

**The Effectiveness of State Technology
Incentives: Evidence from the
Machine Tool Industry
Executive Summary**

Sheila A. Martin

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**Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011**

Sheila A. Martin is senior economist, Research Triangle Institute Center for Economics Research.

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THE EFFECTIVENESS OF STATE TECHNOLOGY INCENTIVES: EVIDENCE FROM THE MACHINE TOOL INDUSTRY

Few economic issues have captured as much attention in recent years as the apparent decline in U.S. industrial competitiveness. Numerous studies prepared by various national commissions, policy organizations, and academics have documented industrial decline, uncovering its causes, and proposing remedies for U.S. industry. Most of the research has identified manufacturing as the industrial sector that has experienced the most serious erosion of cost and quality superiority.

Concerned with the future of manufacturing as a source of stable employment and economic activity, policy makers, particularly at the state level, have responded to the problems of manufacturing with a host of proposals for improving the productivity and efficiency of manufacturing. These widespread efforts have been launched without the benefit of a systematic study of the determinants of manufacturing efficiency, the effects of efficiency on survival, or the potential of public policy for improving both efficiency and survival. While some evaluation of productivity initiatives has been attempted, the recentness of the programs, the variety of their objectives and approaches, the complex relationships between policy and economic outcomes, the political nature of the evaluation process, and the limitations of firm-, plant-, and policy-specific data have limited the availability of careful analysis based on sound experimental methods (Feller 1988; Glasmeier 1990). Considering the fiscal crisis facing many state governments, an evaluation of development policies is needed to guide decisions on the funding and formulation of policies to accelerate economic growth through improvements in productivity.

With a view toward building a stronger basis for such public policy decisions, researchers at the Center for Agricultural and Rural Development set out to study some essential questions about the efficiency of manufacturing. Using the machine tool industry

from 1972 to 1987 as an example, the study, which is summarized here, examines determinants of manufacturing efficiency and plant survival, and the effectiveness of public policy. Manufacturing or industrial extension programs, which provide a variety of technical and managerial assistance, were chosen for policy evaluation. The study suggests public and private responses to the productivity crisis that might improve the competitiveness of manufacturing for industries experiencing problems similar to those observed in the machine tool industry.

Background

The signs of a long-term trend of manufacturing output decline are clear. While manufacturing jobs represented 38 percent of employment in 1960, the share had dropped to 16.9 percent in 1991. This decline was the result of structural changes and not cyclical swings alone. Between 1985 and 1989, a period during which total employment expanded by 10.8 million, manufacturing employment grew by only 182 thousand—less than 2 percent of total employment growth (U.S. Bureau of Labor Statistics, *Monthly Labor Review*, various issues).

Productivity and Efficiency

Analyses of manufacturing decline and competitiveness frequently focus on one of two measures of the relationship between inputs and output. While much of the literature has focused on declining productivity (see, for example, Baily and Chakrabarti 1988), other studies focus on technical or engineering efficiency. Changes in total factor productivity are measured by calculating the growth of output and subtracting an average of the growth in all inputs, weighted by the importance of those inputs in the production process. Technical efficiency is closely related to the measurement of total factor productivity, but there are important differences. Technical efficiency measures the abilities of plants relative to the most productive plant, and provides a finer disaggregation of the components of economic growth than that obtainable by the calculation of total factor productivity.

Technical efficiency is used in this study to compare the performance of different plants. Intuitively, technical efficiency is the degree to which the greatest amount of output possible is produced from a given input vector, or equivalently, the degree to which as few inputs as possible are used to produce a given output level. A plant that is not technically efficient relative to other plants could lower its costs by using more efficient production methods. This methodology compares the efficiency of each plant to that of the most efficient plant; that is, to the plant that produces the highest level of output given the inputs it uses.

The Machine Tool Industry

This study focuses on efficiency and survival of plants in the machine tool industry. The machine tool industry is composed of two segments, identified by four-digit Standard Industrial Classification (SIC) codes: 3541 (metal-cutting machine tools) and 3542 (metal-forming machine tools). While the metal-cutting tool firms are the core of the industry, both segments are composed of many small firms, and few large producers exist in the industry. However, the range of customers of metal-forming tools is much more limited. While metal-cutting tools are used by thousands of machine shops and metal product manufacturers, demand for metal-forming tools comes mainly from automobile and appliance manufacturers that use sheet metal in production (Baily and Chakrabarti 1988). Hence, the fate of the industry is strongly tied to the fate of durable goods manufacturing.

Demand for machine tools is remarkably cyclical. Because the industry uses highly skilled labor with skills that are firm-specific, managers often hesitate to fire workers during slack times. Capacity utilization is also highly volatile. This is likely to cause a decrease in efficiency during recessions. These conditions are fairly uniform in both the metal-cutting and metal-forming segments of the machine tool industry.

The machine tool industry was chosen for several reasons. First, it has suffered from severe import penetration, as well as failure to develop an export market. Second, machine tools hold a critical and strategic position in the competitiveness and productivity of

manufacturing overall. Finally, industrial decline has prompted several other studies of the industry that provide a useful background for the present plant-level analysis, which utilizes data not previously available for the investigation of efficiency.

Industrial Decline and Import Penetration. The number of plants in the machine tool industry has fallen dramatically since 1963, as has total employment in the industry. Imports as a percentage of domestic consumption climbed from 4.7 percent in 1963 to 32.1 percent in 1987, giving an indication that industrial decline is due to loss of market share to imports.

Strategic Importance. Machine tools are used in the transformation of metal into components that are then assembled either into end products or into capital goods that manufacture end products. The manufacture of almost every product involves machine tools at some point in the production process. Direct access to the most efficient machine tools is important for domestic competitiveness in manufacturing.

There is evidence to suggest that the development of an efficient domestic machine tool industry may be required to secure access to the best and most efficient tools at a competitive price. American automobile manufacturers, attempting to buy the most efficient and accurate machine tools from foreign machine tool builders, often have found that their access to state-of-the-art tools lags access by their competitors by several years (March 1989). While it would seem impossible for this to occur in a perfectly competitive machine tool market, under less than perfectly competitive conditions, foreign firms may attempt to block American acquisition of the best machine tools in order to raise general manufacturing costs in the United States. In the tradition of Japanese Kieretsu, this seems a realistic scenario. If U.S. manufacturers cannot obtain leading-edge technology tools from American, German, Korean, or other machine tool manufacturers, then the Japanese may succeed in decreasing relative efficiency and raising the relative production costs of U.S. machine tool users.

Previous Studies. Decline of the machine tool industry has precipitated research into its causes. A comprehensive analysis by the MIT Commission on Industrial Productivity (March 1989) has pointed to the lack of technical assistance for small and medium sized manufacturers

as a barrier to innovation. Technical assistance of the type provided by industrial extension programs was recommended as a method for disseminating information about the comparative performance of new equipment and for encouraging machine tool manufacturers to invest in new technology. This study builds upon that work by assessing the technical efficiency of the machine tool industry, by investigating relationships between efficiency and plant characteristics, and by scrutinizing the effectiveness of industrial extension programs in filling the need for information.

Manufacturing Extension

A period of accelerated growth of state programs focusing on industrial productivity and technology began during the late 1970s and continued through the mid-1980s. Increased state activism in economic development policy during this period occurred as a response to two important developments. First, the federal government severely curtailed its economic development activities targeted to states and local areas (John 1988). Second, the need for industrial restructuring became evident to many states during the recession of 1981-82. Casual observation of the success of states such as Massachusetts, California, and North Carolina promoted the popularity of technology development and application policies and encouraged states to nurture technology-based businesses. Technology and productivity initiatives developed in the 1980s have been almost exclusively state-funded.

State funded technology policies generally affect the operation of client firms in one of three ways: by introducing the firm to information about best-practice technology, thereby enabling the firm to achieve a higher level of efficiency; by taking advantage of agglomeration economies or economies of scale that exist in some types of manufacturing; and indirectly, by promoting research that advances the frontier technology, thereby increasing the highest attainable level of productivity. The programs most likely to have a direct and immediate impact on the efficiency and productivity of manufacturing plants are the first type, which include technology transfer, manufacturing extension, worker training, technical assistance, and

managerial assistance. Because most of these functions are performed by industrial or manufacturing extension programs, and because several manufacturing extension programs have been in place for many years, this study focuses on these programs and their impact on efficiency, rather than attempting to evaluate programs that are less directly involved with the manufacturing process itself. The evaluation procedure focuses on plant-level responses to policy, and is well suited to the type of plant-level intervention typically provided by manufacturing extension services.

A survey by the National Governors' Association (Clarke and Dobson 1989) identified 43 manufacturing extension programs in 28 states. Most of these programs have been established since 1980, and almost one-half of the programs are administered by universities. The remainder are administered by state agencies, quasi-public organizations, community colleges, or private nonprofit organizations. The staffs of these organizations are usually engineers with industrial experience, often university faculty or graduate students, who provide technology assistance to small and medium-sized manufacturers. Direct services may include:

- Review of current or proposed manufacturing methods and processes;
- Productivity and quality assessments;
- Assistance with plant layout and operations;
- Advice on acquisition and implementation of equipment, especially computer systems;
- Assistance with total quality management programs, including statistical process control (SPC);
- Access to databases and other information resources; and
- Networking.

Indirect services (i.e., those for which referrals are made to other providers) often include technical data, research and development, and training. Further details regarding program characteristics can be found in Clarke and Dobson (1991).

Procedures

The analysis began with estimation of the technical efficiency of each segment of the machine tool industry over the period between 1972 and 1987. Statistical techniques were used to characterize the most efficient plants, and to compare each plant to the efficient standard. This methodology is referred to as technical efficiency analysis. Statistical analysis and visual inspection of the frontiers provided insight about the degree of technical inefficiency in the industry, and how it has changed over time.

The analysis explored several independent variables as determinants of efficiency: size, age, wage, ownership, and manufacturing extension. Simple correlation and regression analysis were used to describe the strength of these relationships.

Changes in efficiency over time can be explained by a combination of shifts in the most efficient technology and a change in the efficiency of plants below the frontier. In order to determine the components of the change, we compared changes in efficiency with overall shifts in the most efficient technology. This was done both by visual inspection and by calculating Malmquist indexes, which numerically separate changes in efficiency from shifts of the technological frontier.

New technology is responsible for a great deal of the improvement in productivity throughout the history of manufacturing. We explored the role of new technology in technical efficiency by calculating simple correlations between the number of relatively new technologies used in a plant and the plant's technical efficiency.

Finally, we examined the effect of manufacturing extension programs on the efficiency of machine tool plants. Two approaches were used. First, we searched for a relationship between technical efficiency and the availability of extension assistance. Availability was used as a proxy of actual assistance due to the lack of data regarding actual extension assistance on a plant-by-plant level. With the plant level data that were available, we examined changes in technical efficiency before and after direct intervention by extension agents.

Results in Brief

The machine tool industry has suffered from inefficiency over a number of years. It was expected that the examination of efficiency in the machine tool industry would uncover significant evidence of technical inefficiency. The industry's decline over the last 20 years has raised a number of questions about the causes of this decline, and inefficiency has been one of the widely discussed sources. Furthermore, studies of plant-level total factor productivity have revealed heterogeneity among plants in a wide range of industries (e.g., Baily et al. 1992). Since technical efficiency is a relative measure, it is positively associated with industrial heterogeneity with respect to productivity.

Ample evidence was found to verify that many machine tool plants were technically inefficient. Statistical analysis revealed a significant difference between the best and worst firms. Visual evidence was provided by comparing the best practice with average production functions for each industry and finding significant divergence. These comparisons also provided evidence of the relative average efficiencies of the two industries. Metal-cutting machine tools exhibited more inefficiency.

Even the best machine tool plants suffer from efficiency problems. The parameters of the frontier production function were unstable over time, indicating that best practice technology in the machine tool industry had shifted. Once the data were partitioned appropriately and separate frontiers estimated for each time period, the reason for this instability became apparent. Best practice technology had actually regressed over time, particularly in the metal-cutting machine tool segment. Although plots of the average efficiency scores by year and industry showed substantial progress for plants in the metal-cutting machine tool industry, evidence from plots of the production function aroused suspicion that this was at least partially a result of the frontier shifting backward toward the plants, rather than the plants moving toward the frontier.

Efficiency problems are associated with problems of capacity utilization. Decomposition of the Malmquist indexes confirmed the casual observation that frontiers had shifted backward. The

most plausible explanation for this result is that all plants, even the most efficient plants in the industry, suffered from low capacity utilization rates. In fact, failure to employ resources to their full capacity is most likely driving many of the results of the analysis. For example, the finding that large plants are more efficient than small ones probably reflects a large, diversified plant's ability to shift capital and labor to alternative uses when a particular segment of their business is slow. While capacity utilization was low for both industries, regression of the best practice technology was not nearly as severe in the metal-forming machine tool industry as it was in the metal-cutting machine tool industry. This result is driven by the homogeneity of plants in the metal-forming machine tool industry. Changes in the efficiency of plants defining the frontier did not drastically alter the placement of the frontier.

Large, high-wage plants are more efficient. A number of procedures were performed to determine the association between plant characteristics and technical efficiency. These results showed that efficiency is associated with large plants, plants that pay high wages, and plants that reside in states with industrial extension programs. The advantage of size is not surprising, since larger plants often are able to specialize production and nonproduction activities, hire workers with specialized skills, and cover the fixed costs of product and process development over a larger scale of output. Wage probably acted as a proxy for worker skill, but the effect of wage was not significant in metal-forming machine tools. This may be due to less intense use of advanced technology demonstrated in this industry.

Plants residing in states with manufacturing extension programs are more efficient. The positive result for industrial extension was interpreted with the proviso that the variable used to indicate access to extension was a poor proxy for actual intervention. However, the access variable does reflect improvements in the information available to machine tool manufacturers, even when direct intervention does not occur.

Efficiency contributes to plant survival. Estimates of the probability of survival in the machine tool industry showed that efficiency contributed to survival probability, as did size and lower wages. Survival of plants was difficult to predict and model for metal forming

machine tools. This is probably a reflection of the importance of variables not included in the data set that might be important to the survival of a plant. These variables might include worker and manager skills and access to capital. While wages probably reflect worker skill to some extent, this relationship is imperfect and a more direct measure of skill would probably improve our ability to predict survival.

The machine tool industry lags other industries in use of new manufacturing technologies.

There was only weak evidence that plants using a greater number of advanced technologies were more efficient. However, patterns of technology use in the machine tool industry did reveal that this industry generally lagged a number of other industries in the adoption of advanced technologies. This is especially relevant to the issue of international competitiveness, since Japanese and German machine tool makers are competing successfully with U.S. manufacturers for markets for sophisticated manufacturing technologies, including flexible manufacturing systems and machining centers. One strategy international machine tool manufacturers have used to develop this market is to experiment with these technologies on the floors of their own plants.

Few conclusions can be drawn about the direct effects of manufacturing extension. No conclusions could be drawn about the impact of intervention by industrial extension on the efficiency of plants in the machine tool industry. The main result of this analysis was that low efficiency plants are more likely to seek the advice of the extension services, or are targeted by the service providers. A more complete analysis of the effect of intervention requires substantial effort for gathering data from individual clients of extension services. Since many of these services have only recently become operational, a well-conceived plan for systematically collecting these data would contribute a great deal to future evaluation efforts.

Recommendations

The results enumerated here suggest policy actions for improving efficiency and survival in the machine tool industry.

Improve market share . By far, the most pressing problem facing the machine tool manufacturers in the United States is that their capital stock is not being fully employed. This is largely a function of severely cyclic demand. When manufacturers are adding to their capacity during periods of peak economic activity, machine tool builders have added to their own capacity. As the business cycle slows, plant and equipment are used less intensively as orders for new machine tools tumble. The only way to solve this problem is to recapture markets lost to the foreign machine tool manufacturers and to develop new international markets. International markets are especially important for smoothing the cyclic nature of the industry without accumulating backlogs that force customers to other suppliers for prompt service.

One way to build markets is to communicate more effectively with potential customers. Users of machine tools in the United States have expressed dissatisfaction with the quality of the tools available from domestic producers. Results from this study suggest that manufacturing extension might be an effective vehicle through which communication might develop between users and suppliers. These strategies might include encouraging interaction between users and suppliers with technology workshops, maintaining directories of manufacturers and referral services, and disseminating information regarding new product technology that might encourage customers to replace existing machine tools.

In order for market strategies to succeed, U.S. machine tool manufacturers must be willing to listen closely and invest in "relationship specific capital," developing the manufacturing technology that will meet the specific needs of a particular user or industry. This is a strategy that entails long-term risk, which U.S. manufacturers have often avoided. This strategy has been successful for the Japanese, but their machine tool manufacturers were backed by the significant resources of the Ministry of International Trade and Industry (MITI). MITI's investment in the development of the Japanese machine tool industry has been substantial (March 1989). In order to encourage U.S. machine tool manufacturers to invest in new capital and develop new products, similar risk sharing arrangements might be needed.

Encourage cooperation among manufacturers to capture size and agglomeration advantages.

Because so many machine tool manufacturers are small, family owned and operated businesses, few can benefit from the advantages of large size that were demonstrated by the relationship between size and efficiency. However, groups of firms may be able to take advantage of economies of scale and scope by working together to develop pools of skilled workers, developing worker training programs, specializing and developing joint marketing plans, or launching international marketing agreements. Because these activities are expensive and pay benefits only in the long term, individual plants and firms often cannot afford to undertake these investments alone. However, as part of a manufacturing association, it may be possible for small plants to gain the benefits of these investments.

Enrich worker skills to improve efficiency, and encourage more young engineers to focus on the problems of manufacturing. Plants with higher average production worker wages are more productive, and there is evidence that wage is closely tied to skill. Use of advanced technologies is also related to the average skill of workers, and advanced technology leads to greater efficiency. Plants hiring skilled workers who know how to use advanced technology are likely to keep up with technical frontiers more effectively than other plants. The most advanced equipment is often the most flexible, so hiring labor that is able to use it effectively gives plants the flexibility to manufacture alternative products, such as machine tool accessories and parts, during periods in which orders for new machine tools are low.

Advocate manufacturing extension programs to the industry as a vehicle for improving plant efficiency. While the evidence of efficiency improvement due to manufacturing extension is still sketchy, there is some reason to believe that plants are more efficient when they are provided assistance in making technical decisions, especially when they are considering investment in new plants and machinery. This type of assistance can shorten the time of adjustment to new technologies.

Install systems of data collection for manufacturing and industrial extension programs. Policy decisions will be better guided if more information is available about the direct impact of

assistance on the efficiency, productivity, profitability, and survival of plants before and after they seek assistance from extension programs. A thorough evaluation of manufacturing programs will only be possible after such systems have been in place long enough to compile a convincing body of data.

Finally, the machine tool industry must find ways to improve performance for its existing customers. However, having the capacity to deliver orders quickly during busy times could require a capital buildup that can drag down efficiency. Achieving the flexibility to manufacture alternative products, such as machine tool accessories and parts, might be the key to this strategy. Perhaps the machine tool manufacturers should consider a stronger adoption of the most flexible manufacturing technologies from their own industry.

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