MANUFACTURING MANAGEMENT QUALITY AND FACTORY PERFORMANCE

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Abstract

Recent studies on the use of Total Quality Management (TQM) tools in manufacturing management have produced mixed evidence of their performance benefits. This study builds on the resource approach, the manufacturing strategy literature and the process reengineering literature to develop a model of *manufacturing management quality*. The latter is defined as a combination of the six quality dimensions, delegation and integration supported by participation, process measurement, communication, and employee development. Management quality applied across the key business processes yields process improvement as an outcome. An improvement track record, in turn, drives factory growth.

We find empirical evidence for this model, based on data from two separate data sets:

- Higher manufacturing management quality leads to higher continuous improvement in the key manufacturing processes, which in turn leads to higher volume growth for the plant.
- We find support for the resource-based view of the firm: manufacturing management quality offers competitive advantage because its six dimensions are characterized by resource dependence and time compression diseconomies, which makes management quality difficult to imitate.
- Manufacturing management quality is found to be higher in the automotive and electronics industries than in other sectors. This provides evidence that even imperfectly imitable management practices diffuse sooner or later, first within and then across industries. No competitive advantage lives forever.
- There are differences in growth drivers by economic region. In Japan, most profitability leverage derives from improvements in new product introduction into the plant, and in the US and Europe from new product development. Manufacturing improvements are important across all three regions.

Key words: TQM, competitive advantage, resource theory, manufacturing management quality, resource connectedness.

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1. INTRODUCTION

Manufacturing strategy refers to two sets of decisions that contribute to competitive advantage: (1) defining the *mission* of the manufacturing function (the "manufacturing task", Skinner 1969), and (2) a pattern of *consistent choices* concerning "bricks and mortar" (facilities, technologies, and capacity) and "infrastructure" (organization, quality methods, and workforce policies) in order to accomplish this mission (Skinner 1969, Hayes *et al.* 1988, Miller and Roth 1994). A major question in strategy research focuses on the way in which manufacturing strategy brings competitive advantage.

Porter (1980, 1996) proposed that competitive advantage rests on *uniqueness*. The resource-based view of the firm holds that resources, or any tangible or intangible asset tied semi-permanently to the firm, can provide a competitive advantage, provided it is imperfectly imitable (Wernerfelt 1984, Rumelt 1984). It has been demonstrated empirically in strategic management literature that internal resources play an important role in determining a firm's success, possibly to a greater extent than industry membership or market share (e.g., Rumelt 1991, Powell 1996). Resource heterogeneity among firms *combined with* imperfect imitability allows for the persistence of equilibria in which competitors can earn dramatically different rates of return. Powell (1995) compresses Rumelt's (1984) ten "isolating mechanisms" to five: (1) time compression diseconomies (long lead time to make the resource functional); (2) historical uniqueness (origination under unique circumstances); (3) resource connectedness (success depends on the presence of complementing resources); (4) causal ambiguity (the causal link between the resource and success is unintelligible to others); and (5) social complexity (the resource builds on social phenomena too complex to manage).

However, it has not yet been shown operationally what these firm-specific resources are. A number of general factors have been proposed, such as culture (e.g., Fiol 1991), or know-how as a system of skills, technical and managerial systems, and values (e.g., Leonard-Barton 1992). The manufacturing strategy literature has offered a specific factor, namely the ability of identifying correct trade-offs in a given environment and proactively aligning organization and programs with these trade-offs (e.g., Skinner 1969, Schonberger 1982, Swamidass and Newell 1987, Powell 1992, Tunälv 1992, Ward *et al.* 1995). However, the causal relationship between manufacturing strategy and performance remains ambiguous (Miller and Roth 1994).

During the decade of about 1985 to 1995, Total Quality Management (TQM) was seen as a powerful set of programs to improve a firm's performance, but has since declined in popular attention (see, e.g., Powell 1995, De Meyer 1996). TQM is an integrated management philosophy emphasizing quality for the customer through the reduction of waste, training, leadership with constancy of purpose, stable processes that are in (statistical) control, and a continuous emphasis on improvement (e.g., Walton 1986, Juran 1992, Ross 1993). The empirical evidence, however, of the benefit of TQM programs is mixed (e.g., De Meyer and Ferdows 1990, Schmenner 1991, Lawler *et al.* 1992).

Ittner and Larcker (1997) define five 'higher level' TQM constructs, which they refer to as "process management attributes": process focus, human resource (HR) practices, information utilization, supply chain relations, and organizational commitment. They find that their constructs have limited influence on financial performance and suggest that these constructs may represent lower-level "enablers" required for *other* process management techniques in order to be successful (p. 528).

Powell (1995) concludes that TQM *programs* (such as SPC, benchmarking, or continuous improvement programs) represent imitable tools. Only three behavioral, tacit and intangible resources seem non-imitable, namely top management commitment, an open culture, and empowerment. Powell (1995) sees, therefore, only these as true sources of sustainable advantage, independent of the implementation of formal TQM tools. However, the overall evidence remains weak. Powell (1996) states that "the resource-based view remains essentially theoretical, and would benefit from a deeper empirical base to support its claims."

A complementary view of manufacturing strategy has been offered by the literature on operations management and business process reengineering (BPR), which has brought a *focus on processes* to the debate (e.g., Blackburn 1991, Hammer and Champy 1993, Davenport 1993, Loch 1998). This literature has proposed that superior performance can be achieved by changing the structure of a small number of key business processes, defined as an ordering of work activities in space and time, with a beginning and end, and clearly defined inputs and (customer-oriented) outputs (Davenport 1993, 5). The differences between BPR and TQM are a more explicit focus on processes and an emphasis on "radical" rather than continuous changes, but the two views are compatible and complementary (see Cole 1993 and Hammer 1996).

The BPR literature has produced a substantial amount of anecdotal evidence that processes offer a great potential of strategic performance improvement, which is difficult to imitate due to culture, incentives, knowledge, and existing systems (e.g., Stalk 1988, Blackburn 1991, Hammer 1996).[1] Consistent with the resource-based view of the firm, they observe that BPR loses its strategic competitive advantage after a time, when "best practices" diffuse through the competing firms and are no longer unique (e.g., Stalk and Webber 1993, Porter 1996). However, one weakness of the BPR literature is a lack of systematic empirical studies.

The present paper makes a contribution to this lack of empirical identification of advantage-generating resources in manufacturing strategy. Clark (1996) argues in a conceptual article that JIT, TQM and continuous improvement are not simply new techniques, but, taken together, they represent a new conceptualization of the manufacturing system. The present article builds on Clark (1996) and also Powell (1995) in arguing that TQM produces competitive advantage if applied as an integrated set of *management practices* rather than as a set of isolated improvement programs. Our contribution comprises three parts. First, we combine the manufacturing strategy studies and the BPR approach in specifying a *framework of manufacturing management quality* defined at the process level in the factory, with six management quality dimensions driving the performance of three key operational processes. Second, we empirically demonstrate that manufacturing management quality in our framework leads to process improvement which, in turn,

[1] In practical applications, BPR has often been used as a pure cost cutting tool, a narrow view that has not been supported by its proponents.

drives factory performance (measured as volume growth at the factory level, and profitability growth at the business unit level). Third, we provide evidence that *resource connectedness* is one source of non-imitability, that is, the dimensions of management quality must be applied consistently together in order to generate the full benefit. This is complemented by anecdotal evidence from the subset of factories we visited. They confirm that establishing management quality takes considerable time (3-4 years), so time compression diseconomies also seem to contribute to non-imitability.

Our empirical analysis is based on the INSEAD Best Factory Survey (BFS) 1997 in France and Germany, which we designed to test our manufacturing management quality framework at the plant level. In addition, we confirm some of the key findings on a second data set, the Manufacturing Futures Survey (MFS 1996). This data set was not designed specifically for our framework, but it allowed us to measure the most important constructs at the business unit level, whereby it provided us with additional validation of our results.

2. A MODEL OF MANUFACTURING MANAGEMENT QUALITY

This section develops a model of *manufacturing management quality*, building on the manufacturing strategy, TQM and BPR literatures. Consistent with the BPR view, the model situates the plant at the intersection of three basic business processes (Figure 1). First, the *supply chain process* is concerned with the execution of current business, comprising the flow of goods and services from suppliers through the factory and its delivery channels to customers, as well as its associated information flows. For the supply chain to be managed as one process, performance information must be shared throughout the chain, and goals of the separate links in the chain must be consistent.

The second basic process is the *strategy deployment process*, namely the deployment of a consistent set of priorities and targets for the plant, in line with the manufacturing strategy. At the same time, to achieve enhanced competitiveness, this process needs to build on initiatives from the factory floor which leverage new capabilities developed there. Strategy deployment is necessary in order to create common goals, attain clarity wih regard to the trade-offs and choices, to create fit across the different manufacturing activities (Porter 1996), to implement the manufacturing strategy at every level of the plant, and, at the same time, to motivate initiatives from all employees to contribute to, or even change, the adopted strategy.

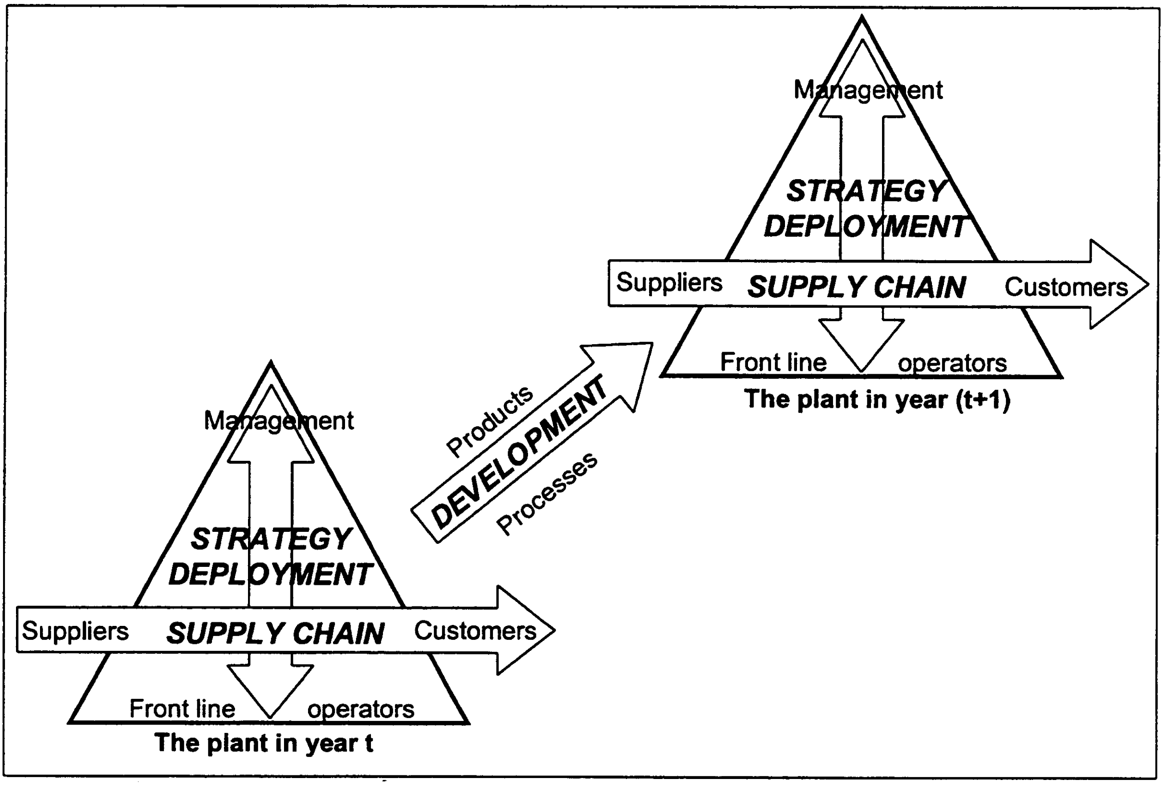

Figure 1: The Plant at the Intersection of Three Business Processes

Third, the future performance of the plant rests largely on *product and process development*, which is concerned chiefly with the creation and delivery of future business. The factory plays an important part in this business process in two ways: First, its capabilities constrain the possible product and process designs, and second, design heavily influences the factory's cost structure (e.g., Wheelwright and Clark 1992). The interface between the plant and new product development is the volume ramp-up of new products, the quality and ease of which is determined by the cooperation between the plant and the R&D unit of the enterprise.[2]

We are now in a position to apply the management practices from the extant literature to these three business processes. We define *manufacturing management quality* through the six dimensions described below (Figure 2).

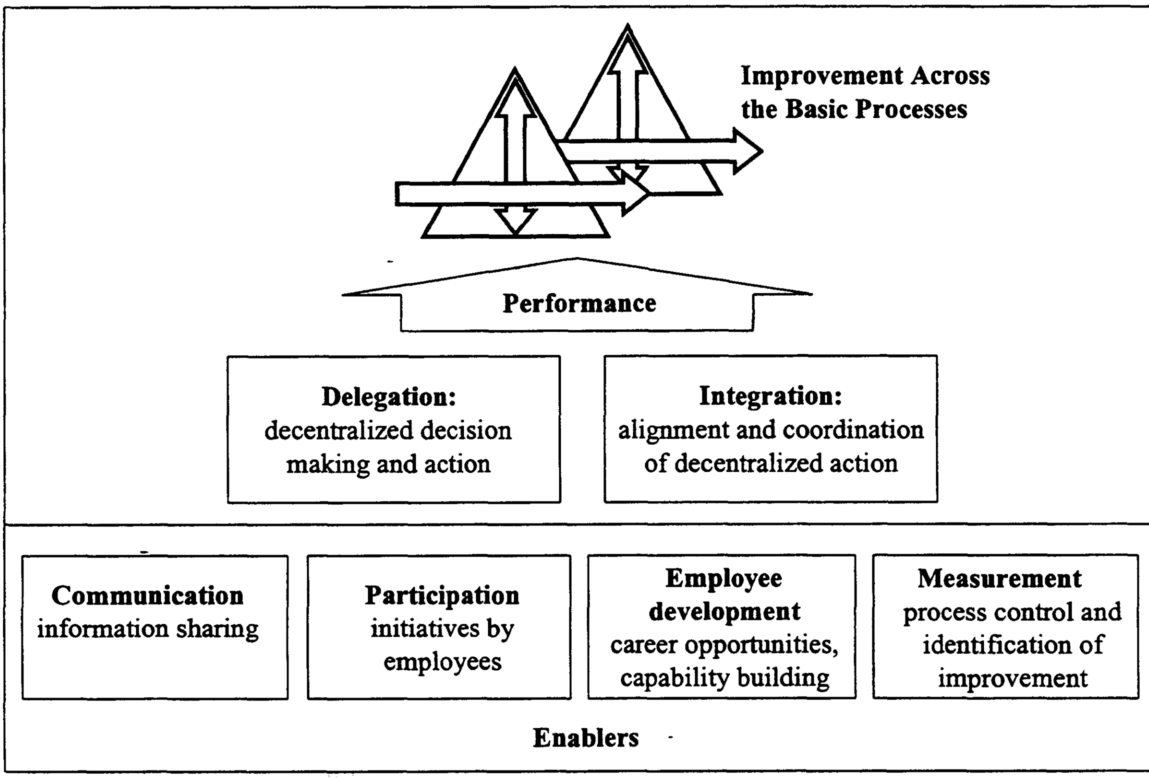

Figure 2: Dimensions of Manufacturing Management Quality

The terms "delegation" and "integration" refer to the classic organizational concepts of decentralization and integration introduced by Lawrence and Lorsch (1967). Today, unlike in the past, a factory is often characterized by complex and capital-intensive technology, and the need for faster response to changes in the competitive environment. It can no longer, therefore, be run in a traditional command-and-control mode. Management must increasingly *delegate* decisions to the various levels where the detailed knowledge of the manufacturing processes resides.

[2] Note that we implicitly include knowledge creation in product and process development. Based on informal discussions on knowledge-building activities in the visited plants, we have the impression that even the best factories perform very few separate, formalized, knowledge-building activities. This ongoing research is to be included in the next round of the survey.

Delegation implies decentralized action and decision-making power. Powell (1995) and Ittner and Larcker (1997) refer to it as "empowerment".

Decentralized action necessitates *integration* in order to ensure the alignment of common goals within the plant *and* across the business processes, of which the plant is only a part. We operationalize integration by focusing on the three basic processes. Horizontal integration connects the plant with suppliers and customers along the supply chain, which is vital for achieving fast response times, high quality levels, and competitive costs. Vertical integration applies to the strategy deployment process, including consistent sub-goals for all organizational sub-units, priorities and responsibilities. Temporal integration of the plant, with the new product development process, reduces time-to-market and improves manufacturability.

Delegation and integration must be supported by four *enablers*. *Communication* is necessary to both establish an open culture (Powell 1995) and to coordinate, that is, to equip empowered employees with the necessary understanding in order to make decisions that are consistent with the overall goals of the plant. *Participation* refers to motivating employees to contribute initiatives that go beyond their narrow job descriptions. As a demonstration, one plant manager lamented that "employees who responsibly manage a $60,000 budget in their sports club at home 'turn off their brains' when they enter the locker-room at work." Ittner and Larcker (1997) refer to participation as "emphasis on non-financial and team-based performance measures [to foster] cooperation." *Employee development* refers to continuous training as well as the existence of career paths for employees to advance to broader tasks and responsibility. Finally, *measurement* is the systematic tracking of qualitative and quantitative measures of process performance and its drivers, providing feedback and the understanding of where to best target improvements.

Figure 3 compares our six dimensions of manufacturing management quality to Powell (1995) and Ittner and Larcker (1997), the two studies that also view TQM techniques broadly as management practices, and which are thus most closely related to ours. Figure 3 shows a broad consistency among the constructs identified.

One key characteristic of our model, which differentiates it from the other two studies in Figure 3, is that we view *process improvement as a result* of manufacturing management quality rather than as a separate "program" in parallel with the other management practices. That is, we believe that improvement is not a program that can be implemented in isolation, but manufacturing management quality produces the feedback and dynamics in a factory that *lead to* improvement.

Present Article: Manufacturing Management Quality	**Powell's (1995) 12 TQM Principles**	**Ittner and Larcker's (1997) Process Management Techniques**
Delegation	Employee empowerment	HR:* empowerment, teamwork, delegation of improvement project authorization
Integration - strategy deployment - with supply chain - with product development	 Leadership, mission statement Customer and supplier relationships	 Customer- and supplier relationships, co-design
Communication	Open organization	
Participation		HR: rewards and incentives to elicit teamwork
Employee development	Training	HR: training
Measurement	Benchmarking, zero defect mentality, flexible manufacturing, measurement	Process focus (= SPC, value analysis), information utilization, benchmarking
Outcome: process improvement	Process improvement through process analysis	Organizational commitment to improvement

* HR refers to Ittner and Larcker's human resource management practices.

Figure 3: Comparison With Previous Frameworks

Process improvement, in turn, is at the root of *factory performance*, which we measure as *volume growth* of factory output. We believe that this is the most appropriate performance measure for a plant which is part of a larger network of factories in the same company. Volume growth is preferable to profitability as a performance measure because a multi-factory company usually has in place several filters between the plant and the level at which profitability is measured. Even in those cases where profitability is measured at the plant level, it is often distorted by the artificial transfer prices or similar manipulations. In addition, the better factories in a plant network will, in the medium term, win volume from the poorer performers.

Swamidass and Newell (1987) also used an aggregate form of growth in their study. They argue that 'growth provided a more rigorous test of performance than perhaps any other measure of performance that could have been devised' (*op. cit.* p. 516). They reject in particular a financial measure such as Return on Assets, because this favors factories which have not, in the recent past, invested in new facilities, and which may well be on their way to decline. Ward *et al.* (1995) also used (perceptual) measures of market share and sales growth.

3. HYPOTHESES

The complete model and the two key hypotheses are summarized in Figure 4. It states that the six dimensions of management quality drive improvement in the basic manufacturing processes, which, in turn, drives growth. In contrast to the related studies (Powell 1995, Ittner and Larcker 1997), we see improvement not as one of several management practices, but as a result of the positive dynamics created by management quality. In a second step, an improvement track record enhances a factory's competitiveness, and leads to growth.

H1 Greater improvement in the basic processes (strategy deployment, supply chain, new product introduction) leads to higher volume growth for the plant.

H2a Higher levels of the management quality dimensions lead to higher improvement rates in the three basic processes.

Clark (1996) suggests that it is not the emphasis on one program which leads to improvement, but the integration of a broad set of advanced manufacturing programs. In the language of the resource-based view of the firm, this implies that *resource connectedness* prevents imitability of manufacturing management quality, and thus, gives it a competitive advantage:

H2b Process improvement cannot be obtained by one or a few of the manufacturing management quality dimensions in isolation, but requires the simultaneous achievement of a broad set of the dimensions.

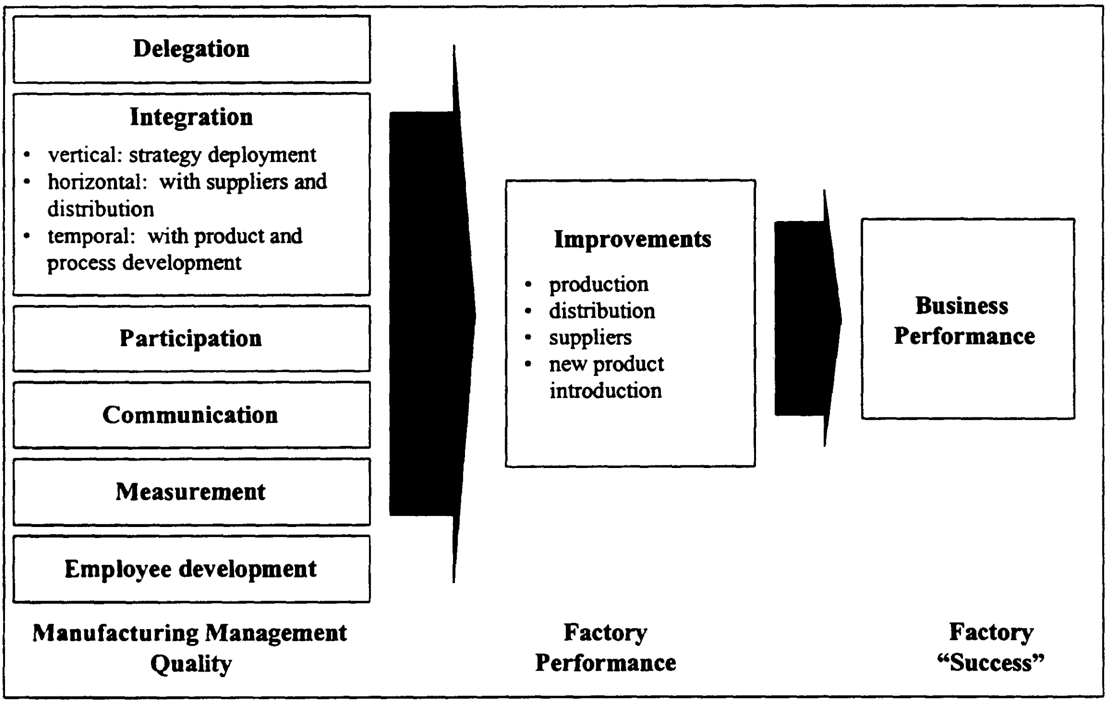

Figure 4: Manufacturing Management Quality, Improvement and Growth

The model presented in Figure 4 does not depend upon specific sector characteristics or economic context. It is thus a generic model of plant performance. However, the *relative* importance of the management quality dimensions, as well as the extent to which manufacturing management quality is applied, may be dependent on the economic environment. This observation prompts two additional hypotheses.

In particular, Japanese companies have traditionally been strong in manufacturing efficiency, while US and European companies have excelled in product development (e.g., Miller *et al.* 1992). Recently, there has been evidence that companies in each region are attempting to improve on their weaknesses, with Japan focusing on product design, and the US and Europe on supply chain efficiency (De Meyer and Pycke 1996). This leads to the following hypothesis:

H3 In Japan, most profitability growth is expected to come from new product development, whereas in the US and Europe it results from manufacturing and supply chain integration improvements (to be tested on the MFS data alone).

Significant differences in management practices have also been observed across industries. For example, "lean manufacturing", including empowerment and the delegation of decisions to line workers, combined with tight quality management, was first embraced in the automotive industry, as it globalized during the 1980s (e.g., Womack and Jones 1990). The electronics industry also has become highly global and competitive (e.g., Cimento and Knister 1994). However, the available evidence does not seem sufficient to determine which sectors are now leading in their management practices. Thus, we can only predict that

H4a *some* industries are leading in the application of the management quality dimension (i.e., those sectors which invest more heavily in the different management quality dimensions).

Companies respond in a competitive environment. The effect of manufacturing management quality on volume growth is not the consequence of its absolute level, but of the relative level, compared to the competition. Thus, the volume growth of an individual plant is influenced by manufacturing management quality, although overall growth in a sector is largely determined by market conditions (Porter 1980). This leads to hypothesis 4b.

H4b The industries which employ higher levels of manufacturing management quality do not grow faster than other industries, i.e., growth is dependent on relative performance within a sector, rather than on absolute performance across sectors.

4. DATA AND MEASURES

4.1. Samples

The Best Factory Survey (BFS) was performed in a preliminary form in France in 1995 and 1996, the details being reported in de Groote *et al.* (1996). In 1997, the survey was carried out, for the first time, in France and Germany simultaneously. The unit of analysis of the survey is the individual plant.

A 16-page questionnaire was designed according to the structure of the manufacturing management quality model (copies can be obtained from the authors), with sections corresponding to the three basic business processes. For each process, questions covered the six quality dimensions.[3] The survey was publicized by the well-known weekly business magazines *L'Usine Nouvelle* in France and *Wirtschaftswoche* in Germany, and 51 plants self-selected by filling out the questionnaire. The respondents represented different manufacturing sectors; some descriptive statistics are shown in Table 1. In a second phase, the 16 best candidate plants (in terms of management quality levels) were visited for one day each, and underwent a thorough investigation by at least four persons who carried out multiple decentralized interviews on the shop floor and in the departments, verify the responses to the questionnaire. Six of the participating plants received an award, mention of which was published in the two business magazines. All plants received detailed benchmarking feedback.

The BFS respondents are *not a representative sample* of factories in France and Germany. Rather, they are ambitious plants, which at the minimum are interested in competitive benchmarking, and possibly even believe that they are competitive enough to win in a national competition. Thus, the absolute levels of manufacturing management quality, improvement and growth in our sample do not correspond to the averages in the two countries. However, as we are interested in the effects of *differences* in management quality, this does not invalidate our results.

In addition to producing the BFS data, we had access to a second data set, namely the Global Manufacturing Futures Survey (MFS). The MFS whose objective is to follow current thinking on manufacturing strategy has been carried out bi-annually in Japan, Europe, the US and eight other countries since 1984. The 1996 survey had a total of 461 respondents representing successful, international companies in the US, Europe and Japan (details can be found in De Meyer and Pycke 1996). As the unit of analysis is the manufacturing function in a business unit,

[3] In 1997, the questions were updated for clarity and variance maximization, based on the experience from 1995 and 1996.

respondents represent, in the main (74%), the company or division level rather than the single plant level. Variables are, therefore, at a higher level of aggregation than in the BFS. Table 1 shows that the MFS data points have much larger sales volumes than the BFS data points, which reflects the fact that they represent business units rather than single plants. The business units in the MFS grew roughly with their industries, while the plants in the BFS grew faster.

Although the MFS survey was not designed specifically with our manufacturing management quality model in mind, we were still able to formulate measures of our management quality constructs, albeit at a higher organizational level (business unit rather than factory), which reduces the effectiveness of the measures. The MFS survey offers legitimate additional support for our model, thus representing a first test of generalizability.[4]

Variable	*Best Factory Survey 1997*		*Manufacturing Futures Survey 1996*	
Respondents by region	France:	24	Europe:	145
	Germany:	27	Japan:	182
			USA:	134
Respondents by sector	Automotive:	31%	Automotive:	8%
	other industrial:*	49%	other industrial:*	63%
	consumer:*	20%	consumer:*	28%
Production process type	discrete flow:	86%	discrete flow:	79%
	continuous flow:	14%	continuous flow:	21%
Average turnover (US $ million)	395		1 273	
Avg. No. of employees	492		not available	
Avg. annual growth (units)	18.2%		5.2%	
Avg. material or subassembly cost	43.2% of total cost		63.4% of sales	
Avg. manufacturing lead time	20 days		22 days	
Avg. annual inventory turnover	7.6		7.6	
Avg. capacity utilization	79%		87%	

* the other sectors are without automotive suppliers

Table 1: Composition of the Samples

4.2. Measures

In both samples, measures of manufacturing management quality, process improvement and growth are formulated. The variable definitions are not discussed here in detail, but are shown in Tables A-1 (BFS) and A-2 (MFS) in the Appendix.

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[4] Other studies, such as Ittner and Larcker 1997, are based entirely on data sets not specifically designed for them. We use the MFS data as corroborating evidence, in addition to our own data.

Important differences between the two samples to bear in mind are the following: with respect to management quality, communication as a variable is not available in the MFS (too detailed to be included). In contrast, strategic deployment is not available as a variable in the BFS.[5] With regard to improvements, the wider scope of the MFS allowed the inclusion of an additional variable, namely improvements in product development itself (not only in the actual introduction of new products into production). Finally, business success is measured differently for the two samples. At the business unit level in the MFS, the appropriate dependent success variable is profitability growth (index for 1995, with 1993 = 100). At the plant level in the BFS, volume growth is preferred as the dependent variable, as discussed above.

Descriptive statistics and correlations among the variables are shown in Tables A-3 (BFS) and A-4 (MFS). Moderate correlations exist among the different improvement variables. A number of management quality dimensions are highly correlated (e.g., delegation tends to occur in parallel with communication, measurement, and upstream and downstream integration), which is consistent with Hypothesis H2b. The multi-collinearity this introduces in the regression analysis is addressed below. In the analysis section, we use regression to test our hypotheses as we are looking for relationships among continuous variables.

5. RESULTS OF THE BFS

5.1. Process Improvement and Volume Growth

Table 2 presents the regression results with plant growth as the dependent variable and improvement rates as the independent variables. In addition to improvements in the business processes, *capital* is included as a control variable. While an important resource, capital is viewed as a commodity that does not in itself provide competitive advantage. Thus, we separate its influence from management quality.

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[5] Three variables were included in the questionnaire, but they turned out not to offer enough variance to be useful. They are, therefore, not reported in this article. Improvements have been made to the 1999 version of the questionnaire.

The first column shows the basic growth regression, with improvements in production and new product introduction being significant. Capital intensity and supply chain (supplier and distribution) improvements are not significant even when regressed alone against growth. The regression is highly significant with an explained variance of 42%, which is high for such a cross-sectional study.

Variable	*Growth regression*	*local vs. capacity intensity*	*local vs. improvement production*
Capital intensity	*.09*	*.15*	*.04*
Impr. production	*.42***	*.25*	*.39***
Impr. suppliers	*-.14*	*-.06*	*-.11*
Impr. distribution	*-.27*	*-.09*	*-.17*
Impr. new products	*.57***	*.47***	*.59***
Local x *capital intensity*	-	*-.48****	-
Local x *improv. production*	-	-	*-.31**
Constant	*-.66*	*3.62*	*1.23*
Adj. R^2	*.42****	*.64****	*.49****
N	*22*	*22*	*22*

Significance levels: *** ≤1 %, ** ≤5%, * ≤ 10%

Table 2: Growth Regression for the BFS

These results support the first part of Hypothesis 1 (at the plant level). Columns 2 and 3 demonstrate an interesting refinement: the mechanism through which improvements help plant growth differs between local and international plants. Plants are classified as local (dummy value = 1) if they belong to a purely national company (either French or German) with no manufacturing facilities outside the country. Plants belonging to an international concern (such as Honeywell or Procter & Gamble) are labeled "international" (dummy value = 0). The interaction terms of capital intensity and production improvements with the "local plant" dummy are significant. This implies that for local plants, both the size of capital investment and the improvement rates in production are less important as growth drivers than for international plants.

This points to a difference in how growth is determined between local and international plants: the latter often compete against other plants in the same company (this was explicitly mentioned to us by several plant managers during our visits). A good track record on improvement rates helps to attract new products and to "steal" volumes from other plants, which is, in turn, also associated with further investments. Plants of local companies, however, often have no competing sister plants, and their growth is thus linked much more closely to that of the company as a whole. Therefore, the influence of the plant improvement rates on plant growth is weaker. Indeed, the growth regression comes out not significant on the local plant subsample, while it is still strongly significant for the international plant subsample (not shown in the Table).

5.2. Manufacturing Management Quality and Improvement Rates

Table 3 shows the regression results with production improvement as the dependent variable and the management quality dimensions as independent variables.[6] Because of the multi-collinearity of the variables, they were included stepwise in order to see their separate significance levels. Capacity utilization, a common control variable, is not significant, even when it is the only independent variable.

Variable	*Model 1*	*Model 2*	*Model 3*
Capacity utilization	*-.02*	*.01*	*.27*
Communication	*1.89***	*2.1***	*.76*
Communication²	*-1.83***	*-2.1***	*-1.09*
Measurement	*.25*	*.35**	*.30*
Integration suppliers	-	*.33***	*.40***
Integration distribution	-	*.05*	*.44***
Integration new product intro.	-	*-.18*	*-.36**
Participation	-	-	*.14*
Delegation	-	-	*-.19*
Employee development	-	-	*.32*
Constant	*-36.4***	*-57.3****	*-47.8***
Adj. R^2	*.13**	*.24***	*.56 ****
N	38	33	25

Significance levels: *** ≤ 1%, ** ≤ 5%, * ≤ 10%

Table 3: Production Improvement Rates Regression

Models 2 and 3 show the following interesting results. Communication has a *quadratic* association with improvement, that is, it helps it up to a point, but then reduces it. Over-communication can thus result in *information overload*, or a decline in performance after the number of available information "cues" passes a critical number (e.g., Streufert 1973, Huber 1990).

[6] We observed a non-linear influence of communication in scatter plots of the data, and therefore included a non-linear term for this variable.

Integration with suppliers and distribution are associated with higher rates of production improvement. This infers to important benefits from integration, not only in the way of better delivery performance, but also in improvement within the factory itself. Integration with development, however, has a *negative* relationship with production improvements. Typical reasons for this are that resources are tied up in product development, and working on prototypes and experiments may disrupt the factory flow (Terwiesch and Bohn 1998). This does not imply, however, that integration between the factory and product development should be discouraged. On the contrary, the growth regression in Table 2 shows that high improvement rates in new product introduction help the plant in volume growth, that is, in the longer run. An interesting trade-off between short-term disruption and longer-term benefits emerges.

Table 4 demonstrates that manufacturing management quality also supports improvement rates in distribution and supplier performance, although the connection is not as strong. Two interesting additional effects emerge.

Variable	*Improvement Distribution*	*Improvement Suppliers*
Capacity utilization	$-.47^{**}$	$-.57^{*}$
Communication	-.21	.27
Measurement	$.36^{*}$	.28
Integration distribution	$.53^{**}$	-
Participation	-.20	.16
Employee Development	-.17	$-.53^{**}$
Supplier Response Time	-	$-.85^{***}$
Constant	-33	46^{*}
Adj. R^2	$.23^{*}$	$.31^{**}$
N	28	23

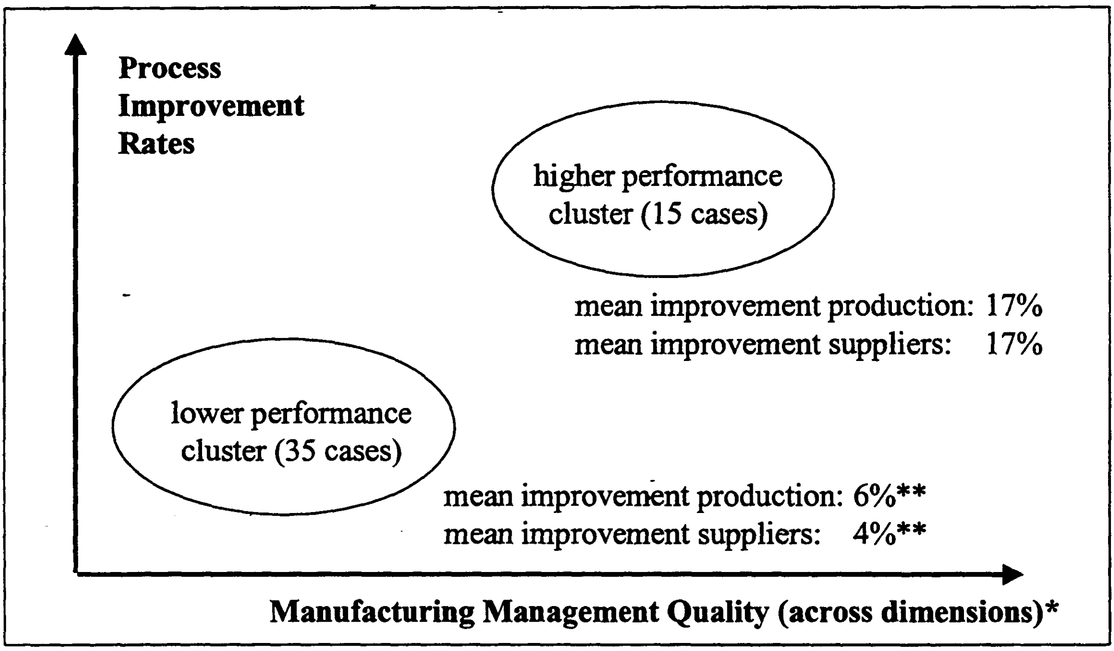
*Significance levels.. *** ≤ 1%, ** ≤ 5%, * ≤ 10%*

Table 4: Distribution and Supplier Improvement Regressions

First, capacity utilization has a significant and *negative* association with improvements in these two parts of the supply chain. One interpretation is that higher capacity utilization leaves less slack for concentrating on customer lead times and on-time deliveries, and it leads to more short-term orders which suppliers find difficult to satisfy. Second, supplier responsiveness becomes a significant variable: shorter supplier response times to problems in the plant are strongly associated with supplier improvement rates.

Tables 3 and 4 provide strong support for Hypothesis 2a. The linear regression models used do not, however, test whether the advantage from manufacturing management quality is protected by resource connectedness (Hypothesis 2b). We provide two lines of support for this claim.

First, a cluster analysis using all nine manufacturing management quality variables in the production improvement regression from Table 3 (normalized to zero mean and unit variance to avoid any implicit weighing of the variables) identifies two highly significant clusters.[7] One of them has higher mean levels on *all* variables, the difference being highly significant on seven of them.



* High performance cluster has higher means on all dimensions. Differences significant at 5% level for all dimensions except integration with new product introduction and integration with suppliers.

** Differences across clusters significant at 1% level. Difference for distribution improvement not significant.

Figure 5: Manufacturing Management Quality Clusters

The two clusters are qualitatively illustrated in Figure 5, where manufacturing management quality is collapsed to one dimension (low-high is the same for all

[7] We also tested a multiplicative regression model of the nine variables. It yielded significance levels similar to those of the additive model and could not, therefore, settle the question of whether manufacturing management quality should be applied as a package.

variables). The existence of these two clusters[8] is consistent with the correlations among the quality dimensions in Table A3-2, and shows descriptively that the dimensions appear together as a "package." In addition, a comparison of mean improvement rates reveals that the high performance cluster is characterized by higher improvement rates both in production and for suppliers, significant at the 1% level. This provides evidence that manufacturing management quality leads to higher improvements when applied consistently across its dimensions.

As a second piece of evidence, we count the number of dimensions for which a plant is in the upper (high performance) 40%. This variable, an integer ranging from 0 to 9, corresponding to the 9 dimensions, is positively correlated with production improvement rates at a 3% significance level. This again suggests that it is of value to have high manufacturing management quality across *many* dimensions, rather than to focus on only a few of them. These two lines of evidence provide strong support for Hypothesis 2b.

Having high manufacturing management quality across a broad set of dimensions does not, however, mean "doing *everything*." First, only 2 plants were in the top 40% in all 9 dimensions, and none was in the top 20% in more than 6. Second, although we find an overall mutual reinforcement among the dimensions, a few interesting *substitute* interactions appear to exist. We use two approaches to examine interactions. Table 5 shows the effects of the multiplicative interaction terms in the production improvement regression, which are included one at a time because of the low remaining degrees of freedom in the regression.[9] Three interactions turned out significant, and their negative signs suggest that participation, delegation and supplier integration may be partial substitutes.

We provide the following interpretation of these substitution effects. When many responsibilities are delegated to the shop floor, for example in the form of auto-control, machine maintenance or quality circles, a formal suggestion system seems

[8] The factories in the high-performance cluster are almost identical to the visited candidate plants in the competition; a few plants were not visited to avoid duplication within industries.

[9] The effect of communication comes out negative because the quadratic terms have been left out, again in the interest of saving degrees of freedom.

less necessary, and thus less useful. For example, in several plants that we visited, the formal suggestion system had been abandoned because line workers were empowered to institute (or negotiate) changes themselves. Similarly, the interaction between delegation and supplier integration suggests that problem-solving in the plant by the supplier regarding, for example, machines delivered by them, may substitute responsibilities taken by workers, and *vice versa*.

Variable	Participation *vs.* delegation	Participation *vs.* integr. suppliers	Delegation *vs.* integr. suppliers
Capacity utilization	*.36***	*.26*	*.44****
Communication	*-.34**	*-.34**	*-.41***
Measurement	*.36***	*.09*	*.28**
Integration suppliers	*.39***	*.72****	*1.33****
Integration distribution	*.48****	*.69****	*.45****
Integration new product introduction	*-.31**	*-.29**	*-.31**
Participation	*1.32***	*1.30***	*.25**
Delegation	*.01*	*-.32**	*.36*
Employee development	*.33**	*.34**	*.44***
Participation X delegation	*-1.31**	-	-
Participation X integr. suppliers	-	*-1.26***	-
Delegation X integr. suppliers	-	-	*-1.28****
Constant	*-47.6****	*-29.2***	*-55.5****
Adj. R^2	*.63****	*.66****	*.70****
N	*25*	*25*	*25*

Significance levels: *** $\leq 1\%$, ** $\leq 5\%$, * $\leq 10\%$

Table 5: Substitutes Among Manufacturing Management Quality Dimensions

6. CONFIRMING RESULTS FROM THE MFS

In this section, we confirm the support of Hypotheses H1 and H2a (above), based on the independent MFS data. In addition, we find support for Hypotheses H3 (differences across economic environments) and H4 (differences across sectors).

6.1. Process Improvement and Profitability Growth

Table 6 shows the profitability growth regressions, by region. Because of the multi-collinearity among the independent variables, a partial regression model (with the significant variables of the full model removed) is shown for both Japan and the US, in order to see how variable significance is shared. For the European sample, the partial regression is not significant at all, and thus not shown.

We checked for non-linearities by fitting quadratic curves and examining the scatter plots for each of the independent variables. In the European and US samples, the quadratic terms had an influence on supplier, production, and distribution improvements. These quadratic terms were thus included in the regressions. In the Japanese sample, however, no indication of nonlinearities was visible, so the quadratic terms were left out of the regressions.

Variable	*Europe*	*Japan*		*USA*	
		partial	*full*	*partial*	*full*
Capital intensity	.06	.11	.02	-.05	.0
Improvement production	1.71^{*}	-	$.25^{**}$	-	-1.18^{***}
(Impr. production)²	-1.33	-	-	-	2.08^{***}
Improvement suppliers	.75	.211*	-.10	$-.72^{***}$	.08
(Impr. suppliers)²	-.84	-	-	1.41^{***}	-.17
Improvement distribution	-.42	-	$-.18^{**}$	$-.50^{*}$	.32
(Impr. distribution)²	.20	-	-	$.57^{**}$	-.32
Impr. new prod. introduction	-.11	-	$.88^{***}$	.02	-.01
Impr. new prod. development	$.27^{**}$	$.29^{***}$	-.03	-	$.16^{***}$
Constant	-484	-209^{**}	-38	390^{***}	117
Adj. R^2	$.13^{***}$	$.13^{***}$	$.71^{***}$	$.78^{***}$	$.85^{***}$
N	103	86	86	118	117

Significance levels: $^{***} \leq 1\%$, $^{**} \leq 5\%$, $^{*} \leq 10\%$

Table 6: Profitability Growth Regressions by Region in the MFS

Overall, the results support the second part of Hypothesis 1 (at the business unit level). The European regression is significant, but shows the lowest explained variance of the three. Explained variance is very high in the US and Japan, suggesting greater homogeneity in the sample. In all three regions, production improvements are significant (with increasing returns in the US). In Japan, new product introduction, that is, the cooperation between product development and the plants, plays an important role. In the US and Europe, in contrast, improvement in product development performance itself is related to profitability. Only weak evidence exists of the benefits of supplier performance (only in Japan and the US, and only in the partial models).

Interestingly, distribution performance is *negatively* related to profitability in Japan. This may be related to the specific structure of Japanese distribution channels, which used to be inefficient and completely controlled by the manufacturers who were able to pass all costs on to the consumer. As the supply chain performance improves, and consumer pressure increases at the same time, costs can no longer be passed on, which depresses profits, at least in the short term.

Overall, these results do *not* support Hypothesis 3: the previously found profit drivers of new product introduction in Japan and new product design in the US and Europe (Miller *et al.* 1992) are still the significant predictors of profitability growth. Recently found evidence of a shift (De Meyer and Pycke 1996) is not supported by our data.

6.2. Manufacturing Management Quality and Improvement Rates

In order to be conservative and to have greater compatibility between the BFS and MFS results, we perform the regression of manufacturing management quality against improvement rates on the European sample (although the profitability growth regression is weakest here), as shown in Table 7.

Variable	*Europe overall*	*Auto & electronics*	*Other industries*
Capacity utilization	*.12*	-	-
Communication	-	-	-
Measurement	*.18**	*.22*	*.16*
Integration suppliers	*-.11*	*-.12*	*-.03*
Integration distribution	*-.19*	*-.16*	*-.13*
Integr. new product introduction	*.01*	*-.23*	*-.12*
Integration strategy	*.30****	*.53****	*.18*
Participation & Delegation	*.26***	*.42**	*.21*
Employee development	*-.15*	*-.19*	*-.11*
Constant	*92.1****	*83****	*105****
Adj. R^2	*.15****	*.26***	*.01*
N	*101*	*33*	*89*

Significance levels: *** ≤ 1%, ** ≤ 5%, * ≤ 10%

Table 7: Production Improvement Regression in the European MFS

The first column shows that the model is significant although explained variance is weaker than in the BFS. This is to be expected since the MFS data are at a higher level of aggregation, thus further away from the shop floor. The significant variables are measurement, participation/delegation, and strategy deployment.[10] This provides the desired confirmation of support for Hypothesis 2a.

[10] None of the remaining variables becomes significant when these three variables are excluded from the model.

Columns 2 and 3 compare the effect of manufacturing management quality in the auto and electronics subsample with that of the other industries.[11] For the auto and electronics industries, the model is significant, while it is not for the other industries, a fact which supports Hypothesis 4a. Other industries are not (yet) as familiar with the practices recommended in our model as automotive suppliers and electronics manufacturers, and do not yet apply them systematically. This becomes evident from a t-test: auto and electronics units use more strategy deployment (significant at the 10% level), participation and delegation, integration with distribution and with new product introduction (5% level), and integration with suppliers (1% level).[12] This is again consistent with Hypothesis 4a.

The electronics and automotive supplier business units have been able to increase their profitability faster than the other sectors (56% vs. 17% since 1993, significant at the 8% level), against competition from Asia and the US. This suggests that manufacturing management quality has helped these business units competitively in terms of profits. However, the difference in growth (19% vs. 7% over the previous year) is not significant. This is consistent with Hypothesis 4b.

7. DISCUSSION AND IMPLICATIONS

Our results confirm previous findings that TQM practices, implemented as a series of "programs," do not necessarily provide competitive advantage. However, our study is the first one to show that, at least at the factory level, one does not need to retreat to intangible and tacit resources such as "culture" and "openness" (Powell 1995) in order understand the benefit of TQM. There seems to exist a more concrete path to competitive advantage.

First, TQM practices must be elevated from the status of shop floor tools to that of a broad set of management practices, which we refer to as *manufacturing*

[11] We removed capacity utilization, the least significant variable, from the regression in order to retain enough degrees of freedom in the auto/electronics subsample.

[12] The differences for the other management quality variables are not significant, but none goes the other way.

management quality. Manufacturing management quality must be applied across the key business processes (strategy deployment, supply chain, product/process development) in the plant and at the interfaces to the rest of the organization.

Second, the six dimensions of manufacturing management quality (delegation, integration, communication, participation, employee development, and measurement) exhibit *resource connectedness*, that is, their full benefit is only felt if they are applied consistently together. Thus, resource connectedness represents a barrier to imitability, as implementing the majority of the six dimensions, which requires organizational vision and stamina, is required before benefits accrue. Indeed, discussions with plant managers at the BFS plants we visited provide consistent anecdotal evidence that it takes 3-4 years of persistent effort to arrive at a self-reinforcing level of management quality. This implies that resource connectedness is further associated with diseconomies of time compression (Rumelt 1984). Our observations at the plants visited also indicate that none of them simply took TQM tools (such as SPC or 5S) "off the shelf", rather they adapted them to local "ways of doing things" and to particular process demands in the plant.

Further evidence of the difficulty of implementing manufacturing management quality is provided by our finding that no plant was able to execute all dimensions at once. Moreover, it is possible to do "too much of a good thing" – too much communication may cause information overload, and thus hinder improvement. Some dimensions also present the manager with trade-offs: close integration of the plant with new product introduction causes disruption (i.e., lower improvement rates) in the short term, but it helps the improvement of the product introduction process, and thus future plant growth. Finally, limited substitution seems possible among different management quality dimensions at the task level.

Third, our results, unlike those of previous studies, suggest that process improvement is not a TQM program to be implemented alongside others, but an *outcome* resulting from the dynamics of decentralization, strategic vision, employee initiatives, and understanding of the process drivers. Manufacturing management quality does not lead *directly* to business performance, but through an *improvement track record.*

Fourth, we provide additional evidence that volume growth is a good measure of plant success, especially in international multi-plant companies (Swamidass and Newell 1987): sister factories compete against one another for volume. This makes plant growth an accurate indicationof plant performance, measured almost independently of the growth of the company overall. Other measures (such as costs or plant profits) are subject to distortions from transfer pricing and allocation rules. At the business unit level, in contrast, profitability seems a more appropriate performance measure.

These findings have a direct and obvious managerial relevance, offering one route to improvement. At the same time, the comparison of different sectors points to the *limit of barriers to imitability*, and thus to competitive advantage: the automotive and electronics industries are at present leading in the application of management quality in the factory, and high manufacturing management quality is essential in order to gain high improvement rates and plant growth. We believe this reflects the higher *competitive pressures and the diffusion of best practice* (e.g., Womack *et al.* 1990, Stalk and Webber 1993, Cimento and Knister 1994). Once the source of advantage from a management method is understood, it can, in principle, be imitated, even if resource connectedness and time compression diseconomies make imitation slow and costly. But over time, "best practice" spreads, first within an industry and then across industries. No competitive advantage lasts forever. Several managers of the plants visited were aware of this and thus determinedly seeking further improvements in order to stay ahead.

As an aside, we find that the relative importance of the three business processes differs across the economic regions of Japan, Europe, and the US. While production improvement is important in all three regions, effective integration of the plant with new product introduction counts most in Japan. In contrast, the most important improvement in the US and Europe is in the development of new products *per se* (not their introduction in the plant). This finding mirrors differing competitive strengths that have been observed over the last decade.

8. CONCLUSION

The data set in our study has two clear weaknesses, i. e., the relatively small sample size of 51, and a self-selection bias leading to a sample of "ambitious" plants. We believe that the comparison of relative levels of manufacturing management quality is still valid, and allows conclusions to be drawn and recommendations to be made for other plants as well. In addition, we provide evidence for the generalizability of our model by testing it on a second data set (although this data set was not designed specifically for our study) and finding strong evidence in both. We are in the process of extending our BFS to more countries, in order to enhance the sample size and breadth, and to enlarge the scope to a whole supply chain, capturing integration more fully. Better measures have been developed for strategy deployment, and we are intending to incorporate organizational learning as another key process.

Our study makes several contributions to the manufacturing strategy literature. Several studies have proposed to view TQM techniques as management practices, but ours is the first to offer a consistent management quality model and to find empirical support for it. Our model also connects the manufacturing strategy literature with the operations management and process reengineering literature by proposing that manufacturing management quality must be measured at the process level. Finally, we contribute to the resource-based theory of the firm by demonstrating that manufacturing management quality is a non-imitable resource due to resource connectedness and time compression diseconomies. In addition, we show evidence for the limit of competitive advantage through the diffusion of knowledge within industries. In summary, this study enhances the understanding of how competitive advantage arises from detailed manufacturing management practices.

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APPENDIX

Growth	average annual volume growth over the last 3 years
Improvement:	
Production	average annual improvement rate over the last 3 years, averaged over: average production throughput time, average unit cost, total inventories (days), scrap rates, lost capacity due to operational problems and maintenance, and average setup times (%) [note: average was taken only over those items filled out]
Distribution	average annual improvement rate over last 3 years, averaged over: percent on-time-delivery, percent of correct deliveries, and customer rejects (%)
Suppliers	average annual improvement rate over last 3 years, averaged over: percent on-time-delivery, average lead times of all suppliers, reject rates of deliveries, and percent of incorrect deliveries (%)
New Product Introduction (in manufacturing)	average annual improvement rate over last 3 years, averaged over: rampup times to full volumes, warranty costs during first year of new products, defect rates of new products in their first year, average number of components/ subassemblies per final product, and average response time of product development to change requests from manufacturing (%)
Capital Intensity	The sum of maintenance costs, energy costs, and capital costs for buildings and equipment, as a proportion of total cost (%)
Management Quality	
Capacity Utilization	average capacity utilization over the last year reported (1996) for the whole plant
Measurement -	total number of measures reported in the questionnaire over all 3 key processes, normalized as % of the maximum number possible per process (production, new product introduction, suppliers, distribution) and added up (0 - 4)
Communication	total number of measures for which conununication in the plant was reported, summed over all information recipient groups (plant management, production manager, department head, line heads, operators, marketing, distribution, purchasing, product development, process development)
Integration suppliers	% of suppliers involved in cost reduction and quality improvement initiatives in the plant
Integration distribution	number of departments in the plant that are in regular contact with direct customers (0 - 6)
Integration product development	% of product development time during which plant is involved (0 - 200%: for two plants, involvement starts before development)
Participation	number of suggestions per year and employee
Delegation	Sum of Likert scales (1 - 5) for extent of use in the plant of the following: production cells, autonomous teams, multi-functional work teams, machine maintenance performed autonomously by operators, self-control of quality (0 - 30)
Employee developmt.	number of training days per year and (non-management) employee
Supplier responsiveness	average response time of a supplier to solve a problem associated with a material delivery (e.g., quality or delivery correctness), in days

Table A1: Definition of Variables - Best Factory Survey (BFS)

Performance:	
Profitability	end of 1995 index of profitability (1993 = 100)
Growth	growth rate in unit sales, last fiscal year reported over previous fiscal year (%)
Improvement	average over the following 1995 indices (1993 = 100):
Production	defect rates at the end of manufacturing, typical unit production costs, work-in-process inventory turnover, manufacturing cycle time, productivity of direct production workers
Distribution	overall quality as perceived by customers, customer return rates, on-time delivery to customers, delivery lead times (from order to delivery)
Suppliers	procurement lead time (from order to supplier to delivery), average defect rates of procured materials
New Product Introduction (In Mfg.)	speed of introducing product design changes in manufacturing, number of avoidable engineering change orders for a typical new product (manufacturability of new product)
New Product Development	speed of new product development, on-time completion of projects, extent to which products meet customer needs
Capital Intensity	% of total cost which is neither materials nor direct labor
Management Quality:	
Capacity Utilization	capacity utilization in the last year reported (%)
Measurement	relative payoff, over the last 2 years reported, from the development of new performance measures (Likert scale 1 - 7)
Communication	not available
Integration suppliers	relative payoff over the last 2 years (Likert scale 1 - 7) averaged over: integrating information systems with suppliers and distributors, information sharing and monitoring, joint planning and problem-solving, communication at multiple levels, reduced supplier base, sharing risks and rewards, supplier partnerships. The Kronbach-α on this variable combination is 75.1 %
Integration distribution	relative payoff over the last 2 years (Likert scale 1 - 7) averaged over: integrating information systems with suppliers and distributors, information sharing and monitoring, joint planning and problem-solving, communication at multiple levels, sharing risks and rewards, reduced distributor base, information flow on demand forecasting, customer partnerships. The Kronbach-α on this variable combination is 75.9%
Integration product introduction (in manufacturing)	relative payoff over the last 2 years (Likert scale 1 - 7) averaged over: value analysis/product redesign, developing new processes for new products, developing new processes for old products, DIM (design-for-manufacture). The Kronbach-α on this variable combination is 62.8%
Integration with strategy (strategy deployment)	relative payoff over the last 2 years (Likert scale 1 - 7) derived from developing a manufacturing strategy to support the business strategy
Participation/ Delegation	these 2 constructs could not be separated in this aggregate database. Relative payoff over the last 2 years (Likert scale 1 - 7) averaged over: giving workers a broad range of tasks, cross-functional teams, functional teamwork (e.g., production cells). The Kronbach-α on this variable combination is 72.4%
Employee development	relative payoff over the last 2 years (Likert scale 1 - 7) averaged over: worker training, management training, supervisor training. The Kronbach-α on this variable combination is 85.8%

Table A-2: Definition of Variables - Manufacturing Futures Survey (MFS)

Variable	mean (%)	std. dev.	N	1	2	3	4
1. Improvement production	12.3	13.3	46	-			
2. Improvement suppliers	12.0	13.3	39	0.33	-		
3. Improvement distribution	13.6	32.3	41	-0.04	0.14	-	
4. Improvement new product introduction	12.0	13.6	32	0.49	0.18	0.52	-
5. Capital intensity	14.6	10.3	50	0.05	-0.14	-0.10	0.31

Table A-3-1: Independent Variables of Growth Regression BFS

Variable	mean (%)	stand. dev.	N	1	2	3	4	5	6	7	8	9	10
1. Capacity utilization	79.1	17.0	42	-									
2. Measurement	3.1	0.8	51	.13	-								
3. Communication	60.9	25.5	51	.42	.67	-							
4. Integration suppliers	54.6	39.0	48	.10	.15	.23	-						
5. Integration distribution	2.8	1.0	51	.14	.37	.26	.06	-					
6. Integration new product Introduction	79.3	60.1	45	.28*	.20	.31	.08	.12	-				
7. Participation	2.25	3.0	41	.00	.38	.20	.44	.09	.02	-			
8. Delegation	5.3	1.9	51	.09	.39	.42	.28	.06	.50	.38	-		
9. Employee development	0.32	0.28	50	.01	.14	.22	.11	-.11	.49	.02	.31	-	
10. End customer sales information	2.41	1.23	48	.32	.05	.02	.28	.18	.07	.23	.20	.18	-
11. Supplier Response Time	0.30	0.22	49	-.27	-.20	-.26	-.08	-.01	-.33	-.01	-.16	-.18	-.06

Table A-3-2: Independent Variables of Improvement Regressions BFS

The definitions of all variables used in the BFS and MFS regressions are shown in Tables A-1 and A-2, respectively. No replacement of missing entries was performed, thus the degrees of freedom in the regression analyses diminished with the number of variables included. One outlier was eliminated in the BFS sample. It was judged non-representative because it had been opened only two years earlier and had grown by 400% in each of these two years in the course of its volume ramp-up. 50 observations remained.

Variable	mean	std. dev.	N	1	2	3	4	5
1. Improvement production (index)	114.1	24.7	425	-				
2. Improvement suppliers	107.6	20.8	413	0.74	-			
3. Improvement distribution	110.0	21.4	425	0.52	0.54	-		
4. Improvement new product introduction	106.7	23.5	392	0.38	0.25	0.37	-	
5. Improvement new product development	110.1	17.5	395	0.47	0.28	0.43	0.47	
6. Capital intensity	26.1%	18.5	372	-0.07	-0.02	0.0	-0.11	-0.08

Table A-4-1: Independent Variables of Growth Regression MFS

Variable	mean	stand. dev.	N	1	2	3	4	5	6	7
1. Capacity utilization	82.4	19.2	320	-						
2. Measurement	4.1	1.5	409	-.07	-					
3. Integration strategy	4.3	1.5	413	.04	.25	-				
4. Integration suppliers	24.2	9.1	461	.09	.20	.36	-			
5. Integration distribution	27.6	9.9	461	.11	.17	.32	.95	-		
6. Integration new product Introduction	12.9	6.4	461	.09	.25	.40	.48	.48	-	
7. Participation and delegation	11.1	5.0	461	-.08	.49	.42	.43	.37	.57	-
8. Employee development	12.0	4.8	461	-.03	.47	.37	.37	.33	.42	.68

Table A-4-2: Independent Variables of Improvement Regressions MFS

Tables A-3 (BFS) and A-4 (MFS) summarize means, variances and correlations of the independent variables. There is some multi-collinearity present in the independent variables for both regressions. To help assign statistical significance (if present) to individual variables, we show several partial models throughout the paper, with fewer variables present, in order to find significant ones which may be hidden in the full models.