Comparative Factory Productivity

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Why do some factories outperform other factories? What is it about what the better performing factories do that results in greater productivity gains for them? Is their productivity gain tied to people motivation? Investment in new equipment? The adoption of MRP II (manufacturing resource planning) systems? Improvement in quality management? Focused factories? Just-In-Time manufacturing? Everybody, it seems, has an anecdote to support his own personal view of what contributes to productivity. The research summarized here was an effort to tie hard facts and numbers to the stories. Significantly, it was themes like quick throughput, low inventories, and high quality—all intimately related to Just-In-Time manufacturing—that shone through the results.

The Data

Two databases were developed expressly for this research. One was a mail survey of eight pages, created to gather 220 items of data. There were 265 plants in diverse industries nationwide that responded. These were mainly large plants, many belonging to sizeable parent corporations.

The second database was derived from intensive visits to 26 plants, 14 of which could be classified as computer plants and 12 of which could be classified as vehicles plants (fabrication and assembly of auto/truck/farm vehicles, or their components). Detailed information on the productivity performance of these plants during the last five years was collected as well as time series information on a variety of plant characteristics.

This type of data collection was selected to promote an objective and generalizable set of results. Regression analysis was the statistical tool used to analyze the data. Fortunately, the results from both data sets are quite consistent with one another, and thus I am increasingly confident that these results have general application.

Productivity, unfortunately, has many different definitions. This fact complicates any study of it. However, as this study focused primarily on changes in productivity and not absolute levels of productivity, the exact definition of productivity is not as important as its consistent measurement over time.

The plants responding to the mail survey answered several questions about their productivity measures. The first, and probably the "hardest" single quantitative measure, asked for the rate of change of the plant's measured labor productivity. A follow-up question asked for the rate of change of any more general productivity measure, if any was used. Three other questions asked each plant for more qualitative measures: 1) self-ranking within its parent company, 2) self-ranking within its industry, and 3) identifying whether productivity had quickened or slowed over time.

The 26 plants that were visited provided their own measures of productivity and productivity gain. They also supplied information sufficient to calculate a total factory productivity index, which, although of debatable significance for line managers, at least corrects for some bias inherent in labor productivity measures and, thus, is of interest for a study such as this one.

The study's explanatory variables are numerous. With such detail from both the mail survey and the plant visit data, there was the opportunity to examine a host of possible forces acting on productivity. Fortunately, the diverse variables relating to process, product, management policy, investments, and the like, can be aggregated into categories that make considerable sense, such as quality, workforce policies, equipment investment, and the like.

Mail Survey Results

Tables in Figs. 1 and 2 summarize the results from both databases. Let's examine the first table, which summarizes the results from the mail survey. Across the top are the five measures of plant productivity that were investigated. It groups the particular variables found to be statistically significant into themes that correspond to various concepts about productivity advance. "Plus" signs indicate that the set of variables taken together "explain" an increase in productivity, while "minus" signs indicate that they are associated with a decrease in productivity. The more "plus" or "minus" signs, the more statistically significant the results and/or the more variables enter those various themes. Question marks are placed for those groups of variables for which there is conflicting information. N.A.'s are entered for those groups of varia-

bles which did not enter the regression in a statistically significant way and thus are not likely to have an effect one way or another on productivity.

It is interesting to compare how the results of the different regressions run. The dependent variables arrayed in Fig. 1 stretch from hard number values (labor productivity change and general productivity change) to fuzzy perceptions of productivity performance (rank-in-industry and rank-in-company). The differences in these results are both intriguing and plausible. Consider the results for each grouping of independent variables.

Throughput time and flow-related variables consistently show up as important in each of the regressions, except for the rank-in-industry one. There, a move toward job-shop flexibility is valued. In all of the other cases, the variables that argue for lower throughput time and a smoother production flow (better layouts, linking process segments) are the ones that achieve statistical significance.

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Similarly, the harder the dependent variable (measure of productivity gain), the more that elements of chaos and confusion in the factory (such as engineering changes, expediting, demand fluctuations) affect productivity adversely. On the other hand, at the fuzzier end of the spectrum, product complexity and the ability to expedite appear to be valued.

The materials management results dovetail with these throughput time and flow-related results. In general, they indicate that lower inventories, better vendor performance, and smoother production planning yield higher productivity gains. Only at the fuzzy end of the spectrum, that which favors complexity and expediting, are the short-term benefits of production control apparently of more value than the longer-term benefits of production planning, purchasing, and inventory control.

Productivity Measures
(Dependent Variables)

Explanatory Variable Category	Labor Productivity Gain	General Productivity Gain	Productivity Gain: Quickened or Slowed	Rank in Company	Rank in Industry
Faster throughput	++	+	+	+	
Lower inventories	++	++	NA	+	-
Better quality	+	+	++	NA	+++
Less confusion and chaos	+	+++	+	NA	
More worker participation, better communication	++	++	++	++	?
Hardware advance	NA	NA	+	+	++
Better product design, materials substitution	+	+	+	+	+
Factory focus	?	+	?	+	NA

Fig. 1. *Results from the mail survey data.*

Design, Quality Factors

Improved product designs also appear to augment productivity in a consistent fashion. Materials substitutions are clearly an important variable in several regressions. The results also support the view that the smoother the engineering and manufacturing interface, the higher the plant's productivity.

The quality-related results support the contention that quality and productivity complement one another. Attention to quality and its improvement appears to lead to productivity gain.

A couple of results are particularly intriguing. The quality variable that enters the labor productivity regression is machine up-time. Given the direct labor orientation of many definitions of labor productivity, this is quite understandable. Having machines running well consistently will naturally increase output per worker. The results also suggest that quality concerns are more of an issue within an industry than within a company (the results are strong for rank-in-industry but not rank-in-company regressions). This is quite plausible as well because quality is easier to assess and compare across companies within the same industry than across industries within the same company.

The workforce results, with some exceptions, are consistent with one another and with expectations. Worker and supervisor ideas are valued as are fewer labor grades, broader job content, more cross-training, and better workforce morale, effort, and involvement. Intriguingly, only for the rank-in-company regression does unionism attain significance, and that is understandable given the anti-union stances of many companies' managements. Unionism, while important to a plant's perception of its rank within its company, however, does not appear to be much related to other, "harder" measures of productivity performance.

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When it comes to hardware advance, however, the interpretation is more difficult. Except for a variable that values hard automation (and

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Productivity Measures
(Dependent Variables)

Explanatory Variable Category	Plants' Own Measures	Total Factor Productivity Index
Faster throughput	+	++
Lower inventories	+	+
Better quality	+	++
Less confusion and chaos	++	+
More worker participation, better communications	+	NA
Hardware advance	?	?
Better product design, materials substitution	NA	NA
Factory focus	+	NA

Fig. 2. *Results from the plant visit data.*

that is probably related to process industry productivity advance), only the rank-in-industry regression results support the importance of hardware advance. Investment in new plant and equipment does not appear to be that important an influence on productivity advance, at least over the short term.

Several results related to the "focused factory" notion are also difficult to interpret, because they conflict in their impact on productivity.

Plant Visit Results

A total of six different regressions were run using the data assembled from the plant visits. These six regressions fall into two major classes: one class uses the plant's own measures of productivity. The other class uses a total factor productivity index[1] that was constructed from plant-supplied data. Using each of these two classes of productivity measure, three regressions were run: one that explains the level of the productivity measure itself; one that explains the percent changes in that measure from quarter to quarter; and one that explains a standardized value of the level of productivity. This standardized value carries a mean of zero and a standard deviation of one and thus permits comparisons across plants. Statistically, the standardized measure is the most defensible of the lot and is thus worthy of special consideration. Fig. 2 presents the results from these plant visit regressions.

The explanatory variables indicate that the major themes of the study—throughput time reduction, improved quality, and low inventories—are borne out by the results. In particular, the most defensible regression, that using a standardized value of the plant's own measure productivity, indicates that the lower the throughput time, the greater the percentage of the process covered by control charts, and the higher the inventory turns, the more productive is the plant.

From a variety of angles, the results consistently underscore the importance of Just-In-Time (JIT) manufacturing concepts. The importance of throughput time reduction, lowering inventories, raising quality, and interacting well with engineering and design all tend to support the basic tenets of the JIT movement.

The other regressions in general support and embellish this finding. The more productive the factory, the less confusion, less vendor expediting, better quality, lower inventory, fewer engineering changes, and the more concern for layout. While there are some perplexing results, namely those involving investment and in-plant expediting, the plant visit results do confirm many of the findings of the mail survey.

Interpreting the Results

From a variety of angles, the results consistently underscore the importance of Just-In-Time (JIT) manufacturing concepts. The importance of throughput time reduction, lowering inventories, raising quality, and interacting well with engineering and design all tend to support the basic tenets of the JIT movement. The study, of course, was not designed to explore just JIT issues; it was more general than that. Therein may lie its value, because from a host of possible influences on productivity, it was JIT-related policies that had the most effect on productivity.

Currently, I am on leave at IMEDE in Switzerland pursuing, via a mail survey, the same kind of information as I collected in the United States. Naturally, I would relish results that supported these from the United States, because that would be even more evidence to support the universality of Just-In-Time. I hope to have the European results analyzed by the summer of 1987, upon my return to the United States.

[1]The total factor productivity index is essentially an index of the value added by the plant, divided by the full labor costs for all employees of the plant, and an estimate of the "services" derived from the plant, equipment, and inventories at the facility. As such, it is a measure that is not biased toward capital-for-labor substitution.

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