



# Manufacturing strategy and competitive performance – An ACE analysis



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## ABSTRACT

In this study, we investigate the relationships between competitive dimensions of manufacturing strategy and competitive performance in two clusters. One consists of plants in countries known for their manufacturing excellence (i.e., "JUG" referring to Japan, the United States and Germany); and the other of plants in emerging manufacturing countries (i.e., "BC" referring to Brazil and China). Data from the third round of the High Performance Manufacturing (HPM) project, which is a worldwide plant-level questionnaire survey project, were used in this study. The Alternating Conditional Expectations (ACE) algorithm, which is a nonlinear statistical tool, was applied to capture nonlinear relationships among the factors. Specifically, the possession of proprietary resources and the use of manufacturing as a competitive resource exhibit negative relationships with competitive performance for BC, but positive relationships for JUG. The achievement of functional integration varies negatively with competitive performance for JUG, but positively for BC. These relationships plateau over the mid-ranges. A proactive IT posture demonstrates the most statistically significant positive relationship with competitive performance for both JUG and BC. Based on our findings in an exploratory approach, managerial implications are also discussed.

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## 1. Introduction

There is a dearth of research that examines the differences between the relationships between competitive dimensions of manufacturing strategy and competitive performance in countries with an established reputation for manufacturing excellence, and emerging manufacturing countries. In our study, the former consists of Japan, the United States and Germany (JUG), and the latter Brazil and China (BC). India was excluded in the latter because we did not have manufacturing data at the plant level.

Our contributions of this study are as follows. To the best of our knowledge, the study is the first empirical investigation of the relationships between competitive dimensions of manufacturing strategy and competitive performance for both JUG and BC. Related studies used linear regression tools, where linearity was assumed. More in line with reality is nonlinearity. We use the Alternating Conditional Expectations (ACE) algorithm (Breiman and Friedman, 1985). The ACE algorithm derives transformations among variables to achieve the best fit, and these transformations

are unambiguously defined and estimated without the use of heuristics, restrictive distributional assumptions, or restriction of the transformation to a particular parametric family. The ACE algorithm has been used by previous studies involving soil-water diffusivity (De Veaux and Steele, 1989), engine exhaust emissions (Rodriguez, 1985), material requirements planning (Sum, et al., 1995), the effects of service guarantee (Sum et al., 2002), and estimating optimal transformations for multiple regressions (Wang and Murphy, 2004). Details on the ACE algorithm can be found in (Breiman and Friedman, 1985; De Veaux, 1989). See Appendix B for a discussion on the ACE algorithm.

Following the introduction, Section 2 reviews the existing literature. Section 3 sets out the basic research hypotheses. The research methodology and the variables for the study are discussed in Section 4. Section 5 provides the results from the ACE algorithm. Section 6 concludes the study and highlights the managerial implications.

## 2. Literature review

Manufacturing strategy refers to a set of coordinated action programs aimed at improving manufacturing performance and enhancing competitive advantage (e.g., Skinner, 1969; Hayes and Wheelwright,

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1984; Hill and Hill, 2009). Swamidass and Newell (1987) describe manufacturing strategy as a set of tools/practices intended to produce effective manufacturing strengths for enhanced competitive performance. Alternative definitions are offered by Leong et al. (1990), Platts et al. (1998) and Ward et al. (1996).

Most studies focus on understanding the linkages between manufacturing strategy and performance (Vickery et al., 1993; Ward and Duray, 2000). Various theories/views have been proposed. Schroder et al. (2002) use the resource-based view of a firm to explore the linkages. This view identifies a firm's key resources that are unique and not easily imitable, and deploying them to generate competitive performance. Trade-off is at the heart of economics (Skinner, 1969). Central to the trade-off theory is that firms cannot perform well on all capabilities. Superior performance in some can only be gained at the expense of others. Ferdows and De Meyer (1990), however, argued that manufacturing firms can augment their capabilities in a sequential manner and that there is no need to engage in trade-offs. This cumulative capabilities view is shared by Nakane (1986) and Noble (1995). Swink and Way (1995) propose the contingency perspective. Leong et al. (1990), and Dangayach and Deshmukh (2001) postulate a theoretical framework, the main thrust of which consists of decomposing manufacturing strategy into competitive priorities and decision categories.

Although this area has generated much interest, differences of opinions exist because views/theories being postulated generate debates regarding their merits. Efforts are channeled to such debates. We want concrete findings that can guide firms to enhance competitive performance. Moreover, a theory can be too over-arching and embracing. For example, using the contingency theory, contingency variables tested include country (e.g., Noble, 1995), industry (e.g., Corbett and Claridge, 2002) and process choice (e.g., Safizadeh et al., 2000). Leong et al.'s framework only serves as a guide because decomposition into constituents usually leads to further decomposition. We prefer to work with the factors (or dimensions) that exploratory factor analysis generates. This is preferred since our focus is to identify the determinants or drivers of competitive performance (Ketokivi and Schroeder, 2004). We seek to operationalize manufacturing strategy in a meaningful manner, namely the factors that make up manufacturing strategy.

Data for this study were obtained from the third round of High Performance Manufacturing (HPM) project, which was initiated by Schroder and Flynn in an attempt to study how the best US manufacturing plants compared with the Japanese plants operating in the USA in practices and performance. The question items on competitive dimensions of manufacturing strategy as well as competitive performance were carefully formulated by the original members of the HPM project after extensive literature review (Schroder and Flynn, 2001). In particular, they drew heavily on Hofer and Schendel's (1978) three levels of strategy: corporate, business, and functional. Manufacturing strategy is a part of functional strategy. A detailed discussion can be found in Schroder and Flynn (2001).

We use the question items subsumed under manufacturing strategy, and factor analyze them to generate the competitive dimensions of manufacturing strategy. The four factors extracted are: (1) achievement of functional integration, (2) proactive information technology (IT) posture, (3) possession of proprietary resources, and (4) manufacturing as a competitive resource. Section 4 contains a more detailed discussion.

### 3. Research hypotheses

The main purpose of manufacturing in JUG is to achieve product/process innovation, maintain product/process quality, or to reduce lead-time to the market in developed countries. On the

other hand, the primary purpose of manufacturing in BC is to reduce production cost. Hence, competitive dimensions of manufacturing strategy, competitive performance, and the relationships between them can be different between JUG and BC.

In addition, most studies use linear models. However, due to the complexity of organizational phenomena, nonlinear models such as ACE are more appropriate for such studies. Our assumption of nonlinearity is reinforced by the existing literature, which indicates organizational learning which occurs all the time is nonlinear (Argote et al., 1990). Organizational units could learn from their own direct experience or from the experience of other units (Levitt and March, 1988). Organizational change involves transformation and redefinitions of events (e.g., performance outcomes).

Since our focus in this study is on the examination of the nonlinear relationships in an exploratory approach, we formulate only two basic hypotheses. The specific nonlinear relationship (e.g., a plateau over the mid-range values, a concave curve over low values, and a convex curve over high values) is difficult to anticipate/hypothesize. Therefore, we formulate only general hypotheses vis-à-vis the nonlinear relationships as follows:

**Hypothesis 1.** There are nonlinear relationships between competitive dimensions of manufacturing strategy and competitive performance both in JUG and BC.

**Hypothesis 2.** There are differences between JUG and BC in the relationship between competitive dimensions of manufacturing strategy and competitive performance.

## 4. Research methodology

The data used in our study were collected from the third round of the ongoing HPM project. The project surveyed both managerial and nonmanagerial staff of manufacturing plants across the automotive supplies, electronics, and machinery industries in Austria, Brazil, China, Finland, Germany, Italy, Japan, South Korea, Spain, Sweden and the U.S.A. A total of 339 manufacturing plants took part in the questionnaire survey project.

We used the Dbank software to run the ACE algorithm. The ACE algorithm was applied to both BC and JUG clusters. The combination stepwise deletion method, as explained in Appendix B, is used to determine the most appropriate model. Using this method, superfluous independent variables, if any, which do not contribute significantly to the adjusted *R*-squared value and/or *p*-value of the models would be removed. In our study, none of the variables were removed for either model.

The ACE algorithm, which supports nonlinear regression analysis, increases the model fit by approximating the optional transformations for the dependent and independent variables. When significant relationships between the factors are not found in linear regression analysis, we normally reject the hypothesis and conclude that there are no positive or negative relationships between them. However, using the ACE, we might be able to find significant relationships. In our study, two independent variables for BC are not significant in a linear regression, but they are significant in the ACE. On the other hand, all variables for JUG are significant in a linear regression, and they are also significant in the ACE with a higher value of *R*-squared.

### 4.1. Plant samples

The unit of analysis for our study is the manufacturing plant. The total sample used in our study is 163 manufacturing plants. BC comprises 66, and JUG 97. The breakdown of the plants, by country

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