen to eliminate fringe firms because they may bias the measure of economies of scale, for example Caves et al. 1975). We rank order all the plants in an industry in terms of value of shipments and eliminate from further consideration the smallest plants which together account for 20% of the industry shipments. To avoid repeated use of a cumbersome expression, from now onward, we shall refer to the remaining plants which account for 80% of industry shipments as the representative plants in an industry.

We divide the representative plants in an industry into four categories: large, medium, small, and tiny. The largest plants which together account for 20% of the total industry shipments are called "large" plants; the next largest set of plants which together account for 20% of the total industry shipments are called "medium" plants; and so on for the definition of "small" and "tiny" plants. We calculate all variables for four plant categories: large, medium, small, and tiny, for each of 429 manufacturing four-digit SIC industries in the Census.

In addition, we calculate some descriptive trends in plant size from 1980 to 1984 using the Trinet, Inc. "Large Establishment" database, which reports number of employees for each plant.

Variable Definitions

We calculate the average shipments per plant in four categories: large, medium, small, and tiny. Since we are interested in plant size (that is, plant capacity) rather than plant output, we determine the average plant size in a category by dividing the average shipments per plant in that category by the capacity utilization for the industry in that year. If one year is a recession year and output drops, we do not want our measure of plant size to drop as well since plant size is a construct representing fixed investment. Because the Survey of Plant Capacity (1982) reports only the industry wide capacity utilization, we have to assume that capacity utilization is the same for each category of plants in an industry. We also define plant size in terms of the number of employees per plant, adjusted by capacity utilization, for descriptive purposes.

To define the dependent variable in our model, P_2/P_1 (that is $(Q_2/L_2)/(Q_1/L_1)$), we use total shipments and payroll expense in 1982 and 1972 for time subscripts 2 and 1, respectively. This ratio of output/labor in the model also has the benefit of deflating the nominal measure of sales (Q) by the nominal measure of payroll expense (L). For descriptive purposes, we define labor productivity as value added divided by total payroll expense, where value added is equal to total shipments minus the cost of materials, energy and outside services. Payroll expense represents the factor cost of labor and since it is in nominal terms, deflates the nominal measure of value added.

We measure product focus (S) using the Census variable "specialization ratio." The Census classifies an establishment in a particular four-digit SIC industry if its production of the products of that industry exceeds in value its production of products of any other single industry. Specialization ratio for a plant is equal to its shipments in its primary industry divided by its total shipments. We admit that this measure of product focus is rather poor; for example, a plant which made large and small electric motors would, in the lexicon of manufacturing strategy, be considered "unfocused" (Harvard Business School 1978), but would have a specialization ratio of 100% since large and small electric motors fall in the same SIC industry. It is thus likely that, even if there was a significant trend towards product-focused plants, the Census data would not pick up this trend. Furthermore, the Census only reports an industry-wide average specialization ratio; we are therefore forced to assume that the specialization ratio is the same for all plant categories in an industry.

Capital intensity controls for investments in plant and equipment that affect productivity through the substitution of capital for labor. It is important to control for capital intensity because automation per se might affect productivity independently of a shift toward a focused or smaller plant. Ideally we would like data on capital used, or the actual depreciation of the capital stock. However, the Census gathers information only on "new capital expenditures." Since capital intensive industries will also have high capital expenditures as a means of maintaining depreciating capital equipment, new capital expenditures should be correlated with capital use or true capital depreciation. We use new capital expenditures as proxies for the capital stock (K). For descriptive purposes, we use new capital expenditures divided by employees as a surrogate for capital intensity per worker.

We operationalize supervisory overhead (SO) at the plant level as the ratio of all employees to production workers. Production workers are defined by the Census to include workers up through the line-supervisor level, engaged in activities closely associated with the production operations at the establishment, such as fabricating, processing, assembling, inspecting, receiving, storing, maintenance, and product development.

Vertical integration (VI) is measured as the ratio of value added to shipments, where value added is equal to total shipments minus the cost of materials, energy, and outside services.

To measure capacity utilization (CU), we use the "preferred" rate of capacity utilization which is based on the level of operations that the plant would prefer not to exceed. The preferred level of operations is the level of operations that a plant would have to maximize profits rather than the maximum potential output of the plant (U.S. Department of Commerce 1982).

Research Results

Trends in Plant Characteristics

Table 1 reports statistics on percentage changes in industry average plant characteristics; medians across industries are presented to exclude the effects of industries with outlier trends. Plant size is growing considerably, though the rate of growth is roughly half in the 1977–82 period of what it is in the 1972–77 period. This finding is consistent with Kaufman (1979) which finds a dominant trend toward increasing plant size in Census data through 1972. It is also consistent with the finding of a "scale frontier" in which the largest economically feasible plant continues to grow over time (Hughes 1971, Levin 1971, and Lieberman 1987). Vertical integration (at the plant level) is declining, especially in the first period, suggesting that firms are increasing the process focus of plants. This is consistent with the observation of Carlsson (1989) for the 1975 to 1985 period. Product specialization is increasing slightly over the entire period. Capital intensity is increasing rapidly and supervisory overhead is increasing moderately.

Table 2 reports the annual growth rates in plant size over the first two periods mentioned earlier as well as

Table 2 **Changes in Industry Average Plant Size: Medians Across All Manufacturing Industries (Annual Growth Rate)**

Plant Size	1972–1977	1977–1982	1980–1984
by Employment	+2.20%	+1.38%	+0.40%
by Shipment	+2.32%	+1.17%	N.A.

an additional period for 1980 to 1984 using the Large Establishment database compiled by the firm Trinet, Inc. The results once again indicate that plant size increased over time, but at a decreasing rate. It is encouraging that the results using two entirely different databases are so consistent. These results do not provide support for the popular perception of "rebellion" against scale intensive plants (*Business Week* 1984); however, the declining growth rate of plants and increasing product and process focus may be construed as limited support for this popular notion.

We next investigate how the above trends in plant characteristics are different for different size categories of plants (Table 3). It is interesting that growth in plant size measured by employment is negatively related to plant size category. This effect is less pronounced when plant size is measured by shipments. This negative relationship may be construed as limited support for the popular view that it is the large plants which are shrinking in size.

Changes in vertical integration and supervisory overhead are fairly uniform across all plant size categories (see Table 3). Capital intensity is increasing faster for the larger plants than for the smaller plants, which is consistent with the conventional view that links together capital intensity, technology, and large scale. This is inconsistent with the more recent argument that new manufacturing technologies, such as flexible automation, are economically viable even for small plants (Acs et al. 1990, Carlsson 1989).

Analysis of the Trinet, Inc. data yields similar results for the 1972–1982 period. For the period 1980–1984, we find that the medium size plant category actually decreased in size at the annual rate of 0.26%, and the large size plant category decreased at the rate of 0.43%. This is the strongest support we find for the popular view that plants in the United States are shrinking.

Table 3 Changes in Plant Characteristics, 1972–1982: Median Percent Change Across All Manufacturing Industries

	Plant Size Category			
	Large	Medium	Small	Tiny
Labor Productivity	+8.2%	+9.0%	+9.2%	+8.0%
Plant Size				
by Employment	+16.6	+17.3	+21.6	+24.3
by Shipments	+16.5	+13.6	+19.4	+17.7
Vertical Integration	−5.8	−6.0	−5.7	−6.8
Supervisory Overhead	+4.3	+3.9	+3.7	+3.9
Capital Intensity	+26.8	+20.8	+21.4	+10.8

Regression Results

We first estimate the total factor productivity model pooling together all manufacturing industries. Table 4 presents regression estimates of Equations (3) and (4). Equation (3) gives the estimates for the coefficients in 1982, and negative values of 1972 coefficients. Equation (4) presents changes in the coefficients over the period 1972 to 1982, as well as 1982 coefficients. The R^2 on the pooled sample equation in Table 4 (and 5) quite high at 0.590.

Since the model is multiplicatively interactive and is estimated in log form, it can be shown that the coefficients of the independent variables are approximately equal to elasticities. Thus a coefficient can be interpreted as the percentage change in the dependent variable associated with a 1% change in the independent variable.

The coefficients on plant size in 1972 and 1982 ($\delta 1$, and $\delta 2$ in Table 4) are positive and significant. This is consistent with the traditional view that plant size increases are associated with productivity increases and rejects our hypothesis H1a that reducing plant size increases productivity. We interpret the rejection of our hypothesis H1a as evidence that plants in the U.S. economy are not too large and that on average U.S. plants are characterized by increasing returns to scale. However, since $\delta 2 - \delta 1$ (in Table 5) is negative and significant, the returns to scale are diminishing over the period 1972 to 1982. This supports our hypothesis H1c that economies of scale are declining over time. This may be due to the diffusion of flexible manufacturing and information technologies which enable smaller plants to be more productive.

The elasticity on product specialization in 1972 ($\tau 1$) is positive as expected and significant; the elasticity in 1982 ($\tau 2$) is also positive, but it is not statistically significant. Thus there is support for our hypothesis H2, that increasing plant focus through product specialization improves plant level productivity. The elasticity on product specialization is declining over time ($\tau 2 - \tau 1$

Table 4 Total Factor Productivity Regression Analysis Based on Equation 3

Dependent Variable ln $P2/P1$	Equation 3 Reduced-Form Parameter	Equation 3 Pooled Segments	Equation 4 Reduced-Form Parameter	Equation 4 Pooled Segments
Constant	$\ln(c2/c1)$	0.210 (0.81)		
$\ln(R_2)$	$\alpha 2$	−0.004 (−0.60)		
$\ln(R_1)$	$-\alpha 1$	−0.035** (−5.84)	$\alpha 2 - \alpha 1$	−0.039** (−6.00)
$\ln(R_2/R_1)$			$\alpha 2$	−0.004 (0.60)
$\ln(L_2)$	$\alpha 2 + \beta 2 - 1$	−0.551** (−34.56)		
$\ln(L_1)$	$-\alpha 1 - \beta 2 + 1$	0.556 (32.33)	$\alpha 2 - \alpha 1 + \beta 2 - \beta 1$	0.005 (0.45)
$\ln(L_2/L_1)$			$\alpha + \beta 2 - 1$	−0.551** (−34.56)
$\ln(M_2)$	$\gamma 2$	0.459** (29.15)		
$\ln(M_1)$	$-\gamma 1$	−0.452** (25.42)	$\gamma 2 - \gamma 1$	0.007 (0.66)
$\ln(M_2/M_1)$			$\gamma 2$	0.459** (29.15)
$\ln(PS_2)$	$\delta 2$	0.073** (8.87)		
$\ln(PS_1)$	$-\delta 1$	−0.080** (−9.82)	$\delta 2 - \delta 1$	−0.008** (−2.80)
$\ln(PS_2/PS_1)$			$\delta 2$	0.073** (8.87)
$\ln(SO_2)$	$\mu 2$	−0.029 (−0.84)		
$\ln(SO_1)$	$-\mu 1$	0.080* (2.47)	$\mu 2 - \mu 1$	0.051** (2.85)
$\ln(SO_2/SO_1)$			$\mu 2$	−0.029 (−0.84)
$\ln(VI_2)$	$\nu 2$	0.081** (4.24)		
$\ln(VI_1)$	$-\nu 1$	−0.100 (−3.74)	$\nu 2 - \nu 1$	−0.019 (0.93)
$\ln(VI_2/VI_1)$			$\nu 2$	0.081 (4.24)
$\ln(S_2)$	$\tau 2$	0.085 (1.18)		
$\ln(S_1)$	$-\tau 1$	−0.160 (−2.48)	$\tau 2 - \tau 1$	−0.075 (−1.47)
$\ln(S_2/S_1)$			$\tau 2$	0.084 (1.18)
$\ln(CU_2)$	$\rho 2$	0.114** (7.35)		
$\ln(CU_1)$	$-\rho 1$	−0.090** (−3.75)	$\rho 2 - \rho 1$	0.024 (1.15)
$\ln(CU_2/CU_1)$			$\rho 2$	0.114** (7.35)
R^2		0.590		
SSR		38.438		
SST		65.148		
No. of Obs.		1637		

Two-tailed tests:

T-statistics are given in parentheses.

** = *T*-statistic is significant at 99% confidence level.

* = *T*-statistic is significant at 95% confidence level.

~ = *T*-statistic is significant at 90% confidence level.

Table 5 Change in Average Plant Characteristics 1972–1982 (Percent Change of Medians)

Two-digit SIC Industry Group	Productivity	Capital Intensity	Plant Size (Shipments)	Supervisory Overhead	Vertical Integration	Specialization
Food	19%	−1%	28%	1%	1%	0%
Tobacco	−6%	46%	−20%	0%	−3%	0%
Textiles	3%	−10%	2%	2%	−7%	4%
Apparel	11%	−15%	15%	2%	1%	−1%
Wood Products	−1%	−31%	−10%	4%	−6%	1%
Furniture	13%	−17%	11%	3%	−2%	0%
Paper	10%	12%	12%	3%	−11%	2%
Printing	14%	25%	−5%	3%	−4%	1%
Chemicals	2%	13%	44%	6%	−21%	2%
Refining	−1%	−2%	58%	2%	−32%	0%
Plastic	4%	−12%	0%	−1%	−14%	1%
Leather	14%	−8%	9%	3%	−4%	0%
Glass	3%	−5%	31%	4%	−12%	1%
Prim. Metals	−6%	29%	14%	6%	−15%	2%
Fab. Metals	7%	15%	14%	4%	−6%	1%
Machinery	7%	32%	24%	7%	−6%	3%
Elec. Machinery	9%	48%	14%	6%	−5%	1%
Transportation	12%	40%	39%	6%	−2%	−1%
Instruments	8%	30%	13%	8%	−2%	3%
Miscellaneous	10%	2%	33%	5%	−5%	1%

is negative in Table 4, Equation (4)), though this change is statistically insignificant.

The elasticity on vertical integration in 1982 ($\nu 2$) is positive and significant, and in 1972 ($\nu 1$) it is also positive but insignificant. This is contrary to the expectations of the focused factory literature that argues in favor of focusing by process. Hypothesis H3a, that reducing vertical integration will improve productivity, is rejected. However, the positive effect of vertical integration on productivity is diminishing over time ($\nu 2 - \nu 1$ is negative in Table 4, Equation (4)), which is consistent with hypothesis H3b, but the change is not statistically significant.

The elasticity on supervisory overhead in 1972, ($\mu 1$), has the expected negative sign and is significant; the elasticity in 1982, ($\mu 2$), also is negative, but it is not significant. This supports our hypothesis H4 that reducing supervisory overhead in the plant increases productivity.

The coefficients in 1972 and 1982 on the control variable capacity utilization ($\rho 2$ and $\rho 1$) are positive as expected and significant. The elasticities on the factor inputs (that is, capital, labor, and materials) all have the expected sign and most are statistically significant. This increases our confidence in the validity of the model.

To test whether the relationship between plant size and productivity is different for different plant size categories we specify a model with dummy variables which allows the coefficients for plant size to be different for each of the four plant size categories. An *F*-test comparing the unrestricted model (with dummy variables for plant size categories on the variable plant size) to the restricted model fails to reject the hypothesis that the coefficients for plant size are stable across plant size categories. Thus there is no support for our hypothesis H1b that the relationship between plant size and productivity is more negative for larger plants than for smaller plants.

Descriptive Trends for Two-digit Industries

The median changes over the period 1972–1982 in plant characteristics in twenty two-digit SIC industries are reported in Table 5. Average plant size declined in only three industry groups corresponding to Tobacco, Wood Products, and Printing.

Regression Results Within Two-digit Industries

An *F*-test of the restricted versus the unrestricted model rejects the hypothesis that the relationship between productivity and plant size and focus is stable across two-digit SIC industry groups. The regression model represented by Equation (4) is estimated within nineteen two-digit SIC industries and the results are reported in Table 6. As can be seen from the higher values of R^2 in Table 6, the regression estimates within two-digit SIC industry groups fit the data better than the regressions estimated in the pooled model reported in Tables 4.

Five industry groups: textiles, chemicals, glass, fabricated metals, and machinery, have positive and significant plant size elasticities for 1982, suggesting that economies of scale have not yet been exhausted in these industry groups. Consistent with this result on scale economies, the average plant size in all these industries actually increased during the period 1972–1982 (see Table 5). Furniture and leather are the only industry groups that have negative and significant plant size elasticities for 1982; in these two industry groups, we find support for hypothesis H1a that reducing plant size improves productivity. This is consistent with our intuition (based on casual observation) that the furniture and leather industries are characterized by high labor intensity, low automation and technology, high product variety, and in the case of furniture also high transportation costs. However, our results are not congruent with firm actions; the average plant size increased during 1972–1982 in these industries (see Table 6), albeit at a relatively slow rate of 9% in leather and 11% in furniture.

There are significant decreases in the elasticity of plant size over time ($\delta2 - \delta1$) in the plastics industry; hypothesis H1c that economies of scale are declining over time is supported in only this industry. On the other hand, the paper and fabricated metals industries have statistically significant increases over time in returns to scale. Carlsson (1989) speculated that there would be improvements in productivity for small and medium scale production within engineering/metalworking industries such as fabricated metals, machinery, electrical machinery, transportation, and measurement instruments. We find returns to scale diminishing over time in only two of these five industries: electrical machinery and measurement instruments.

The elasticity on product specialization, $\tau2$, is significant with the hypothesized positive sign in refining, glass, electrical machinery, and transportation industries. Plants in these industries that reduce the variety of products, and presumably reduce the confusion associated with producing many products in one facility, gain in productivity, which is consistent with hypothesis H2. The specialization elasticity is significant with a negative sign in the printing and plastics industries; this implies that there are potential economies of scope available in these industries.

The elasticity on vertical integration, $\nu2$, is significant with the expected negative sign in textiles, glass and fabricated metals industries. Consistent with hypothesis H3a, plants which reduce their vertical integration, and reduce the complexity of managing multiple processes, improve their productivity in these industries. In the food, wood products, furniture, paper, printing, chemicals, leather, primary metals, machinery, electric machinery, and miscellaneous industries the elasticity on vertical integration, $\nu2$, is positive and significant, contrary to our hypothesis H3a. In these industries, contrary to the focused factory argument, the benefits of vertical integration at the plant level outweigh the negative effects of process complexity.

The change in the elasticity on vertical integration ($\nu2 - \nu1$) is declining significantly in five industries and is negative but insignificant in eight. This is ample evidence supporting the argument that there is a trend towards diminishing benefits of vertical integration and is strong support for hypothesis H3b and the arguments put forth by Carlsson (1989) and Womack et al. (1990). The only significant positive coefficient is in the leather industry. Two of the statistically significant declines, fabricated metals and machinery, are within the engineering/metalworking industries cited by Carlsson (1989) for their declines in vertical integration. All five of the two-digit engineering industries, including transportation as predicted by Womack et al. (1990) have a diminishing relationship between productivity and vertical integration. The three other industries with statistically significant declines are chemicals, refining, and primary metals.

Table 6 Regression Results for Two-digit Sic Industries Based On Equation (6) (Coefficients)

	Plant Size		Supervisory Overhead		Vertical Integration		Specialization		
Industry	$\delta 2$	$(\delta 2 - \delta 1)$	$\mu 2$	$(\mu 2 - \mu 1)$	$\nu 2$	$(\nu 2 - \nu 1)$	$\tau 2$	$(\tau 2 - \tau 1)$	R^2
Food	−0.014	0.011	−0.297*	0.029	0.187**	0.024	−0.141	−0.187	0.756
Tobacco	–	–	–	–	–	–	–	–	–
Textiles	0.127**	−0.004	0.613~	0.341	−0.221**	−0.109	0.267	0.770**	0.802
Apparel	0.039	−0.001	0.009	0.157	−0.009	0.176	−0.197	−0.908**	0.810
Wood Prod.	0.007	0.019	−0.137	−0.107	0.306*	−0.005	−0.228	0.498	0.773
Furniture	−0.090**	−0.007	−0.824**	−0.453	0.666**	−0.675	0.081	0.786	0.917
Paper	0.045	0.021~	−0.504*	0.069	0.350**	0.216	−0.084	0.063	0.788
Printing	−0.033	−0.002	0.034	−0.008	0.569*	0.136	−1.153*	−0.756**	0.829
Chemicals	0.115**	−0.018	−0.198~	−0.260	0.365**	−0.193*	−0.119	−0.026	0.708
Refining	−0.013	−0.004	−0.783**	0.168	−0.054	−0.884*	401.47**	306.25**	0.999
Plastic	−0.123	−0.086*	1.439**	0.243	−1.011	0.907	−85.754*	−5.238*	0.986
Leather	−0.107*	−0.014	−0.029	−0.409	0.647*	0.542~	0.714	0.912	0.919
Glass	0.168**	−0.005	0.107	0.240	−0.512**	−0.222	1.016**	0.223	0.740
Prim. Metals	0.030	−0.016	−0.420~	0.644*	0.159**	−0.265**	−0.752	−0.498	0.800
Fab. Metals	0.120**	0.022~	−0.198	0.053	−0.614**	−0.753**	−0.047	−0.023	0.752
Machinery	0.057**	0.005	−0.289**	−0.072	0.388**	−0.320**	0.307	−0.512	0.786
Elec. Machin.	−0.033	−0.011	−0.262*	0.134	0.382**	−0.086	0.590*	−0.012	0.615
Transport.	0.005	0.008	−0.357**	0.226	−0.024	−0.281	0.885~	−0.470	0.939
Instrument	0.050	−0.015	−0.172	0.268	−0.330	−0.262	0.327	−0.088	0.646
Misc.	−0.012	−0.005	−0.151	0.026	0.496**	−0.051	0.048	−0.114	0.858

Two Tailed Tests:
** = *T*-statistic is significant at 99% confidence level.
* = *T*-statistic is significant at 95% confidence level.
~ = *T*-statistic is significant at 90% confidence level.

The elasticity on supervisory overhead is significant with the expected negative sign in eight industries: food, furniture, paper, refining, primary metals, machinery, electrical machinery, and transportation. This finding supports hypothesis H4 that a reducing supervisory overhead increases productivity. The coefficient on supervisory overhead is positive and significant in two industries: textiles and plastics.

Correlation Between Two-digit Industry Coefficients and Descriptive Trends

We now want to investigate the relationship between the actual change in average plant size in an industry and our estimate of scale economies in that industry. We divide industries into two groups based on whether average plant size in that industry is growing faster or slower than the median rate across all industries (which is 17.5%). We construct a table of the sign of the estimated elasticity for plant size on one dimension, and the actual plant size growth (relative to median rate) on the other dimension (see Table 7). Firms would be acting consistent with our model if they are in the upper left or lower right cells of Table 7. In general, the results in Table 7 are consistent with our model, particularly when only the significant coefficients are considered. The only exceptions are the textiles and the fabricated metals industries. Both have significant positive coefficients on plant size but the plants are growing less rapidly than the median rate, particularly in the case of textiles. This may be due to a lack of opportunities for domestic expansion of U.S. textile mills because of increased import penetration—the flip-side of the effect cited by Manne (1961) for rapidly growing industries. Though none of the coefficients in the upper right-hand

Table 7 Estimated Scale Economies Vs. Actual Change in Plant Size

	Output Elasticity of Plant Size ($\delta 2$)					
	Positive Coefficient (+)			Negative Coefficient (−)		
	Coefficient (+)	Industry Name	Growth Rates	Coefficient (−)	Industry Name	Growth Rates
Above	0.168**	Glass	31%	−0.014	Food	28%
Median	0.115**	Chemicals	44%	−0.013	Refining	58%
Growth	0.057**	Machinery	24%	−0.012	Miscellaneous	33%
Rate in Plant Size	0.050	Transportation	39%			
Below	0.127**	Textiles	2%	−0.123	Plastics	0%
Median	0.120**	Fabricated Metals	14%	−0.107*	Leather	9%
Growth	0.050	Instruments	13%	−0.090**	Furniture	11%
Rate in Plant Size	0.045	Paper	12%	−0.033	Electric Machinery	14%
	0.039	Apparel	15%	−0.033	Printing	−5%
	0.030	Primary Metals	14%			
	0.007	Wood Products	−10%			

Two Tailed Tests:
** = *T*-statistic is significant at 99% confidence level.
* = *T*-statistic is significant at 95% confidence level.
~ = *T*-statistic is significant at 90% confidence level.

corner is significant, firms in these industries (food, refining, and miscellaneous) should be wary about the potential for economies of scale if considering expansion or building a new large plant.

Conclusions

Citing anecdotes from a few firms including Litton, FMC, Westinghouse, Iron Age (1973) prophesied that "the big industrial plant may be going the way the big bands went." Contrary to that prophecy and other more recent business literature, plant size, on the average, increased from 1972 to 1982. However, the rate of this increase has been decreasing, and the larger plants grew in size at a slower rate than the smaller plants. Additional data from 1980 to 1984 show that the rate of growth slowed dramatically and even turned negative for some large plant size categories. The prophecy in Iron Age (1973) may yet come true! The growth rate of plant size varies substantially across the two-digit SIC industry groups, with declines in three out of 20 groups. Consistent with the prescriptions of Skinner (1974a), plants have become more focused on the product and process dimension as specialization and vertical integration have declined, though supervisory overhead has increased.

For the manufacturing sector in general, using a total factor productivity model, we find statistical evidence that plant size is positively associated with productivity. This undercuts the extreme view of the popular business press that the representative U.S. plant has grown too large in a mistaken search for economies of scale. However, the estimates also show that there has been a statistically significant decrease in the output elasticity of scale between 1972 and 1982. The benefits of scale are declining.

We find a positive relationship between product focus and productivity. We also find a positive relationship between vertical integration (at the plant level) and productivity, which is contrary to the argument for greater process focus. This is a surprising result given the consistent decline in vertical integration between 1972 and 1982. We find that in many industries there is a significant decline over time in the relationship between vertical integration and productivity. This is strong support for the arguments of Carlsson (1989), and observers of the automobile industry, who argue that vertical disintegration improves productivity (Womack et al. 1990). Finally, decreasing supervisory overhead improves productivity; this is consistent with the focused factory argument, as well as the more recent literature on lean manufacturing (Womack et al. 1990).

There are, of course, limitations in the data, methods and statistical means by which our results were determined. The benefit of comprehensive coverage of the population of U.S. manufacturing plants is also associated with demands for confidentiality and so the final data is only available in the aggregate form of size classes of plants. We have used these classes to represent tiny, small, medium, and large plants within each industry. Some information is lost in this aggregation and the available definitions of variables relating to focus, product focus in particular, are not always exactly what we would like. Manufacturing plants may have strategic objectives besides productivity such as flexibility, delivery performance, quality, reliability. It may be that focused factories (smaller plants) perform better than unfocused factories (larger plants) on these dimensions. A limitation of our research is that the total factor productivity model we use takes into account only the objective of improving productivity.[1]

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