Paradigms of choice in manufacturing strategy: exploring the performance relationships of fit, best practices, and capability-based approaches

Giovani J. C. da Silveira
Haskayne School of Business, University of Calgary
2500 University Drive NW, Calgary, Alberta T2N 1N4, Canada
Tel. (403) 220-6975
Fax (403) 210-3327
giovani.dasilveira@haskayne.ucalgary.ca

Rui S. Sousa
Catholic University of Portugal (Porto)
Rua Diogo Botelho, 1327
4169-005 Porto, Portugal
Tel. +351- 22 6196 229
Fax: +351-22 6196 291
rsousa@porto.ucp.pt

Article under review at the Journal of Operations Management

1 © Giovani da Silveira and Rui Sousa, 2007. Draft only. This paper cannot be cited without authorization of the authors.
2 Giovani da Silveira’s research is supported by the Natural Sciences and Engineering Research Council of Canada (Discovery Grant #283134-04). Rui Sousa’s research has been supported by Fundação para a Ciência e Tecnologia and POCI 2010 (Programa Operacional Ciência e Inovação 2010). We thank Peter Sherer for comments and suggestions on a previous version of this paper.
Paradigms of choice in manufacturing strategy: exploring the performance relationships of fit, best practices, and capability-based approaches

Abstract

This paper explores direct and moderated relationships between performance and three paradigms of manufacturing strategy choice: fit, best practices, and capability building. Criterion variables of performance include efficiency, quality, and flexibility. Hierarchical regression analyses are used to test hypotheses of paradigm-performance relationships in a large database of international manufacturers. The results suggest that paradigms of capabilities and best practices have direct relationships with efficiency, quality, and flexibility, and that three-way interactions between paradigms provide additional explanation for efficiency and quality variation. Thus, manufacturing strategy choice may be conceptualized as decision-making based on a “two plus one” model of paradigms having capabilities and best practices as predictors, and fit as a moderator of performance outcomes.

1. Introduction

One of the most enduring debates in manufacturing strategy concerns the paradigms of structural and infrastructural choice in operations. Since the late 1970s, researchers have been discussing the merits of using alternative approaches at the time of designing or improving operations processes.

In a seminal paper, Voss (1995) identified three distinct paradigms of choice, named “competing through manufacturing”, “strategic choice”, and “best practice”. He
suggested that all paradigms had to be considered in manufacturing strategy due to their merits and limitations, and that paradigms overlapped each other. His study, which has been recently updated (Voss, 2005) encapsulated a long-standing debate in the manufacturing strategy field.

Studies on world-class manufacturing and trade-offs, e.g. Schonberger (1986), Ferdows and De Meyer (1990), and New (1992) served as an early illustration to that debate. However, it is the more recent work that appears to highlight the problem. A major example has been Hill et al.’s (1998) study of strategic realignment in a pharmaceutical company. They suggested that improving marketing-manufacturing fit through changes such as increased batch sizes (leading to inventory build-up) helped to boost operations competitiveness. However, Schonberger (1999) pointed out that such choices were inconsistent with accepted best practices, to which Hill et al. (1999) replied they were still appropriate because of the company’s market and industry background. Another major example has been Pilkington’s (1998) suggestion that success of the four major car manufacturers in Japan must be attributed to their focus on building capabilities and aligning manufacturing to markets, instead of simply adopting “lean” best practices.

Despite the increased research on the three paradigms, we do not seem close to resolving that debate yet; we cannot tell what paradigm or combination of paradigms can best explain variation in particular performance dimensions. For a start, most empirical research has explored effects of each paradigm as independent from the others. Exceptions include Morita and Flynn (1997) and Ketokivi and Schroeder (2004) who explored performance relationships with both best practices and manufacturing strategy alignment. However, their studies did not incorporate capability scales and did not
directly explore interactions between paradigms (this limitation is explicit in Morita and Flynn (1997) and seems to apply also to Ketokivi and Schroeder (2004)). Morita and Flynn (1997) particularly encouraged new research to address paradigm interactions and the role of capabilities in manufacturing.

This study explores performance relationships involving the three manufacturing strategy paradigms. Specifically, we test the extent to which scales of fit, best practices, and capability development explain variation in efficiency, quality, and flexibility performance in an international sample of manufacturing companies. Furthermore, hierarchical regression analyses explore the extent to which such relationships can be moderated by two-way or three-way interactions between paradigms, which is perhaps the best explanation for the “overlap” argument in Voss (1995). The results suggest that paradigms may have different roles in manufacturing strategy: whereas capabilities and best practice may be directly associated to performance improvements, fit may have an ‘hygienic’ role by positively moderating performance relationships with the other two paradigms.

This study makes two important contributions to manufacturing strategy research and practice. First, and to the best of our knowledge, this is the first empirical examination of the performance relationships of the three individual paradigms and their interactions in manufacturing. Second, the results lead to an innovative model of paradigm choice that may help to resolve the enduring debate on strategic choice in manufacturing strategy.

The remaining of this paper is organized as follows. Section 2 presents the theoretical background and develops hypotheses on direct and moderated performance
relationships with fit, best practices, and capability building. Section 3 presents the research data with emphasis on data collection and common method bias. Section 4 addresses the measurement of the dependent and independent variables. Section 5 describes the regression analyses and their results. Section 6 discusses the results with emphasis on the roles of paradigms in manufacturing strategy. Section 7 presents the study’s conclusions, implications, and limitations.

2. Background

Manufacturing strategy as an academic discipline has been marked by lively and sometimes fierce debates since its inception. Even though these debates may have theoretical shortcomings (as noted, for example, by Schmenner and Swink (1998)), they have often contributed to strengthening the conceptual and methodological bases of the discipline. The analysis of paradigms for manufacturing strategy decision-making is perhaps the best example of such a debate.

Voss (1995) discussed three paradigms of manufacturing strategy choice, namely “strategic choice”, “best practice”, and “competing through manufacturing”. The first relates to the well-known concept of “fit” between strategy, structure, and organization. Skinner’s (1969) foundation article essentially promoted this idea. However, the idea of fit was challenged in the 1980s by best practices studies, e.g. Schonberger (1986) that championed “World-Class Manufacturing” principles. More recently, the capabilities paradigm emerged around ideas expressed by authors such as Hayes and Pisano (1994) of building core competences for “long-term” competitive advantage.

The key idea in Voss (1995) was that paradigms were interdependent rather than mutually exclusive. This idea was tested by studies, e.g. Morita and Flynn (1997) and
Ketokivi and Schroeder (2004) that explored performance relationships with multiple paradigms. However, these studies did not incorporate either “functional capabilities” or paradigm interactions. Swink et al. (2005) provided evidence to a model relating practices to cost efficiency and flexibility (moderated by fit), and fit to market performance (mediated by efficiency and flexibility). However, Swink et al. (2005) appeared to use the word “capabilities” to denote manufacturing performance dimensions such as cost and flexibility. Here, we use the word “capabilities” as in the “knowledge” sense in Voss (1995) and Schroeder et al. (2002). The paradigms are discussed next.

2.1. Fit

For over thirty years, the concept of fit has been at the core of organization, strategy, and operations management studies. Venkatraman and Camillus (1984) and Drazin and Van de Ven (1985) indicated that the concept was originally developed in contingency theory studies, based on the assumption, “… that context and structure must somehow fit together if the organization is to perform well” (Drazin and Van de Ven, 1985: 514). More recently, as pointed out by Pettigrew et al. (2001) and Birkinshaw et al. (2002), contingency theory seems to have been expanded into configurational studies. However, just as with contingency theory, the focus of configurational studies has been to identify profiles of fit that maximize performance, except that these profiles may involve a broader set variables than appeared in the old contingency studies (Pettigrew et al., 2001; Birkinshaw et al., 2002; Geiger et al., 2006). Regardless of their affiliation to contingency or configurational theories of organization, studies have consistently approached fit as a vehicle for improved performance.
Conceptualizing fit is not a straightforward task. As pointed out by Doty et al. (1993), the literature provides several alternative definitions of fit. This, according to Venkatraman (1989), is due to the multiple perspectives employed by scholars. In broad terms, fit refers to “matching” or “consistency” among variables of strategy and organization (Venkatraman and Camillus, 1984; Doty et al., 1993).

The idea of maximizing fit across business strategy, manufacturing priorities, and structural and infrastructural choices has been probably the most significant concern in manufacturing strategy since the early works of Skinner (1969) and Hayes and Wheelwright (1979). “Strategic choice” studies focused on aligning process and infrastructure with strategic variables to maximize competitiveness (Voss, 1995). Bozarth and McDermott (1998) reviewed the manufacturing strategy research following on the tracks of configurational theory discussed earlier. They divided those studies between “taxonomies” (e.g. Miller and Roth, 1994) that classified operations into strategic groups and “typologies” (e.g. Hayes and Wheelwright, 1979) that matched choices in process and strategy.

Several manufacturing strategy studies, e.g. Smith and Reece (1999), Lindman et al. (2001), Papke-Shields and Malhotra (2001), Anand and Ward (2004), da Silveira (2005), and Brown et al. (2007) found significant performance relationships with either external (i.e. environment-structure) or internal (i.e. structure-organization) fit (such correspondence between Miller’s (1992) “external” and “internal” fit perspectives and manufacturing strategy concepts has been established by Bozarth and McDermott (1998)). Studies on strategy and organization have similarly found evidence of performance relationships with both external and internal fit (e.g. Venkatraman and
Prescott, 1990; Powell, 1992; Naman and Slevin, 1993; Yin and Zajak, 2004; Olson et al., 2005). However, the studies by Habib and Victor (1991) and Barth (2003) found no support to hypotheses that firms with higher strategy-structure fit outperformed firms with lower strategy-structure fit. They both suggested that capabilities such as experience and change ability might lead to performance benefits that were higher than the benefits achieved by simply adhering to theoretical profiles of strategy and organization. Thus, fit alone might not provide a complete explanation for performance. Despite those studies, it appears that the majority of the literature supports the following hypothesis:

\[ H1. \text{ Manufacturing strategy fit is positively related to manufacturing performance.} \]

2.2. Best practices

Research on “best practices” (BPs) in operations management came out in the 1980s as part of the effort to explain the success of Japanese manufacturing in Western markets (Voss, 1995; Laugen et al., 2005). According to Voss (1995), the concept of best practices has been often associated to “World Class Manufacturing” (WCM) (Hayes and Wheelwright, 1984; Schonberger, 1986). Examples of best practices include just-in-time, customer orientation, and advanced manufacturing technologies (Flynn et al., 1999; Narasimhan et al., 2005).

The literature on BPs is extensive, ranging from work on specific programs or technologies (e.g. Christmann, 2000) up to broad strategy and organization frameworks (e.g. Gratton and Ghoshal, 2005). Several empirical studies provided evidence for relationships between BPs and performance. Flynn et al. (1999) found significant correlations between WCM practices and performance. Laugen et al. (2005) carried out an exploratory study to identify BPs based on their ability to explain improvements in
quality, flexibility, speed, and cost. Narasimhan et al. (2005) found that manufacturing clusters with more intensive adoption of BPs also reported higher performance.

Despite the positive evidence, several authors have emphasized the risks of taking BPs for a management panacea. Their arguments evolve around three issues. First, Sousa and Voss (2001) and Davies and Kochhar (2002), among others, pointed out the need to consider variables of internal and external context when selecting BPs for adoption. Second, Pilkington (1998) and Harrison (1998) argued that sound operations strategies rather than BPs were the real drivers of improved performance. Finally, Hayes and Upton (1998) and Schroeder et al. (2002) suggested that an exclusive focus on BPs as opposed to innovation and capability building might constrain competitive advantage.

Overall, the literature leads to the second study hypothesis:

H2. Best practices adoption is positively related to manufacturing performance.

2.3. Capabilities

The idea of “competing through capabilities” in manufacturing has been introduced by authors such as Hayes and Pisano (1994) and Hayes and Upton (1998) who suggested that the true objective with manufacturing strategy was to build competencies for sustainable competitive advantage. Hayes and Pisano (1994) in particular were critical of implementing “faddish” programs such as just-in-time or Total Quality Management for short-term gains only, and even of relying on “strategic fit” in times of competitive turbulence.

The incorporation of capabilities or competence-based analyses in manufacturing strategy was much needed by the time of Hayes and Pisano’s (1994) article. As pointed
out by Snow and Hrebiniak (1980), the idea of “distinctive competencies” was introduced in the late 1950s by Selznick (1957), and expanded by Andrews (1971) to denote the activities a firm can do better than competitors. In economics, Wernerfelt (1984) formalized the “resource-based view of the firm” suggesting that a firm’s competitive advantage could be more easily explained by its resources than by its products. Barney (1991) established further that for resources to provide competitive advantage they must be valuable, difficult to obtain and substitute, and hard to imitate.

Schroeder et al. (2002) tested a model of manufacturing capabilities and performance. They classified resources and capabilities in three categories including “proprietary processes and equipment”, “internal learning”, and “external learning”. They found that performance in manufacturing could be explained by the first type of capability, which in turn was explained by the two learning capabilities. Their framework consolidated the main traditional sources of core capabilities explored in the literature, i.e. equipment investment (e.g. Maritan, 2001), knowledge and skills (e.g. Leonard-Barton, 1992), and supplier collaboration (e.g. McEvily and Marcus, 2005).

The study by Schroeder et al. (2002) followed on the lead of research that aimed at validating the capability building approach through its ability to support performance. Zahra and Das (1993) had earlier developed a framework where “distinctive competence” related to both “manufacturing strategy” and “competitive advantage”, which in turn influenced business and financial performance. Thus, the framework considered both “top-down” (i.e. fit) and “bottom-up” (i.e. capability-based) approaches as necessary to sustain competitiveness. Several studies, e.g. Das and Narasimhan (2000), O’Regan and
Ghobadian (2004), and Tracey et al. (2005) provided evidence for relationships between manufacturing capabilities and performance. They lead to the following hypothesis:

\[ H3. \text{Capability investment is positively related to manufacturing performance.} \]

2.4. Paradigm interactions

A major argument in Voss (1995) was that all paradigms needed to be considered in manufacturing strategy: “We can conclude that all three paradigms of manufacturing strategy have their strengths and weaknesses and each partially overlaps the other” (Voss, 1995: 14). Thus, manufacturing competitiveness should be at least partially explained by adoption of multiple paradigms.

Studies provided either theoretical or empirical validation to paradigm interactions. Hayes and Upton (1998) suggested that operations competitiveness relied on both capability development and fit. Christmann (2000) found that dynamic capabilities positively moderated relationships between environmental best practices and cost competitiveness. Swink et al. (2005) suggested that “strategic integration” moderated the relationship between best practices and operations performance, and that operations performance mediated the relationship between integration and market performance. As discussed earlier, several studies (e.g. Morita and Flynn, 1997; Sousa and Voss, 2001; Davies and Kochhar, 2002; Ketokivi and Schroeder, 2004; Narasimhan et al., 2005) indicated that the choice of best practices should be contingent on the priorities, processes, and existing practices in manufacturing. Thus, performance improvements might be at least partially explained by paradigm interactions. This idea leads to the final study hypothesis:
H4. Two-way and three-way interactions among the paradigms of fit, capabilities, and best practices will be positively associated to performance.

3. Data

The study uses data from the 2005 International Manufacturing Strategy Survey (IMSS-IV). IMSS is a global research program on operations strategies, practices, and performance. It is carried out periodically by operations strategy researchers from various countries and consolidated into a common database that is used by the network. Data from the 2005 round were received between January 10, 2005 and February 20, 2006 in 23 countries. The following general information about IMSS has appeared in several studies, e.g. Voss and Blackmon (1998) and Frohlich and Westbrook (2001).

The survey is focused on manufacturing companies under ISIC 3.1 codes 28 to 35. These codes relate to producers of metal products, machinery, and equipment including transport equipment. The analysis is focused on the business unit, which may consist of a whole company, division, or plant. Responses are obtained from each unit’s Director of Operations/Manufacturing or equivalent.

In most cases, respondents were contacted by varied methods in three stages. First, a phone call was made to check contact information and enquire about the respondent’s interest to fill out the questionnaire. Then, a questionnaire was sent via email, fax, or post. Later, follow-up phone calls were made to respondents and non-respondents. Questionnaires were returned directly to national research offices. Data were input into pre-designed spreadsheets and sent via email to the management team at Politecnico di Milano, Italy. The final database was distributed on November 30, 2006.
Twenty-three countries took part in IMSS-IV. However, one country had a very low response rate of 1% and had its responses dropped from this particular study. The 22 remaining countries were Argentina, Australia, Belgium, Brazil, Canada, China, Denmark, Estonia, Germany, Hungary, Ireland, Israel, Italy, New Zealand, Norway, Portugal, Sweden, the Netherlands, Turkey, UK, USA, and Venezuela. They sent out 3,051 questionnaires, of which 698 were valid returns. One further observation was dropped from the study as it had an extraordinary number of production days as work-in-process (z-score > 18), which would bias the FIT scale (discussed in the next session). The response rate of 23% appears compatible to other large-scale surveys, including those carried out in similar industries (Jonsson, 2000). Twelve country offices tested for demographic differences (size, ISIC) between respondents and non-respondents and found no significant results, suggesting the absence of non-response bias in the survey.

Spurious correlations due to common method bias (CMB) have been considered to have a non-significant influence in statistical analyses involving complex scales of fit (Doty et al., 1993) or interactions between independent variables (Evans, 1985), as these may be hardly anticipated by respondents at the time of the survey. Moreover, all of our independent scales summated multiple items obtained from different sections of the IMSS questionnaire. Still, we tested for the potential of CMB through Harman’s one-factor test by factor analyzing the study’s 37 items (Podsakoff et al., 2003). The analysis generated a large number of factors (k = 8, cumulative variance = 55%, n = 407), and the first factor in the unrotated solution explained just 23% of the variance. Thus, CMB did not appear to be of concern in our analysis.
4. Measures

4.1. Fit

Bozarth and Berry’s (1997) review indicated that the set of variables used in fit studies should meet requirements including theoretical correspondence, parsimony, and measurability. Following the first requirement, we selected IMSS-IV variables to estimate fit based on the Hill (2000) framework of process choice. We used his framework for three main reasons. First, it includes a broad range of structural and infrastructural choices. Second, it clearly associates choices to process types. Third, its application has been at the centre of the debate on “fit” versus “best practices”, as evident in the Hill et al. (1999) and Schonberger (1999) papers, and in the Voss (1995) paper.

Concerning the parsimony and measurability requirements in Bozarth and Berry (1997), we identified in the IMSS-IV database six variables that seemed to provide valid representation to structural and infrastructural choices in the Hill framework. This process was facilitated as IMSS has been designed at the outset to provide data for studies on manufacturing strategy issues including fit (e.g. da Silveira, 2005) and best practices (e.g. Laugen et al., 2005). Table A1 in Appendix A presents the variable definitions, descriptive statistics, and correspondence to aspects in Hill (2000).

In Hill’s (2000) terminology, the six identified variables include one “market-related” variable and five “manufacturing and investment” variables. The market variable – level of product changed required (CUSTOM) – captures the impact on manufacturing of a firm’s market positioning. The selection of the five manufacturing and investment variables drew on da Silveira’s (2005) study on fit, also based on Hill’s (2000) framework and on a previous iteration of the IMSS study (IMSS-III). Two variables –
process choice (PCCHOICE) and work-in-progress inventory (WIP) – were adopted from da Silveira (2005). A third variable – process automation (AUTOM) – was used in place of level of capital investment (CAPINV) since (i) AUTOM had a significantly higher response rate than CAPINV in IMSS-IV and (ii) the two variables were significantly correlated in IMSS-IV ($p = .001$). We also included two other variables to widen the scope of our fit scale: percentage of direct labor costs (LABORCOST) and level of finished goods inventory (GOODSINV).

We calculated fit scores using the “Compute Variable” dialog in SPSS® 15.0 (SPSS, 2006). Following the rationale in Dess (1987) and adopted by Lindman et al. (2001) and da Silveira (2005), we developed first a MISFIT scale by taking the standard deviation among the six variables of fit (note that high standard deviations correspond to low levels of fit). All of the variables were transformed to a 1-5 scale based on the observed maximum and minimum values in the sample (Table A1). Moreover, CUSTOM, LABORCOST, and WIP scores were inverted since their high values corresponded to low values of PCCHOICE, AUTOM, and GOODSINV. Thus, MISFIT was obtained by the following expression in SPSS®:

$$MISFIT = SD((6 - CUSTOM), (((360 - WIP)/90) + 1), (((GOODSINV/90) + 1), ((99.775 - LABORCOST)/19.775), AUTOM, ((PCCHOICE/25) + 1))$$

For example, a “best” MISFIT value of 0 would be given to a hypothetical company having the highest scores in PCCHOICE (100), AUTOM (5), and GOODSINV (360), and the lowest scores in CUSTOM (1), LABORCOST (.90), and WIP (0):

$$MISFIT = SD((6-1), (((360-0)/90)+1), (((360/90)+1), ((99.775-.90)/19.775), 5, (((100/25)+1)) = SD (5, 5, 5, 5, 5, 5) = 0$$
Following the equifinality assumption in Hill (2000), a similar *MISFIT* value of 0 would correspond to any sample company having scores across the six variables that were all at equivalent distance from the variables’ respective midpoint values.

As a last step, the scale of *FIT* was obtained by multiplying *MISFIT* scores by -1.

4.2. *Best practices*

We developed our best practices (*BP*) scale based on the work of Narasimhan et al. (2005). They carried out a thorough review of manufacturing strategy studies to identify seven variables of best practices representing a broad range of technologies and programs currently used in manufacturing. Based on their study and on Bozarth and Berry’s (1997) requirements discussed above, we selected from the IMSS-IV database seven items, each representing one of the best practices in Narasimhan et al. (2005). The major difference between our approach and theirs was that, whereas Narasimhan et al. (2005) used each best practice as a single independent variable, we built a single *BP* scale composed by seven items, each one representing one of their best practices. The difference in approaches is due to the objectives of the studies and the quest for parsimony: Narasimhan et al. (2005) focused on identifying best practices that were used at different clusters; we explored relationships involving other paradigms besides best practices.

Table A2 in Appendix A presents the *BP* items from IMSS-IV with descriptive statistics and their correspondence to practices in Narasimhan et al. (2005). Our first attempt to validate the scale with all seven items was unsuccessful. The principal components analysis generated two components (one with six items, another with *CUSTRD* only; *ORGINT* loaded on both components). Besides, the Cronbach’s alpha for the seven-item scale was .671, which is not usually accepted for scales based on the
literature (Hair et al., 1998). This led us to drop CUSTRD from the scale, which in our view did not significantly affect construct validity since other studies have considered “customer orientation” as intrinsically related to remaining items in the scale such as organizational integration/QFD (e.g. Herrmann et al., 2006) and continuous improvements/TQM (e.g. Chow and Lui, 2001). After dropping CUSTRD, the analysis yielded a single component with eigenvalue greater than one and factor loadings ranging from .519 to .728 (n = 555). The Cronbach’s alpha for the six-item scale was .708, which is above the minimum threshold of .7 (Nunally and Bernstein, 1994; Lattin et al., 2003). Thus, the BP scale was calculated by taking the average between the six items of ORGINT, QPROGRAM, CI, PULL, SUPSTRAT, and FMS.

4.3. Capabilities

The development of the manufacturing capability scale was based on the work of Schroeder et al. (2002). They studied the performance relationships of three types of manufacturing capabilities, namely “internal learning”, “external learning”, and “process and equipment”. They operationalized those constructs with measures of worker development, supply chain relationships, and manufacturing technology. We built a scale composed by items of capability development in IMSS-IV that matched constructs in Schroeder et al. (2002).

Table A3 in Appendix A presents the items and their descriptive statistics. In our capability (CAP) scale, Schroeder et al.’s (2002) “internal learning” and “process and equipment” were each represented by one item but “external learning” was represented by two items, i.e. one for suppliers and one for customers. In our first attempt, we did create a single “external learning” item given by the average answers given to those two
questions; however, the resulting three-item scale had a low Cronbach’s alpha of .637. Moreover, studies such as Frohlich and Westbrook (2001) suggested that coordination with suppliers and with customers represented different types of strategies. Thus, we decided to incorporate the two items in separate.

Principal components analysis validated the CAP scale as the four items loaded on a single component with eigenvector greater than one and loadings ranging from .641 to .790 (n = 601). The Cronbach’s alpha was .703, suggesting the scale was reliable. Thus, the CAP scale was calculated by taking the average of responses given to the four items on Table A3.

4.4. Performance

The dependent variables were obtained from the IMSS-IV question on manufacturing performance improvements: “How has your operational performance changed over the last three years?” Answers were given in a scale with five points: (1) “deteriorated more than 10%”, (2) “stayed about the same”, (3) “improved 10%-30%”, (4) “improved 30%-50%”, and (5) “improved more than 50%”.

Responses were given to 20 items of performance. The items were used to generate performance scales through exploratory factor analysis with principal components and Varimax rotation. Both the Bartlett’s test of sphericity (p < .001) and the KMO measure of sample adequacy (.929) suggested the sample was suitable for factor analysis (Hair et al., 1998).

We carried out the analysis in four rounds to generate performance scales that were valid and reliable. In each of the first and second rounds, we dropped the one item
(delivery speed, labor productivity) that had the highest significant cross-loading. In the third round, we dropped one item (capacity utilization) that did not load on any component. In the fourth round, we obtained three components with eigenvalues greater than one and no significant cross-loadings (Table B1 in Appendix B). Cronbach’s alphas were all greater than .7 and inter-item correlations were all above .4, suggesting that scales had acceptable reliability and consistency (Hair et al., 1998). Inter-item correlations were always higher than average correlations with items from other scales, indicating acceptable discriminant validity (Flynn et al., 1999; Wageman et al., 2005). The summated scales of EFFICIENCY, QUALITY, and FLEXIBILITY were calculated by taking the averages of their respective items.

5. Analysis

Hypotheses were tested via regression analysis. Cases with missing data were deleted listwise from the analysis. Little's tests (Little, 1988) were carried out in SPSS® 15.0 (SPSS, 1997); they were non significant both for the 37 individual items ($\chi^2 = 4651.180$, d.f. = 4653, $p = .505$) and for the six independent and dependent scales ($\chi^2 = 125.837$, d.f. = 119, $p = .316$). So, missing data could be assumed to be missing completely at random (MCAR). Listwise deletion of cases with missing data has been considered a valid approach under MCAR (Chen and Åstebro, 2003; Fichman and Cummings, 2003).

Table 1 presents descriptive statistics and correlations among dependent and independent variables. The descriptive statistics appeared all consistent with the definition of variables. The positive correlations among the three variables of performance indicated that sample companies that achieved improvements in one
performance dimension were more likely to achieve improvements in the other dimensions. The positive correlations between \( \text{CAP} \) and \( \text{BP} \) and between \( \text{FIT} \) and \( \text{CAP} \) suggested that companies that developed capabilities were more likely to maintain fit and to implement best practices. Six of the nine correlations between dependent and independent variables were significant and positive. Those correlations provided further justification to test the study hypotheses.

\[
\text{Table 1 about here}
\]

5.1. Test of direct relationships (H1-H3)

Regression analyses were carried out to test hypotheses H1 to H3. Because of their high correlations, the three independent variables of \( \text{FIT} \), \( \text{BP} \), and \( \text{CAP} \) were entered in separate in models 1 to 3 to assess unique relationships with criterion variables. Standardized residual plots suggested no significant departures from normality in the models.

Table 2 presents the regression analyses. H1 was not supported as \( \text{FIT} \) was not significantly related to any performance variable. H2 was accepted as \( \text{BP} \) related positively and significantly to \( \text{EFFICIENCY} \), \( \text{QUALITY} \), and \( \text{FLEXIBILITY} \) \((p < .001)\). The results suggest that firms that used to a higher extent practices, e.g. quality programs, pull production, and organizational integration obtained higher performance improvements in a three-year period than firms that used those practices to a lesser extent. H3 was accepted as \( \text{CAP} \) related positively and significantly to \( \text{EFFICIENCY} \), \( \text{QUALITY} \), and \( \text{FLEXIBILITY} \) \((p < .001)\). The results suggest that firms that more intensively built on labor, equipment, supplier, and customer-related capabilities achieved
greater performance improvements than firms that gave less emphasis to capability development.

Table 2 about here

5.2. Test of moderated relationships (H4)

To test for H4 on interaction effects, we estimated a series of hierarchical regression models having the main and interactive terms of the paradigms as independent variables, and the three performance scales as dependent variables. We first centered all of the independent variables to minimize multicollinearity in the models (Jaccard et al., 1990). Following Evans (1985) and Aiken and West (1991), we tested two-way interactions through models entering a pair of independent variables in step 1 and their product in step 2. Product terms were introduced over the single variables to test for “additional” effects (Cohen and Cohen, 1983). For example, to explore the interaction of FIT and BP on EFFICIENCY we estimated the following model:

\[
EFFICIENCY_i = \beta_0 + \beta_1FIT_i + \beta_2BP_i + \beta_3(FIT \times BP)_i + \epsilon_i
\]

However, none of the nine possible two-way interactions yielded significant estimates. The interaction terms (and their coefficient significance values) were FIT x BP (\(p = .181\)), FIT x CAP (\(p = .362\)), and BP x CAP (\(p = .278\)) in the EFFICIENCY model; FIT x BP (\(p = .313\)), FIT x CAP (\(p = .623\)), and BP x CAP (\(p = .181\)) in the QUALITY model; FIT x BP (\(p = .566\)), FIT x CAP (\(p = .424\)), and BP x CAP (\(p = .979\)) in the FLEXIBILITY model. The results suggest that no paradigm alone had a significant influence on performance relationships of any other paradigm.
Having discarded the two-way interactions, we carried out three-way interaction tests. Based on Aiken and West (1991), we built hierarchical models having the single variables in step 1, all two-way interactions in step 2, and the three-way interaction in step 3, for example:

\[
\text{EFFICIENCY}_i = \beta_0 + \beta_1 \text{FIT}_i + \beta_2 \text{BP}_i + \beta_3 \text{CAP}_i + \beta_4 (\text{FIT} \times \text{BP}) + \beta_5 (\text{FIT} \times \text{CAP}) \\
+ \beta_6 (\text{BP} \times \text{CAP}) + \beta_7 (\text{FIT} \times \text{BP} \times \text{CAP}) + \epsilon_i
\]

The results in Table 3 (step 3) provide partial support to H4 as the \(\text{FIT} \times \text{BP} \times \text{CAP}\) term had positive and significant coefficients and \(F\)-change in both the \(\text{EFFICIENCY}\) \((p = .038)\) and \(\text{QUALITY}\) models \((p = .037)\), although they were non-significant in the \(\text{FLEXIBILITY}\) model \((p = .304)\). The significant results suggest that performance relationships of one paradigm could be significantly enhanced by adoption of the other two paradigms. This analysis would also suggest a significant interaction between \(\text{FIT}\) and \(\text{BP}\) in the \(\text{QUALITY}\) model; however, we drew no conclusions from that result since it was obtained from a model with all of the two-way interactions rather than from the single-interaction model prescribed by Aiken and West (1991). Moreover, Cohen and Cohen (1983: 348) suggested that results obtained by more parsimonious models are more reliable as they give more degrees of freedom to the error term.

Table 3 about here

To better interpret the three-way interactions, we prepared four regression plots for models of \(\text{EFFICIENCY}\) and \(\text{QUALITY}\) on \(\text{BP}\) or \(\text{CAP}\) as predictor, and \([\text{FIT and CAP}]\) or \([\text{FIT and BP}]\) respectively as moderators (we did not test for \(\text{FIT}\) as predictor because of results in H1). We used the typical plots for three-way moderation having relationships between predictor and outcome shown under the four combinations of either high or low.
adoption (set respectively at -1 and +1 standard deviations from the centered mean) of the
two moderators (Aiken and West, 1991; Dawson and Richter, 2006). We used the “3-way
unstandardised” worksheet developed by Jeremy Dawson and available though his
website (Dawson, 2007). We also carried out tests of differences ($p < .05$) between slopes
that were developed by Dawson and Richter (2006) and were similarly available in
Dawson’s worksheet. Figure 1 shows the three-way interaction plots.

*Figure 1 about here*

The plots in Figure 1 explain how *FIT*, *CAP*, and *BP* moderated performance
relationships with other paradigms. The first model of *CAP* as predictor and
*EFFICIENCY* as outcome showed a significant difference between slopes 1 and 2. Thus,
under high *FIT* only, *BP* appeared to significantly moderate relationships between *CAP*
and *EFFICIENCY*. The model of *QUALITY* on *CAP* indicated that slope 2 was
significantly different from the other three slopes. Again, in a high *FIT* situation, *BP*
appeared to moderate the relationship between *CAP* and the performance variable. The
models of *EFFICIENCY* on *BP* and *QUALITY* on *BP* can be discussed in tandem. Note
that slope 1 was significantly different from slopes 2 and 3 in both models, and also from
slope 4 in the *QUALITY* model. Therefore, the two plots on the bottom of Figure 1
suggest that *BP* relationships with performance were moderated by both *FIT* and *CAP*.

Thus, even though *FIT* had no direct relationships with performance, it did appear to
moderate performance relationships of *BP* and *CAP*, as long as the other moderating
variable (*CAP* or *BP*) was also high. On the other hand, *BP* and *CAP* appeared to have a
dual role both as direct predictors and as moderators of each other’s relationships (when
*FIT* was also high). The difference between *CAP* and *BP* was that *CAP* appeared to relate
to performance even at low levels of \textit{FIT} and \textit{BP}, whereas \textit{BP} appeared to relate to performance especially at high \textit{FIT} and high \textit{CAP}.

6. Discussion

Collectively, the results suggest that all paradigms are relevant, but have different roles. Building capabilities and adopting best practices (BPs) both have direct effects on all performance dimensions (quality, efficiency and flexibility), while fit has no direct relationship with performance. Therefore, developing manufacturing capabilities and adopting best practices seem to be at the core of producing manufacturing performance.

However, fit seems to play a key role in enhancing the performance relationships with capabilities and BPs. As a matter of fact, the absence of two-way interactions between capabilities and BPs shows that none of these two paradigms alone had a significant influence on the performance relationships of the other. On the contrary, the existence of significant three-way interactions shows that the performance relationships (quality and efficiency) of one paradigm could be significantly enhanced only by the adoption of the other two paradigms. In this context, the effects of the fit paradigm seem to be at two levels. First, only when fit is high will capabilities and BPs positively moderate each other’s performance relationships. So, reaping the synergies between the capabilities and BPs paradigms seems to require achieving fit. Second, fit enhances the relationship between one paradigm (capabilities or BPs) and performance when the other paradigm (BPs or capabilities) is also high. So, when one paradigm (capabilities or BPs) is highly adopted, the moderating effects of the other (BPs or capabilities) are enhanced by a good degree of fit. Jointly, these two effects suggest that fit plays a hygienic role, creating a better environment to implement capabilities and BPs.
Overall, the hygienic role of fit lends strong support for a contingency view of best practices and capabilities (Voss, 1995; Sousa and Voss, 2001; Ketokivi and Schroeder, 2004). However, this is not in the sense of fit being a necessary condition (given that capabilities and BPs have direct effects on performance), but rather of being an enhancer of performance effects of capabilities and BPs. This means that, in order to maximize the benefits from best practices and capabilities development programs, these initiatives should strive not to disrupt fit. For example, according to the present wisdom about the applicability of JIT production, the benefits derived from the adoption of JIT scheduling in a low volume/high variety process may not be fully realized, as this practice may disrupt fit (even though this process may be properly aligned with the market). As another example, investments in process and equipment capabilities may not be maximized if they cause misalignment between processes and markets.

Interestingly, our results suggest that, at least within the range of values observed in our sample, situations of misfit per se do not have a significantly negative impact on manufacturing performance. Using a previous edition of the research database used in our study, da Silveira (2005) similarly found that fit appeared to relate to market share only and not to business performance metrics including return on sales and return on investment. In this connection, our results would support Hayes and Pisano’s (1994) capabilities’ view that fit alone cannot explain performance in manufacturing, especially if we consider current markets as increasingly more turbulent than in the past. Similarly, they find resonance with supporters of the best practices paradigm (e.g. Schonberger, 1999) who argue that a plant exhibiting high degrees of coherence between internal and external choices but employing obsolete practices would most likely not be a good
performer. Finally, they conform to previously discussed studies (Habib and Victor, 1991; Barth, 2003) that found no direct relationships between fit and performance. However, they would be at odds with studies that found direct effects of fit on business performance; one hypothesis might be that those studies could be in fact detecting effects of fit on performance through its interactions with existing best practices and capabilities in study samples.

Our results lead us to re-assess Voss’s (1995) seminal “paradigm series” model. This model can be interpreted as comprising three core notions: i) each of the three paradigms contributes individually to performance; ii) there are two-way and three-way interactions between paradigms; and iii) there is a continuous iterative process of paradigm adoption that firms should go through, in the sequence capabilities-fit-BPs.

Due to the cross-sectional nature of our study, we examine the first two notions of Voss’s (1995) model. The results lead us to hypothesize a modified “two plus one” model of manufacturing strategy comprising the following core notions: a) capabilities and BPs have direct effects on performance; ib) fit plays a hygienic role, enhancing the performance effects of capabilities and BPs; ii) three-way interactions between paradigms provide additional explanation for performance improvements in manufacturing.

Such a “two plus one” model of manufacturing strategy paradigms is broadly consistent with Voss’s (1995) framework in the sense that all three paradigms will be somehow relevant. However, it provides a new perspective on the individual role of the paradigms and their interrelationships. The main difference between our results and Voss’s (1995) results concerns the role of the fit paradigm and its implications for paradigm interactions. Voss (1995) proposes that all three paradigms had direct
contributions to performance. On the contrary, in our model the fit paradigm is in a separate category and seems to play a mainly hygienic role. We can derive our model from Voss’s (1995) model by removing the fit paradigm from the performance cycle and assigning it a supportive role to a shorter capabilities-BPs cycle. Moreover, whereas Voss (1995) considers the existence of two-way and three-way interactions between paradigms, our model considers only three-way interactions framed around the hygienic role of fit.

We searched for links between our proposed “two plus one” model and existing theory (following the “triangulation” rationale in Miles and Huberman (1994: 266-267)). In particular, we sought potential explanations for the uncovered interaction effects, an area of the model that was developed post-hoc. We first examine the hygienic role of fit.

Our model suggests that achieving fit enhances the impact of new and better capabilities (under high best practice adoption). This may be due to the fact that a plant with incoherent choices (e.g. way off the diagonal in Hayes and Wheelwright’s (1979) product-process matrix) may consume substantial managerial resources in dealing with these inadequacies, resulting in an environment which may be less amenable to the effective development and deployment of production capabilities. Specifically, such an environment may not be conducive to “induced learning” (or second-order learning), i.e. learning that depends on conscious actions by management and requires efforts and resources that are not present in the current operating situation (Dutton and Thomas, 1984). Such learning consists in explicit and formal changes in technology, equipment, processes, or human capital (Adler and Clark, 1991) and has been shown to be essential for overall organizational learning (e.g. Ittner et al., 2001).
A similar argument can be made about our proposition that fit enhances the impact of best practices (under high capabilities). This may occur again because the environment resulting from a poor fit environment is fraught with problems that make it difficult to reap the benefits from the adoption of best practices (e.g. trying to get benefits from the use of Statistical Process Control in a line process that is inadequately matched to a low volume/high variety market).

We now examine the interactions between capabilities and BPs (under high fit). Our model posits that the impact of best practices is enhanced by sufficiently developed capabilities. This may occur because organizational capabilities allow a firm to know why, how and when to execute a certain practice (Ketokivi and Schroeder, 2004). A plant with poor capabilities may not have the necessary “absorptive capacity” (Cohen and Levinthal, 1990) to adequately recognize the value of and assimilate best practices, especially in today’s business environment in which many of these practices are externally generated. This logic is consistent with the earlier discussed manufacturing strategy studies which suggested that an exclusive focus on best practices in detriment of capabilities hampers competitive advantage (Hayes and Upton; 1998; Schroeder et al., 2002). In a similar vein, our model posits that the use of best practices enhances the impact of capabilities. This is consistent with the perspective that the use of best practices contributes to further learning and developing capabilities (e.g. Hayes and Pisano, 1996; Swink and Hegarty, 1998). For example, it has been shown that the use of quality management practices is an important driver of learning and knowledge creation (Li and Rajagopalan, 1997; Mukherjee et al., 1998; Choo et al., 2007).
Again, however, we emphasize that such moderated effects appeared only under high fit. Thus, we may state that our “two plus one” model finds support in several theories and concepts applied in the manufacturing strategy field with an added twist: that only three-way interactions involving fit, best practices, and capability building may provide additional explanation for performance improvements.

The full-blown model applies to two of our three performance dimensions, i.e. efficiency and quality, but not flexibility. Although flexibility performance appears to be directly related to BPs and capabilities, these relationships did not seem to be moderated by fit. This suggests that fit would not be relevant. One possible explanation for this finding may be that because flexibility is at the last stages of the cumulative model (Ferdows et al., 1986), the three-way interaction effects might be obscured by the effects on flexibility of the quality and efficiency performance improvements per se (which in turn are affected by three-way interactions of the paradigms).

Conclusions

This study sets out to explore performance relationships involving Voss’s (1995) three paradigms of manufacturing strategy: fit, capability building, and best practices. It proposes a “two plus one” model of paradigm implementation that appears empirically and theoretically valid. This model posits that manufacturing strategy relies on a “two plus one” model of paradigms having capabilities and best practices as the main predictors of performance, and fit as a positively moderator of such outcomes.

Our results have important implications for research and practice. Concerning research, the results suggest that although individual paradigms relate to performance, it is by examining the three paradigms jointly and their interactions that their performance
relationships are adequately understood. Hence, existing research that has mainly looked at each paradigm in isolation should be complemented by studies on multiple paradigms. We have put forward a theoretical triangulation of the proposed model (Miles and Huberman, 1994: 266-267) that uses major manufacturing strategy theories and concepts to explain interactions between paradigms that were revealed in our data. Although each paradigm has a solid theory base, comparatively less work has been conducted to date on adequately understanding their interactions beyond the mere discussion of links and relationships between paradigms. This study motivates future work aimed at a deeper theoretical understanding of paradigm interactions.

For practitioners, this study re-asserts the relevance of each paradigm, so that firms should not ignore any of them. In addition, the model provides insights as to the hygienic role of fit in manufacturing strategy choice. In a nutshell, firms are advised to build their performance advantage by developing capabilities, adopting best practices, and exploring synergies between these two; all the while striving to maintain fit. The model may also act as a reference for diagnosing plants from a manufacturing strategy perspective, especially in what concerns detecting deviations from the suggested architecture of paradigm interactions. For example, in a plant fit may exist and best practices may be heavily adopted, but performance may be still lagging due to lack of capabilities to extract the maximum benefit from those practices. Or a plant may have strong capabilities and a high level of best practice adoption, but performance may be still lower than expected due to inconsistencies between structural and infrastructural choices.

The study has some limitations, which in themselves provide opportunities for future research. First, due to limited theory on paradigm interactions, our model development
has been post-hoc. Hence, in what concerns paradigm interactions, our exploratory study can be seen as theory extension/refinement (i.e. attempting to better structure theory in light of the observed results, as explained by Handfield and Melnyk (1998)). Therefore, our model should be further tested. In particular, longitudinal research would allow for scrutinizing the issues of causality and inter-paradigm dynamics in more detail. In addition, such research would allow complementing our model with assertions concerning the optimum sequence of adoption of the paradigms. Second, as discussed earlier, the interaction effects in the model were not supported in what concerns flexibility performance. Future research should attempt to clarify whether flexibility performance adheres to our model or may be a special case.

Finally, at first glance our model would appear to be at odds with past research that found that fit had a direct impact on business performance. However, since our study focused on relationships with operations rather than business performance, new studies should explore if relationships between business performance and fit could be explained by the moderating effects of fit on capabilities and best practices rather than by direct effects. Alternatively, researchers might focus on discovering what specific configurations of fit (i.e. different from the framework employed in our study) might explain performance, for example by testing different sets of variables or by attributing different weights to variables used to estimate fit.

We are confident that this study significantly contributes to the ongoing debate of paradigms of choice in manufacturing strategy, thus helping to move the field forward. We hope that the innovativeness of the proposed model will foster more groundbreaking research aimed at a deeper understanding of the dynamics of paradigm interactions.
References


Table 1

Descriptive statistics and Pearson correlations ($n = 416$)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>S.D.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. EFFICIENCY</td>
<td>1.17</td>
<td>5.00</td>
<td>2.66</td>
<td>.60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. QUALITY</td>
<td>1.17</td>
<td>5.00</td>
<td>2.89</td>
<td>.61</td>
<td>.608***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. FLEXIBILITY</td>
<td>1.00</td>
<td>5.00</td>
<td>2.93</td>
<td>.61</td>
<td>.575***</td>
<td>.617***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. FIT</td>
<td>-2.06</td>
<td>-0.39</td>
<td>-1.56</td>
<td>.21</td>
<td>.027</td>
<td>.001</td>
<td>.044</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. BP</td>
<td>1.00</td>
<td>5.00</td>
<td>2.81</td>
<td>.71</td>
<td>.277***</td>
<td>.278***</td>
<td>.232***</td>
<td>.079</td>
<td></td>
</tr>
<tr>
<td>6. CAP</td>
<td>1.00</td>
<td>5.00</td>
<td>2.69</td>
<td>.76</td>
<td>.323***</td>
<td>.288***</td>
<td>.235***</td>
<td>.143**</td>
<td>.745***</td>
</tr>
</tbody>
</table>

* $p < .05$; ** $p < .01$; *** $p < .001$ (two-tailed).
Table 2
Tests of direct relationships \((n = 416)\)

<table>
<thead>
<tr>
<th></th>
<th>EFFICIENCY</th>
<th>QUALITY</th>
<th>FLEXIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>2.781***</td>
<td>2.891***</td>
<td>3.130***</td>
</tr>
<tr>
<td>(FIT)</td>
<td>.076</td>
<td>.004</td>
<td>.127</td>
</tr>
<tr>
<td>(R^2)</td>
<td>.001</td>
<td>.000</td>
<td>.002</td>
</tr>
<tr>
<td>(F)-Change</td>
<td>.297</td>
<td>.001</td>
<td>.804</td>
</tr>
<tr>
<td><strong>Model 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>1.997***</td>
<td>2.209***</td>
<td>2.367***</td>
</tr>
<tr>
<td>(BP)</td>
<td>.237***</td>
<td>.240***</td>
<td>.201***</td>
</tr>
<tr>
<td>(R^2)</td>
<td>.077</td>
<td>.077</td>
<td>.054</td>
</tr>
<tr>
<td>(F)-Change</td>
<td>34.360***</td>
<td>34.744***</td>
<td>23.576***</td>
</tr>
<tr>
<td><strong>Model 3</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>1.965***</td>
<td>2.258***</td>
<td>2.419***</td>
</tr>
<tr>
<td>(CAP)</td>
<td>.259***</td>
<td>.233***</td>
<td>.191***</td>
</tr>
<tr>
<td>(R^2)</td>
<td>.105</td>
<td>.083</td>
<td>.055</td>
</tr>
<tr>
<td>(F)-Change</td>
<td>48.389***</td>
<td>37.523***</td>
<td>24.236***</td>
</tr>
</tbody>
</table>

\(\ast p < .05; ** p < .01; *** p < .001\); unstandardized regression coefficients are shown.
Table 3
Tests of three-way interactions (n = 416)

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>EFFICIENCY</th>
<th>QUALITY</th>
<th>FLEXIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intercept</td>
<td>2.662***</td>
<td>2.885***</td>
<td>2.932***</td>
</tr>
<tr>
<td></td>
<td>FIT¹</td>
<td>-0.050</td>
<td>-0.106</td>
<td>0.041</td>
</tr>
<tr>
<td></td>
<td>BP¹</td>
<td>0.068</td>
<td>0.121*</td>
<td>0.112</td>
</tr>
<tr>
<td></td>
<td>CAP¹</td>
<td>0.213***</td>
<td>0.153**</td>
<td>0.111</td>
</tr>
<tr>
<td></td>
<td>$R^2$</td>
<td>0.108</td>
<td>0.094</td>
<td>0.063</td>
</tr>
<tr>
<td>2</td>
<td>Intercept</td>
<td>2.644</td>
<td>2.870</td>
<td>2.927</td>
</tr>
<tr>
<td></td>
<td>FIT¹</td>
<td>-0.018</td>
<td>-0.110</td>
<td>0.066</td>
</tr>
<tr>
<td></td>
<td>BP¹</td>
<td>0.073</td>
<td>0.121*</td>
<td>0.116</td>
</tr>
<tr>
<td></td>
<td>CAP¹</td>
<td>0.217***</td>
<td>0.158**</td>
<td>0.112</td>
</tr>
<tr>
<td></td>
<td>FIT x BP</td>
<td>0.321</td>
<td>0.624*</td>
<td>-0.030</td>
</tr>
<tr>
<td></td>
<td>FIT x CAP</td>
<td>-0.056</td>
<td>-0.491</td>
<td>0.182</td>
</tr>
<tr>
<td></td>
<td>BP x CAP</td>
<td>0.041</td>
<td>0.047</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>$R^2$</td>
<td>0.115</td>
<td>0.107</td>
<td>0.065</td>
</tr>
<tr>
<td></td>
<td>F-change</td>
<td>1.091</td>
<td>2.042</td>
<td>0.293</td>
</tr>
<tr>
<td>3</td>
<td>Intercept</td>
<td>2.638***</td>
<td>2.865***</td>
<td>2.925***</td>
</tr>
<tr>
<td></td>
<td>FIT¹</td>
<td>-0.182</td>
<td>-0.277</td>
<td>-0.019</td>
</tr>
<tr>
<td></td>
<td>BP¹</td>
<td>0.065</td>
<td>0.113</td>
<td>0.112</td>
</tr>
<tr>
<td></td>
<td>CAP¹</td>
<td>0.223***</td>
<td>0.164**</td>
<td>0.115</td>
</tr>
<tr>
<td></td>
<td>FIT x BP</td>
<td>0.357</td>
<td>0.661*</td>
<td>-0.011</td>
</tr>
<tr>
<td></td>
<td>FIT x CAP</td>
<td>0.026</td>
<td>-0.408</td>
<td>0.224</td>
</tr>
<tr>
<td></td>
<td>BP x CAP</td>
<td>0.065</td>
<td>0.072</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td>FIT x BP x CAP</td>
<td>0.404*</td>
<td>0.412*</td>
<td>0.209</td>
</tr>
<tr>
<td></td>
<td>$R^2$</td>
<td>0.124</td>
<td>0.116</td>
<td>0.067</td>
</tr>
<tr>
<td></td>
<td>F-change</td>
<td>4.330*</td>
<td>4.364*</td>
<td>1.060</td>
</tr>
</tbody>
</table>

* $p < .05$; ** $p < .01$; *** $p < .001$; ¹centered variables; unstandardized regression coefficients are shown.
Figure 1. Regression plots of three-way interactions. Numbers in brackets indicate significantly different slopes ($p < .05$).
Appendix A. Independent variables.

Table A1

Fit scale \((n = 529)\)

<table>
<thead>
<tr>
<th>Study variable</th>
<th>IMSS-IV Question/Item</th>
<th>Aspect in Hill (2000: 122-123)</th>
<th>(n)</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUSTOM</td>
<td>Which of the following best describes the level of customisation of your dominant activity? (Tick one): (1) standard products; (2) modularized products; (3) platform products; (4) customized to some extent; (5) made entirely to customer’s specification</td>
<td>“Level of product change required”</td>
<td>686</td>
<td>1</td>
<td>5</td>
<td>3.32</td>
<td>1.27</td>
</tr>
<tr>
<td>PCCHOICE</td>
<td>To what extent are your manufacturing activities organized in the following layout categories (indicated percentage of total volume): Dedicated lines __%</td>
<td>“Process choice”</td>
<td>681</td>
<td>0</td>
<td>100</td>
<td>38.30</td>
<td>38.84</td>
</tr>
<tr>
<td>WIP</td>
<td>How many days of production (on average) do you carry in the following inventories: Work-in-process</td>
<td>“Level of inventory – Work-in-progress”</td>
<td>626</td>
<td>0</td>
<td>360</td>
<td>17.40</td>
<td>27.70</td>
</tr>
<tr>
<td>AUTOM</td>
<td>Indicate degree of the following action programmes undertaken over the last three years [(1) none; 5 (high)]: Engaging in process automation programs</td>
<td>“Level of capital investment”</td>
<td>669</td>
<td>1</td>
<td>5</td>
<td>2.68</td>
<td>1.17</td>
</tr>
<tr>
<td>GOODSINV</td>
<td>How many days of production (on average) do you carry in the following inventories: Finished goods</td>
<td>“Level of inventory – Finished goods”</td>
<td>623</td>
<td>0</td>
<td>360</td>
<td>17.85</td>
<td>32.07</td>
</tr>
<tr>
<td>LABORCOST</td>
<td>Estimate the present cost structure in manufacturing (NB: percentages should add up to 100 %): Direct salaries/wages __%</td>
<td>“Percentage of total costs – Direct labor”</td>
<td>629</td>
<td>.90</td>
<td>80</td>
<td>21.01</td>
<td>12.99</td>
</tr>
</tbody>
</table>
Table A2
Best practices scale ($n = 555$)

| Study variable | IMSS-IV Question/Item                                                                 | Variable in Narasimhan et al. (2005: 1018) | $n$ | Min | Max | Mean | S.D.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ORGINT</strong></td>
<td>Indicate degree of the following action programmes undertaken over the last three years [(1) none; (5) high]: Increasing the organizational integration between product development and manufacturing through e.g. Quality Function Deployment, Design for manufacturing, Design for assembly, teamwork, job rotation and co-location, etc.</td>
<td>“Integrated technology development (ITD)”</td>
<td>661</td>
<td>1</td>
<td>5</td>
<td>2.83</td>
<td>1.03</td>
</tr>
<tr>
<td><strong>QPROGRAM</strong></td>
<td>Undertaking programs for quality improvement and control (e.g. TQM programs, $\sigma$ projects, quality circles, etc.)</td>
<td>“Statistical process control (SPC)”</td>
<td>656</td>
<td>1</td>
<td>5</td>
<td>3.10</td>
<td>1.08</td>
</tr>
<tr>
<td><strong>CI</strong></td>
<td>Implementing Continuous Improvement Programs through systematic initiatives (e.g. kaizen, improvement teams, etc)</td>
<td>“Quality culture (QCULT)”</td>
<td>671</td>
<td>1</td>
<td>5</td>
<td>2.93</td>
<td>1.14</td>
</tr>
<tr>
<td><strong>PULL</strong></td>
<td>Undertaking actions to implement pull production (e.g. reducing batches, setup time, using kanban systems, etc.), Rethinking and restructuring supply strategy and the organization and management of suppliers portfolio through e.g. tiered networks, bundled outsourcing, and supply base reduction.</td>
<td>“Just-in-time operations (JIT)”</td>
<td>659</td>
<td>1</td>
<td>5</td>
<td>2.90</td>
<td>1.19</td>
</tr>
<tr>
<td><strong>SUPSTRAT</strong></td>
<td>To what extent is the operational activity in your plant performed using the following technologies [(1) no use; (5) high use]: Flexible manufacturing/assembly systems – cells (FMS/FAS/FMC)</td>
<td>“Strategic supply management (SSM)”</td>
<td>649</td>
<td>1</td>
<td>5</td>
<td>2.73</td>
<td>1.02</td>
</tr>
<tr>
<td><strong>FMS</strong></td>
<td>To what extent do the following stakeholders collaborate with the R&amp;D function in your product development process? [(1) no collaboration; (5) high collaboration]: Customers</td>
<td>“Advanced manufacturing technology (AMT)”</td>
<td>655</td>
<td>1</td>
<td>5</td>
<td>2.31</td>
<td>1.38</td>
</tr>
<tr>
<td><strong>CUSTRD</strong></td>
<td></td>
<td>“Customer oriented manufacturing (COM)”</td>
<td>668</td>
<td>1</td>
<td>5</td>
<td>3.46</td>
<td>1.10</td>
</tr>
</tbody>
</table>
## Table A3

Capability scale \((n = 601)\)

<table>
<thead>
<tr>
<th>Study variable</th>
<th>IMSS-IV Question/Item</th>
<th>Variable in Schroeder et al. (2002: 116-117)</th>
<th>(n)</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EQUIPCAP</td>
<td>Indicate degree of the following action programmes undertaken over the last three years ([(1) none; (5) high]):</td>
<td>“Process and Equipment”</td>
<td>671</td>
<td>1</td>
<td>5</td>
<td>2.85</td>
<td>1.11</td>
</tr>
<tr>
<td></td>
<td>Undertaking programs for the improvement of your equipment productivity (e.g. Total Productive Maintenance programs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LABORCAP</td>
<td>Implementing actions to increase the level of delegation and knowledge of your workforce (e.g. empowerment, training, autonomous teams, etc.)</td>
<td>“Internal learning”</td>
<td>673</td>
<td>1</td>
<td>5</td>
<td>2.89</td>
<td>.98</td>
</tr>
<tr>
<td>SUPPLYCAP</td>
<td>Increasing the level of coordination of planning decisions and flow of goods with suppliers including dedicated investments (in e.g. Extranet/EDI systems, dedicated capacity/tools/equipment, dedicated workforce, etc.)</td>
<td>“External learning” (suppliers)</td>
<td>644</td>
<td>1</td>
<td>5</td>
<td>2.57</td>
<td>1.02</td>
</tr>
<tr>
<td>CUSTCAP</td>
<td>Increasing the level of coordination of planning decisions and flow of goods with customers including dedicated investments (in e.g. Extranet/EDI systems, dedicated capacity/tools/equipment, dedicated workforce, etc.)</td>
<td>“External learning” (customers)</td>
<td>630</td>
<td>1</td>
<td>5</td>
<td>2.58</td>
<td>1.05</td>
</tr>
</tbody>
</table>
Appendix B. Dependent variables.

Table B1
Principal components analysis of performance scales.

<table>
<thead>
<tr>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>EFFICIENCY (*651; b.830; c.447; d.324)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit manufacturing cost</td>
<td>.762</td>
<td>.203</td>
<td>.115</td>
</tr>
<tr>
<td>Procurement lead time</td>
<td>.731</td>
<td>.158</td>
<td>.309</td>
</tr>
<tr>
<td>Procurement costs</td>
<td>.724</td>
<td>.109</td>
<td>.188</td>
</tr>
<tr>
<td>Manufacturing lead time</td>
<td>.689</td>
<td>.232</td>
<td>.238</td>
</tr>
<tr>
<td>Overhead costs</td>
<td>.627</td>
<td>.360</td>
<td>-.035</td>
</tr>
<tr>
<td>Inventory turnover</td>
<td>.446</td>
<td>.344</td>
<td>.291</td>
</tr>
<tr>
<td>QUALITY (*649; b.820; c.434; d.340)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product quality and reliability</td>
<td>.145</td>
<td>.752</td>
<td>.132</td>
</tr>
<tr>
<td>Manufacturing conformance</td>
<td>.175</td>
<td>.669</td>
<td>.225</td>
</tr>
<tr>
<td>Environmental performance</td>
<td>.250</td>
<td>.638</td>
<td>.197</td>
</tr>
<tr>
<td>Customer service and support</td>
<td>.141</td>
<td>.630</td>
<td>.332</td>
</tr>
<tr>
<td>Employee satisfaction</td>
<td>.362</td>
<td>.618</td>
<td>.140</td>
</tr>
<tr>
<td>Delivery dependability</td>
<td>.323</td>
<td>.557</td>
<td>.267</td>
</tr>
<tr>
<td>FLEXIBILITY (*650; b.771; c.406; d.325)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mix flexibility</td>
<td>.203</td>
<td>.116</td>
<td>.787</td>
</tr>
<tr>
<td>Volume flexibility</td>
<td>.248</td>
<td>.155</td>
<td>.728</td>
</tr>
<tr>
<td>Product customization ability</td>
<td>.096</td>
<td>.313</td>
<td>.637</td>
</tr>
<tr>
<td>Product innovativeness</td>
<td>.088</td>
<td>.387</td>
<td>.530</td>
</tr>
<tr>
<td>Time to market</td>
<td>.368</td>
<td>.353</td>
<td>.462</td>
</tr>
</tbody>
</table>

Rotation sums of squared loadings

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eigenvalues</td>
<td>3.330</td>
<td>3.299</td>
<td>2.645</td>
</tr>
<tr>
<td>% of variance explained</td>
<td>19.590</td>
<td>19.406</td>
<td>15.560</td>
</tr>
<tr>
<td>Cumulative variance %</td>
<td>19.590</td>
<td>38.996</td>
<td>54.556</td>
</tr>
</tbody>
</table>

Principal components with Varimax rotation. Factor loadings > .4 are in bold. Numbers in brackets show a scale n; bCronbach's alpha; c inter-item Pearson correlations; and daverage item Pearson correlations with other scales. Missing values in principal components and correlation analyses deleted listwise (n = 615).