

MANUFACTURING STRATEGY-TECHNOLOGY RELATIONSHIP AMONG AUTO SUPPLIERS¹

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ABSTRACT

Each manufacturing plant has to develop its own path to success based on contingencies and on manufacturing practices links. On the basis of the latter, this paper tests the link between two of the most important manufacturing practices areas, manufacturing strategy (MS) and technology, without addressing causality or their combined effect on performance. This is done by selection fit, i.e. congruency adjustment. However, this paper goes beyond grouping both sets of practices in pairs, by using a more general selection view version, with practices from both sets related multidimensionally and subordinated by regression analysis to test for any congruent pattern. Regression results from a wide-ranging survey of auto supplier plants show that, in general, MS seems to have some kind of impact on technology, and that technology has some kind of influence on MS. In addition, a strong congruency between both practices areas is observed when using correlation. This suggests that when implementing or adjusting MS or technology, the other should also be considered; otherwise they may not operate effectively.

Keywords: Congruency, Selection, Fit, Manufacturing Strategy, Technology

1. INTRODUCTION

Each manufacturing plant must find its own unique path to success, based on contingent factors and the links between manufacturing practices. Previous studies on this topic still shed little light on the reasons why the application of the same manufacturing practices works well in some plants, but worse in others (Primrose, 1992; Olhager, 1993; Nassimbeni, 1996).

Thus, before the selection, adaptation (when required), implementation and interconnection of manufacturing practices, there should also be a strategic, well-conceived plan based on the particular situation of the company. Without it, the designed strategy will not have the desired

effect: the achievement of success. All of the above should be linked to a planned path of continuous improvement. Hence plants should be dynamic, constantly drawing upon the best manufacturing practices for their possible inclusion as part of the manufacturing process. Such inclusion depends on both the context of the plant (contingency) and on the effect that the introduction of new practices will have by linking them to what the plant is already doing or is planning to do. This results in a synergy of processes designed to achieve a sustainable world-class competitive advantage by means of the continuous improvement of the manufacturing capacity (Schroeder and Flynn, 2001).

However, achieving a sustainable competitive advantage, by means of using manufacturing practices, is itself an evasive goal: world class plants may sometimes have relatively poor implementation levels of practices. In such cases, it may well be that the success of the plant will quickly diminish when the conditions change, as the solid foundation of a correctly connected network of practices is not supporting the whole. Likewise, there may be cases where plants have implemented a high level of practices and still be unsuccessful. In the latter case, the plants need to consider whether they have chosen the correct practices for their own circumstances and whether the practices are appropriately linked to the overall strategy and with one another (Schroeder and Flynn, 2001). On the other hand, the effective use of technological resources—amongst other things—is essential for achieving a sustainable competitive advantage and for increasing the effectiveness of the company. Therefore, taking into account the importance of MS and technology, as well as the proposition that the lack of success in some plants may be partially due to a faulty link between practices (Schroeder and Flynn, 2001), the present study examines the link between practices from manufacturing strategy (MS) and from technology from an international auto supplier sector survey. The

need to investigate the interconnection between strategy and technology has also been stressed by Porter (1983, 1985).

Accordingly, the present paper is primarily centred on the following research question: Are there any links between practices from manufacturing strategy and practices from technology? This is answered by way of exploratory and confirmatory research.

A review of the literature is made in section 2. Research propositions are described in section 3 along with their respective hypotheses. The research methodology of this work is explained in section 4, describing the constructs and concepts used. Subsequently (section 5), the results are discussed. Finally, in section 6, some conclusions and final considerations are outlined, highlighting the implications and limitations of this study.

2. LITERATURE REVIEW

In relation to the MS-technology relationships, some authors (Hofer and Schendel, 1978; Porter, 1983; Hayes, 1985; Maidique and Patch, 1988; Parthasarthy and Sethi, 1993; Parker, 2000) present a mainly static and unidirectional perspective. In this perspective, the causal relationship goes from technology to strategy and not vice versa (since the existing technical capabilities should guide the formulation of strategy). According to this perspective, competitiveness in a company's manufacturing technology is a springboard for the development of strategy (Parthasarthy and Sethi, 1993). Therefore, manufacturing strategy should reflect manufacturing capacities, including technological initiatives. This argument of complementarities implies that plants which try to achieve high effectiveness from technological practices should implement these in conjunction with the appropriate manufacturing strategy (e.g. Corbett and Van Wassenhove, 1993; Parthasarthy and Sethi, 1993). Technology is therefore a factor that limits strategy in two ways: 1) the existing

technology determines the strategy that an organisation can pursue (Itami and Numagami, 1992), and 2) the company, wanting to pursue a different strategy, should expand or change its technological base (Hofer and Schendel, 1978; Maidique and Patch, 1988; Parker, 2000; Porter, 1983).

Taking the opposite view, other researchers (Skinner, 1969; Stobaugh and Telesio, 1983; Dean and Snell, 1996) uphold that strategy should determine the selection of technology. According to this perspective, for an organisation to be competitive, strategy must drive technological development (Porter, 1983). In this way, technological development can bring both a group of competitive weapons and a deeper technological base applicable to other products/markets to the plant (Itami and Numagami, 1992; Zahra and Covin, 1993). The accumulated resources of past products/markets may change into the driving forces behind the diversification strategy of the plant. The true sources of competitive advantage may be derived more from consolidating technologies with manufacturing skills in the core areas of competition than from generating products that the competition does not anticipate (see Chandler, 1962; Prahalad and Hamel, 1990). Thus, the most important plant decisions in manufacturing should be made to improve the chosen base of competitive advantage (Hayes et al., 1988; Garvin, 1993). Manufacturing technology can clearly be one of these, since it is a significant element in manufacturing (Leong et al., 1990; Marucheck et al., 1990). Hence, in order to use strategy effectively, technology should be considered through its lens.

However, the present study will go beyond the limitations of any single approach regarding the directions of the relationships between manufacturing strategy and technology that can be explored.

Thus, the research question of this paper could be nuanced as to how to identify the MS practices that affect technology practices and vice versa, and to explore the nature of these relationships.

Among the possible models to analyse these relationships, *selection fit*³ has been chosen since it has proven to be the best way to examine how variables interact to explain each other's designs/implementations (Gerdin and Greve, 2004). Additionally, selection is the most common and simplest form of fit in the literature (Burns and Stalker, 1961; Morse, 1977; Drazin and Van de Ven, 1985; Galunic and Eisenhardt, 1994; Meilich, 2006). For this, exploratory and confirmatory research based on three relationships, namely a bidirectional and two unidirectional views of selection (also termed congruency) will be used. The adjustment premise that is assumed in selection is a congruency between both practice sets mutually influencing each other while operating in a plant (see Hannan and Freeman, 1977; Aldrich, 1979; McKelvey, 1982; Van de Ven and Drazin, 1985; Drazin and Van de Ven, 1985).

A closer look at the way the MS-technology relationships have been researched reveals that only nine studies from over 110 papers compiled in a book edited by Schroeder and Flynn (2001), whose two main High Performance Manufacturing (HPM) research foundations were contingency and *links between manufacturing practices*, directly dealt with linkages between practices (Flynn et al., 1992; Flynn, 1994; Morita and Sakakibara, 1994 a, 1994 b; Flynn et al., 1995; Morita and Flynn, 1997; Ahmad, 1998; Morita et al., 1999; Cua, 2000).

Furthermore, Morita and Flynn's paper (1997) is the only study of these nine that is directly concerned with the relationship between MS and technology. However, it does not deal with

³ Fit could be defined as the correlation between two or more factors that leads to a better result.

this relationship in an exclusive or exhaustive way, since, on the one hand, it approaches the relationship of MS (considering only strategic adaptation) with other practices and, on the other hand, it only takes on board the concept of technological adaptation with its scales. The authors do conclude, however, that there is an important link between this technological concept and strategic adaptation.

Since said book, only three works in this same line of HPM research have directly examined this important subject. In these papers there are findings that tend to confirm the importance of this relationship. Matsui (2002) studies the contribution of different practices (including MS) in the development of technology in three practices of process and product technology (effective implementation of processes, interfunctional design effort, simplicity of product design). Parts of his results constitute clear evidence that the participation of manufacturing practices (MS included) in the development of technology has a strong impact on the competitiveness of the production plant. McKone and Schroeder (2002) seek to determine the type of companies making use of process and product technology by taking the relationship within the context of the plant (they include strategic aspects) but without considering performance. Finally, a part of Ketokivi and Schroeder's (2004) study considers the strategic eventualities involved in the adoption and implementation of several manufacturing practices to achieve high performance. However, they include "design for manufacturability" as the only technological variable.

Regarding the general Production and Operations Management (POM) literature, most of the previous studies have explored the relationship between business strategy (not MS) and technology, either in a one-dimensional or a multidimensional way. Some researchers have classified the essential dimensions/practices of technology that are inherent in a specific strategy (e.g. Ford, 1980). On the other hand, Parker (2000) tries to test for current and future

dynamic interaction between business strategy and technology and its effect on the plant's performance, but without using a time series (a longitudinal study).

This literature shows some empirical interconnections between specific dimensions/practices of technology and business strategy. Some of the discoveries indicate the need to determine the fit/adjustment between these practices (e.g. Parthasarthy and Sethi, 1993; Croteau and Bergeron, 2001).

Thus, some of these studies have indeed proposed integrated models that describe fits between several dimensions/practices of technology and business strategy (Maidique and Patch, 1988; Zahra and Covin, 1993). However, they have not empirically shown if there is a relationship of mutual adaptation in the design and implementation of MS and technology practices, which ensures that only world class organisations will survive thanks to the existence of a supposed isomorphic process between the two practice areas (selection fit).

In conclusion, although the above studies have increased the general understanding of strategy-technology relationships, they have not examined the possible congruency/selection aspects of this rapport. Moreover, although they have had an influence on the generation of ideas concerning the relationships between strategy and technology, to date the corresponding empirical validations have been minimal and there have been even fewer regarding MS, since most of these past papers analyse relationships from a business strategy perspective. With this in mind, it is possible to conclude that: 1) previous research has fundamentally been oriented towards theory and 2) the possible impact of a selective relationship between MS and technology has not been well documented.

Due to the above, it is not clear whether the relationship between MS and technology is inherently selective in its nature. Therefore, *the present work tries to shed more light on this*

subject by verifying a possible congruency between MS and technology (T) practices, taking data from an auto supplier survey conducted in ten countries.

3. ANALYTICAL FRAMEWORK AND HYPOTHESES

One important focus of POM research in recent years has been linkages between manufacturing practices. Drawing on this, this paper tries to find whether the variables (in our case, a set of 3 MS practices and another of 3 T practices) show a certain degree of congruency. Thus, this is different from addressing the relationship of how these same variables influence performance (i.e. universal perspective) or from finding whether both practice sets interacting with each other affect performance (i.e. interaction perspective, where one of the sets interacts with the other) (Hartmann and Moers, 1999; Luft and Shields, 2003). The fundamental difference compared to the congruency/selection view is that in the two latter (universal and interaction) the researcher is not primarily interested in examining how variables interact to explain each other's designs, but in showing that some combinations are more related to higher performance than others.

In the contingency literature, the selection form of fit envisions primarily a linear correspondence between the structural and contingency variables. Thus, as a starting-point for the adjustment between both practice sets, this concept of fit could be described as the correlation between two or more factors that leads to a better result (see Venkatraman and Prescott, 1990; Milgrom and Roberts, 1995; Cua et al., 2001). In keeping with this, propositions for the relationship studied here are first described and then their respective hypotheses are presented. On the basis of the fit and misfit concepts, this paper will therefore address the concepts involving the direct relationship between the two sets of practices in question using a bivariate selection model.

Fit starts with the idea that for a manufacturing practice (MP1) to be controlled or improved, its level needs to be regulated or adapted taking into consideration the level of another practice (MP2) and/or vice versa. The key here is not necessarily MPs' levels, but the way they are adapted to each other. Thus, Figure 1a shows the practice levels of both practices adjusted to each other. The straight line illustrates the fit between both practices (i.e. alignment between practices) with no performance variations. A misfit would have resulted in points outside the line (performance variations), allowing for interaction fit but not selection fit. This is shown in Figure 1b, where any point, other than P_0 , represents a performance variation (Pennings, 1992).

Take in Figure 1

Thus, selection fit may operationalise the relationship between the implementation levels of a manufacturing strategy practice set such as MP1 and that of a technology practice set like MP2. Let MP2 be a univariate variable ranging from a lower implementation MP2 to a higher implementation MP2, and let MP1 also be measured with an "implementation level" ranging from lower to higher. Furthermore, assume that high MP2 implementation is best supported by a higher level of MP1 implementation, while a lower level of MP1 implementation works best with lower levels of MP2. From a congruence point-of-view, it could be hypothesised that the higher the level of MP2 implementation, the higher its respective MP1 level (the opposite is also possible: the higher the level of MP1 implementation, the higher its respective MP2 level). Fig. 2a depicts a situation where manufacturing plants in general have adapted their MP2 level to the MP1 level in the way theory predicts. It shows levels of both practices operating in a mutually adapted way; where the straight line illustrates the fit between both

practices (both Hs and Ls are adapted and thus aligned). Consequently, there is no reason to suspect any significant variations in performance due to a misfit between MP1 and MP2 implementation levels. Figures 2b and 2c show the expected performance level across different levels of MP1; where there is no difference in performance (both Ls and Hs have the same performance). Naturally, there may be some variation in performance in reality. However, there is no way to predict such variations from the information given in Figure 2a, since the underlying selection theory (implicitly) assumes that only the successful plants survive. In other words, a large number of the plants must adapt their MP1 level to their MP2 level; otherwise selection fit cannot be identified. On the other hand, selection implies that there is little or no room for alternative methods such as interaction fit, since interaction requires less effective adaptations to also exist, otherwise there is no way to show that ideal adaptations are related to higher performance, and, at the same time, variations from ideal adaptations are related to lower performance, as in Figure 1b (Gerdin and Greve, 2004).

Take in figure 2

The importance of selection fit and the ease with which its functional form of fit can be operationalised have meant it has continued to be used throughout the decades from its conception in the nineteen-sixties to the present day (Burns and Stalker, 1961; Morse, 1977; Drazin and Van de Ven, 1985; Galunic and Eisenhardt, 1994; Meilich, 2006). This form of fit is the most common in the empirical contingency literature (Galunic and Eisenhardt, 1994; Meilich, 2006).

Taking the natural selection version of contingency theory as the hub of the review and knowing that the requirements of this fit form are very specific, this paper examines the

relationship in question by identifying specific technology practices associated with different practices of MS. This paper assumes that there is an association between practice sets from MS and T because anything less would lead to extinction in competitive environments (Drazin & Van de Ven, 1985). In other words, different levels of MS require different levels of T if the organisation is to survive. Hence, it is assumed that non-adjusted/fitted (weak) combinations tend to disappear quickly (due to extinction or adaptation), and that the surviving combinations are those whose MS characteristics are congruent with the characteristics of the technology being used. Thus, the proposal is that a relationship of mutual support exists between MS and technology. On the basis of this assumption, it is hoped that it will be possible to test whether there is a bidirectional relationship between MS and technological practices. Hence, endeavouring to examine this specific interrelationship in greater depth, the requirement of fit can be verified by testing whether there is a state of equilibrium in a sufficient number of plants, where they must therefore have adapted the practices of one MP set to the practices of the other set (otherwise congruency fit cannot be identified).

To examine fit as the way that practices from both domains relate to each other in independent pairs, this paper shall therefore propose relationships that demonstrate some kind of congruency. In this approach it is taken for granted that the variables in each pair jointly affect performance and therefore this is not an explicit part of the research question: the higher the implementation level of practices from one MP set, the higher the use of practices from the other MP set will be, tested as an assessment of selection fit, where the premise

behind the model is that the resulting outcome is the desired/acceptable state⁴. This first focus does not presume to determine the direction of causality, but rather it presents an avenue for a cross-sectional study, by which it is possible to establish whether congruency exists between MS and technology. Therefore, the following is proposed first:

H1: There is a relationship between Manufacturing Strategy and Technology practice sets.

However, assuming that there is a general relationship between both sets of practices, this paper will go beyond by proposing causality in the following way:

H2: Manufacturing Strategy (MS) implantation influences Technology (T) implementation positively, demonstrating a unidirectional relationship from MS to T.

The opposite direction may also be possible, but it has to be borne in mind that this paper is not testing for both directions at the same time, but for mutually exclusive unidirectional relationships.

H3: Technology (T) implantation influences Manufacturing Strategy (MS) implementation positively, demonstrating a unidirectional relationship from T to MS.

Figure 3a, below, known as the “non-recursive reciprocate model”, depicts the operationalisation of H1 and shows a bidirectional arrow, where MS and technology are determined in a simultaneous way or at intervals that are too short for causal influences

⁴ A situation is depicted in which plants in general have adapted one MP to another MP in the way that theory predicts. Consequently, there is no reason to suspect any significant variations in performance due to misfit between the two MPs. In other words, fit in terms of congruency assumes that an association exists between two MPs throughout the data analysed, acting as if the two MPs were the same in relation to performance.

operating in different directions to be empirically distinguished (Berry, 1984; Luft and Shields, 2003). The possibility of a bilateral trajectory between MS and technology is illustrated, where the connections between both variables are simultaneously examined. Technology may be the independent variable that influences MS and vice versa. This model also indicates that, statistically speaking, there is no difference whether the arrow goes from MS to technology or vice versa (for example, Bates et al., 1995; Sakakibara et al., 1997). Figure 3b and Figure 3c show the unidirectional operationalisation of H2 and H3 respectively.

Take in figure 3

4. RESEARCH DESIGN

A survey of ninety auto supplier plants with at least 100 employees in ten countries across Asia, Europe and North America was used to test the propositions in this paper. Different scales of measurements and objective questions in separate questionnaires were directed at twelve different respondents. Reliability and validity of manufacturing strategy (MS) and technology (T) practice sets were then checked, as seen in section 4.2 below.

4.1. Research variables

In the quest for the plants to operate more effectively and efficiently, the challenge should be to substantiate and examine why and under what conditions certain manufacturing practices or practice areas (i.e. an area is a set of common practices) may generate a competitive advantage (Ketokivi and Schroeder, 2004). Moreover, competitive advantage should be considered since the plant is in competition with others. Thus, in order to operationalise the analytical framework and the hypotheses in the preceding section, we introduce some research

variables below (Schroeder and Flynn, 2001). These are divided into two sets of manufacturing practices: manufacturing strategy and technology.

Manufacturing Strategy

Manufacturing strategy (MS) determines how production supports the general objectives of the plant for competitiveness through the appropriate design and use of production resources and capacities (Demeter, 2003). In order to achieve this support, it is essential for MS to be aligned with both marketing strategy and business strategy in general (Bates et al., 2001). In this study, the following MS practices are covered (Bates et al., 1995; Schroeder and Flynn, 2001):

- Anticipation of new technology (MS1)
- Formal strategic planning (MS2)
- Manufacturing-business strategy link (MS3)

Technology

This paper assumes a broad definition of technology (T) that includes human and organisational aspects of the way the plant operates (Maier and Schroeder, 2001; Matsui, 2002). The following practices are included in the construction of the T concept for the models that are later proposed (Schroeder and Flynn, 2001, McKone and Schroeder, 2002):

1. As part of product technology (new product development):
 - Interfunctional design efforts (T1)
2. As part of process technology
 - Effective process implementation (T2)
 - Technology supplier involvement (T3)

4.2. Measurement

All of the measurements used in this study were performed using perceptual scales, each consisting of several questions (items). Each question was answered using a seven-point Likert scale. Reverse-worded items were reverse scored.

Content validity was ensured through both a representative collection of items, as well as a method of test construction (Nunnally, 1967). A comprehensive review of the extant literature was used for the representative list of items. The test construction method followed questionnaire preparation, pilot testing, structured interviews, translation, and back translation when the questionnaires were administered in countries whose mother tongue was not English.

For construct validity, the items of each factor were checked to see if they loaded onto one factor. For this, within-scale factor analysis was performed to test whether each scale from both manufacturing practice sets formed corresponding unidimensional measures, as follows: three scales were used to measure MS practices according to the definition of MP practices described earlier. An item was deleted if it loaded onto a second factor. All factor loadings of the scales were above 0.60, much higher than the cut-off value of ± 0.40 (Hair et al., 1998). A similar procedure was used to construct the technology practices set with its three scales (all of the factor loadings were above 0.70 except for one (0.476, but still higher than cut-off)). Both the MS and technology practice sets are conceptualised and defined as unidimensional constructs. Meanwhile, a reliability analysis was conducted at the plant level for each scale to evaluate internal consistency. The reliability of the scales was measured by Cronbach's alpha according to Nunnally (1978) and all were greater than 0.7 (the corresponding analysis with an acceptable degree of reliability and validity will be provided upon request).

4.3. Methods

The functional form of selection fit is linear correspondence between MS and technology. Some of the advantages of this model are its simple procedure and the fact that it does not require the measure of a third variable as an outcome. In addition, operationalising the selection method is very straightforward using correlation, regression, analysis of variance (ANOVA), and so on. This study uses both correlation and regression.

4.3.1. Correlation

The typical testing scheme associated with the selection approach is the assessment of simple correlation between each pair of MP variables (e.g. Aiken and Hage, 1968; Cohn and Turyn, 1980; Damanpour, 1991). Thus, the first method is the most common in selection and in this paper consists of grouping both sets of variables in pairs, where a series of canonical correlation analyses could demonstrate whether the set of technology practices used here is congruent with the MS set. Hypothesis H1 requires the strength of the relationship between two sets of variables to be tested. Canonical correlation analysis is used to test this relationship. It constructs a weighted linear combination of the variables in each of the two sets being correlated, with weights selected to maximise the correlation between the two weighted vectors, or canonical variates. One of the advantages of canonical correlation analysis is that it requires only multivariate normality of the variables in the data sets. In addition, canonical correlation permits the use of multiple dependent variables.

Three criteria were considered to assess the strength of the overall relationship described by canonical correlation analysis (Hair et al., 1998): 1) level of statistical significance; 2) magnitude of the canonical correlation coefficient; and 3) redundancy measure for the percentage of variance explained by the two sets of variables. The first canonical pair comprises the two canonical variates that have the strongest relationship with each other, and is sufficient evidence to reject the null hypothesis.

For the significant canonical pairs, canonical cross-loadings are calculated as the correlation between

each of the original variables in one set and the weighted canonical variate from the other set of variables. This set of cross-loadings is used to interpret the strength of each of the variables in explaining the relationship with the other set as a whole.

Naturally, canonical correlation analysis is feasible if you do not want to consider one set of variables as the outcome and the other set as predictor variables. This paper therefore presents the following method.

4.3.2. Regression

There might be some limitations to the use of canonical correlation analysis for testing the proposed hypotheses. The main basis for this is that the consideration of variables from the two domains in isolated pairs and the extrapolation of the findings to inferences associating the root domains are problematic. This problem, however, is overcome to an extent by using regression as a more general version of the selection approach, consistent with the definition of congruency. Fit has been widely measured through regression coefficients in the selection perspective (see Simons, 1987; Kaplan and Mackey, 1992; Hair et al., 1998). This analysis not only shows the general direction of the association, but also determines the degree to which the independent variables affect the dependent variables.

Here, as opposed to treating the variables as independent pairs, sets of variables from the two domains are related, essentially depicting a congruent pattern in a multi-attribute configuration, where the practices of the two MP sets are related multidimensionally and subordinated by multivariate multiple regression analysis (MMRA), in order to observe whether they follow a congruent pattern. This type of regression is used when you have two or more variables that are to be predicted from two or more predictor variables. From the research variables, this method will predict firstly technology (T) from MS (H2), and secondly MS from T (H3). In both cases, this paper uses their specific practices.

This regression is "multivariate" because there are three outcome variables (scales of practices) from one of the MP sets. It is a "multiple" regression because there are three predictor variables (scales of practices) for the corresponding MP set. This paper does not recommend this regression method for simultaneous equations, because it may cause the regression coefficients to be biased. Therefore each of the tests (i.e. MS to T and T to MS) is mutually exclusive.

MMRA is a logical extension of the multiple regression concept to allow for multiple response (dependent) variables. Multivariate regression estimates the same coefficients and standard errors as would be obtained using separate OLS regressions for each outcome variable. However, the OLS regressions will not produce multivariate results, nor will they allow for testing of coefficients across equations. On the other hand, multivariate regression, being a joint estimator, also estimates the between-equation covariances. This means that it is possible to test coefficients across different outcome variables. Hence, MMRA allows for multivariate tests for a collection of two or more responses, each in two or more practices. In other words, it allows testing for two or more responses of Ys predicted by two or more practices of Xs.

Finally, there are at least two issues to consider when applying MMRA in this paper:

1. The residuals from multivariate regression models are assumed to be multivariate normal. This is analogous to the assumption of normally distributed errors in univariate linear regression (i.e. OLS regression).
2. The outcome variables should be at least moderately correlated for the multivariate regression analysis to make sense.

5. RESULTS

A two-step procedure was used when performing the data analysis. First, canonical correlation analysis was performed to test the multivariate relationship across the variables representing T and MS practices (H1). The significance of this test provided the basis for two series of individual and mutually exclusive multivariate multiple regression analyses—one for each of the next two hypotheses (H2 and H3). This is a regression procedure that enabled assessment of the effect of all three practices of an MP domain on all three practices from the other MP domain.

The canonical correlation analysis indicated a significant multivariate relationship across MS and T variable sets, thus lending support to the relationship hypothesis H1. The statistical analysis regarding the selective fit between MS and technology practice sets through the association of canonical correlation between these variables allows for the deduction of the combinations that described the following results in Table 1.

Take in table 1

Table 1 shows the results of a canonical correlation analysis between three technology practices and another three manufacturing strategy-related practices representing the main operations management areas. Only the first canonical pair was statistically significant. The canonical correlation (0.77) is high. Although there are no guidelines about the minimum acceptable value for the redundancy index, generally the higher the value of the index the better. Thus, there is evidence of the impact between the MS and T practice sets, since the redundancy index shows that close to half of the variance in the T practices set is explained by the first canonical variables of MS-related practices and that around one third of the variance in the MS practices set is explained by the first canonical variables of T-related practices. These results indicate that there is a very strong relationship between MS practices and T practices.

Traditionally, canonical pairs have been interpreted by examining the sign and the magnitude of the canonical weights. However, these weights are subject to considerable instability due to slight changes in sample size, particularly where the variables are highly correlated.

Canonical cross-loadings have been suggested as a preferable alternative to the canonical weights (Hair et al., 1998). The canonical cross-loadings show the correlations of each of the dependent variables with the independent canonical variate, and vice versa. Table 1 shows the

canonical cross-loadings for the first canonical pair. A loading of at least 0.31 is considered significantly different from zero at the 5% significance level (Graybill, 1961). According to this criterion, each of the MS variables is significantly related to the T canonical variate (canonical variate representing practices). On the other hand, all T variables (practices) are significantly related to the MS canonical variate (canonical variate representing practices). It is important to stress that the manufacturing-business strategy linkage is the most important factor in accounting for the first canonical variable of T-related practices, but the other two MS practices are not far behind. On the other hand, effective process implementation shows the highest correlation with the first canonical variable of MS-related practices, far in advance of the other two T practices.

These results for the international auto supplier plants support hypothesis 1 since there is a congruency displayed through a relationship between Manufacturing Strategy and Technology. Thus, the success of manufacturing industries may often be attributed to the links between their own particular practices: technology-related practices must be accompanied by MS-related practices, which is one of the most important reasons why some manufacturing companies achieve a desirable effectiveness level in the global marketplace. Therefore, canonical correlation analysis provides a good test of the overall relationship specified by the hypothesis, as well as a basis for further regression analysis of the effects of the individual variables.

Next, two separate multivariate multiple regression analyses (one per each MP set as a predictor) were performed to test hypotheses H2 and H3. Thus, two stages for both independent regressions will be shown, the first stage focusing on the multivariate tests and the second on the tests of between-subjects effects. The second stage of MMRA may be treated in a similar way to multiple linear regression. Thus, in line with Umanath and Kim's

(1992) and Umanath's (2003) conclusions on congruency and from the first part of the MMRA, equations [1] and [2] were used, where MS represents Manufacturing Strategy and T, Technology. The MS and T indexes 1, 2, and 3 represent the three corresponding practices for each set of manufacturing practices (3 MS practices and 3 T practices) explained in section 4.1 (page 15), the β s are the fit coefficients associated with their respective variables, $i=1-3$ represents the same three practices above for each set of MS and T manufacturing practices, and ϵ is the error.

$$MS_i = \beta_{msi} + \beta_{msiT1}T1 + \beta_{msiT2}T2 + \beta_{msiT3}T3 + \epsilon_{msi} \quad [1]$$

$$T_i = \beta_{ti} + \beta_{tims1}MS1 + \beta_{tims2}MS2 + \beta_{tims3}MS3 + \epsilon_{ti} \quad [2]$$

The selection perspective is supported by the statistical significance of β associated with the interest independent variable (MS1, MS2 and MS3 for equation 1 and T1, T2 and T3 for equation 2).

Thus, for the first MMRA with MS as a predictor, multivariate tests give the following for the MS practices: Pillai's Trace, Wilks' Lambda, Hotelling's Trace and Roy's Largest Root are all significant. All practices from MS collectively may predict the practices of T as an output.

Hence, for the first stage of the first regression, all MS practices are significant for potentially predicting the T set, or in other words, all 3 MS practices may predict all 3 T practices (Table 2a). Following up, Table 2b shows all results of the second stage of the first MMRA (equation 1) using arrows to indicate significant relationship directions from tests of between-subjects effects. In view of the foregoing results (regardless of the fact that there does not seem to be complete congruency), this paper could conclude with reservations (MS does not influence

T3) that hypothesis 2 has been partially proven: manufacturing strategy influences technology.

Take in table 2

Table 2b shows the results for the first model (equation 1) in more detail. The columns represent MS practices, which were tested to see whether each practice predicted the rows as technology practices. The consequent estimated parameters from this test show technology practices that are influenced by the manufacturing strategy practices. Thus, only formal strategic planning (MS2) does not significantly predict interfunctional design effort (T1), probably due to some type of restriction caused by planning. MMRA showed that both MS1 and MS3 have positive impacts on T1 (β s are 0.300 and 0.328). In the next row, the effective process implementation (T2) row shows that this is significantly predicted by all the manufacturing strategy practices (at the 1%, 10% and 5% significance levels, respectively). MMRA calculations showed that all MSs have positive impacts (β s are 0.309, 0.169 and 0.281) on T2. Finally, technology supplier involvement (T3) does not seem to be significantly predicted by any of the manufacturing strategy practices, possibly due to the fact that it is something that the company cannot completely control (contextual factors related to suppliers). This can all be summarised as follows. 5 out of 9 configurations are significant:

- MS (all but MS2) predicts T1
- MS (all its 3 MS's) predicts T2MS does not predict T3

The following possible unidirectional congruency relationships are therefore obtained:

1. Manufacturing strategy (except MS2) → interfunctional design effort.

Manufacturing strategy → effective process implementation.

Thus, these results show that all of the MS variables (except MS2, which is partial) in the model have statistically significant relationships with the joint distribution of interfunctional design effort and effective process implementation. Therefore, it can be said that manufacturing strategy influences technology to a certain degree, as reflected in most practices, and that as a result, hypothesis H2 has been partially fulfilled.

Furthermore, whilst stressing that bidirectional relationships are not within the scope of this part of the study, hypothesis 3 was independently proven to a certain degree in the MMRA second stage: technology influences manufacturing strategy (Table 3b). This will be explained in detail below.

Thus, in the first stage of the second independent regression, only T1 is not significant for potentially predicting the MS set (possibly due to coordination problems), or in other words both T2 and T3 may predict all 3 MS practices (Table 3a).

Take in table 3

As in Table 2b, Table 3b sets out the results of the second model (Equation 2). In this case, rows are the technology practices, where T2 and T3 were each⁵ tested to check whether they might influence the manufacturing strategy practices (columns). Thus, only effective process implementation (T2) predicts anticipation of new technologies (MS1) at the 1% significance level (MMRA showed a β of 0.657), probably due to technology processes that affect this anticipation strategy. All technology practices but T1 significantly predict formal strategic planning, MS2 (at the 1% significance level), since interfunctional actions may require more room to work. MMRA showed T2 and T3 both had positive impacts (β s are 0.794 and 0.157). Finally, it can be seen that all the technology practices except for interfunctional design effort

⁵ The first stage of MMRA, multivariate test, showed T1 was not significant.

(T1) (see Table 3b) significantly predict the manufacturing strategy and business strategy link, MS3 (at the 1% and 5% significance levels), possibly due to strategies being somewhat rigid. MMRA showed that both T2 and T3 have positive impacts (β s of 0.660 and 0.103).

As with the other regression, on this basis it can be stated that 5 out of 9 configurations are significant:

- T (all but T1) predicts MS2.
- T2 predicts MS1
- T (all but T1) predicts MS3

Therefore, the unidirectional relationships can be summarised as follows:

1. Technology (except T1) → formal strategic planning
2. Effective process implementation → anticipation of new technologies.
3. Technology (except T1) → manufacturing strategy-business strategy link

Thus, these results show that the T variables (except T1) in the model have a statistically significant relationship with joint distribution of MS practices (effective process implementation is the only technology practice with a statistically significant relationship with the MS practice, anticipation of new technologies). Therefore, it can be stated that technology influences manufacturing strategy to a certain degree, thus partially confirming hypothesis H3.

6. CONCLUSIONS AND FINAL CONSIDERATIONS

Propositions were made to test whether an interconnection existed between a set of practices from manufacturing strategy and a set of practices from technology using the selection perspective, without the effect on performance being measured. Canonical correlation analysis demonstrated a high degree of congruency fit, which means that both production practices are in a state of mutual fit or adjustment. In managerial terms, it may be more advantageous for plants to implement them together, i.e. integrated with each other.

Bearing the foregoing in mind, it may be said that the selection (congruency) model has demonstrated that there is some degree of association between technology and MS. Thus, when implementing one of these MPs, the other should also be considered. In other words, different levels of manufacturing strategy practices require different levels of technology, and vice versa, if the plant wants to be more competitive. This was partially confirmed by two unidirectional multivariate multiple regressions. Comparative evaluation of different methods to test fit and the relationship between the results and characteristics of the same sample may help to develop medium-range theories about what approach to take in the sector studied (Drazin and Van de Ven, 1985).

It might be added that, in general terms, the use of an alternative method to correlation for the selection perspective has provided much more detailed information, since the regression analysis method shows multidimensional directions between both practices sets. The use of a confirmatory method not only partially corroborated the results of the previous method, but it also throws light on configuration details that the other model was unable to reveal. Thus, it was possible to assess the link between both manufacturing practices sets more fully. If correlation had been applied alone, this paper might have only had a partial view of the interrelationship. Hence, another main purpose of this research was to share this sort of methodology with POM researchers in what could be an important finding for obtaining a

fuller view of the link between any two manufacturing practices sets by using two different methods of selection fit to complement each other.

Returning to the managerial implications, this empirical research is relevant for plants that wish to adhere to manufacturing concepts relating to the link between manufacturing strategy and technology practices successfully resulting in continuous improvement. It indicates to managers: a) that these practices are important for achieving at least competitive parity in the sector; and b) the positive effects of the links between these same practices—aspects that had not been sufficiently clear to date.

Again from a managerial and concrete point of view, auto supplier plants are able to understand more about the details of this kind of interrelationship in their sector, and whether, and how, they should apply these manufacturing practices to all of their plants. Thus, it was seen that three MS practices (anticipation of new technologies, formal strategic planning, and manufacturing-business strategy linkage), and three technology practices (interfunctional design efforts as part of product technology, and both effective process implementation and technology supplier involvement as part of process technology) have a bidirectional relationship.

In more detail, this paper has also shown that multidimensionally MS practices seem to have a positive impact on two technology practices (interfunctional design efforts and effective process implementation). However, MS practices do not seem to have an impact on technology supplier involvement and formal strategic planning does not seem to impact on interfunctional design effort. In the other direction of the link, two technology practices (technology supplier involvement, and effective process implementation, both as part process technology) seem to have a positive influence on MS practices. Interfunctional design effort is the only technology practice that does not seem to have an impact on any of the mentioned

MS practices and technology supplier involvement does not seem to have any influence on anticipation of new technologies.

However, a high degree of correspondence between statistical methods and core theory assumptions does not mean that the natural selection approach itself is not problematic. On the one hand, using selection to check fit between MPs imposes a linear correspondence between two variables, and it is confined to being operationalised by correlation and/or regression. Thus, since linearity is an implicit assumption of all multivariate techniques based on correlation measures of association (including multiple regression); the most common way to assess linearity in regression is to examine the residuals (Hair et al., 1998, pp. 167-8; Hair et al., 2010). Since residuals from this paper fall randomly, with relatively equal dispersion about zero, the linearity assumption was met.

In any event, selection fit has been chosen since it has proven to be the best way to examine how variables interact to explain each other's designs/implementations (Gerdin and Greve, 2004). To reinforce the results, this study has added a canonical correlation analysis to provide a basis for multivariate multiple regression (Umanath and Kim, 1992; Umanath, 2003). As seen, both canonical correlation analysis and regression provided significant results for selection.

However, this paper would like to highlight the fact that if there is a degree of congruency (as is the case of the fit found between manufacturing strategy and technology); it does not necessarily mean that variations in performance do not exist in reality. Furthermore, this paper disregards more complex relationships, such as the curvilinear (Burns and Stalker, 1961; Morse, 1977; Drazin and Van de Ven, 1985; Galunic and Eisenhardt, 1994; Meilich, 2006), which are beyond the scope of this paper.

However, these limitations may be overcome by future research that could extend and complement this study from another perspective, such as the interaction perspective (i.e. multiplicative with a curvilinear interaction function and matching with curvilinear performance functions), in order to outline a hypothesis which can be developed by a conditional association between the MS and T sets as independent variables with a dependent outcome (Drazin and Van de Ven, 1985, p. 514). In addition, using interaction may allow testing for differences between high and standard (i.e. rest of plants) performers, where, if they show values favouring high performers by giving a stronger relationship between MS practices and T practices, the results could be considered confirmatory for selection fit. However, an advantage of the selection model, when compared to the interaction approach, is that in interaction, the insight about how variables interact to explain each other's designs/implementations is lost.

In addition, managerial implications of contingencies were also left out of this paper, knowing that plant management should also take into account the possible effects of contextual factors. Therefore, future studies should also investigate the possible interaction effects of contextual factors and these manufacturing practices from both MS and Technology.

Finally, other future research studies are also possible. For example, regarding the managerial aspects there is still room to test whether this type of relationship between the two MP areas is found in other sectors with different features. Future research could also include longitudinal studies, examining the causal linkages between practices, and a more detailed examination of the relationships between the two areas of practices (MS and technology), identifying the exact nature of their interaction.

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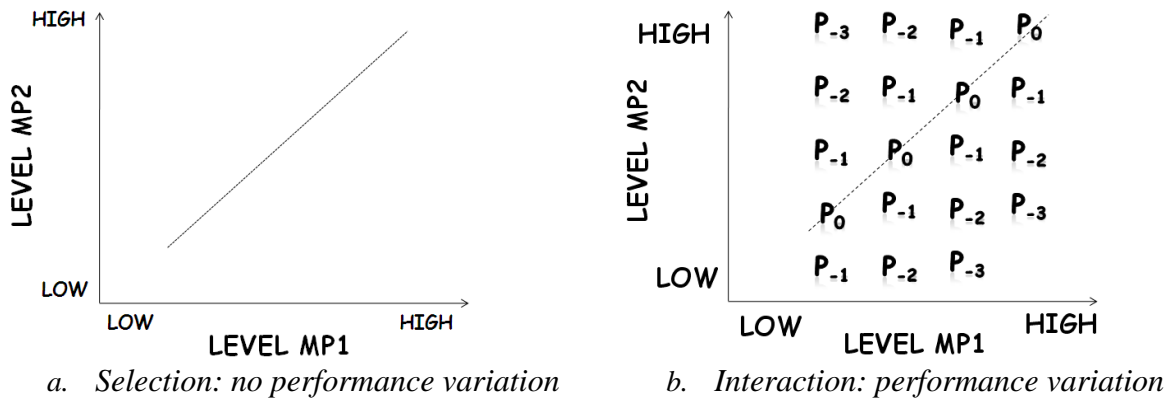


Figure 1. Fit vs. misfit

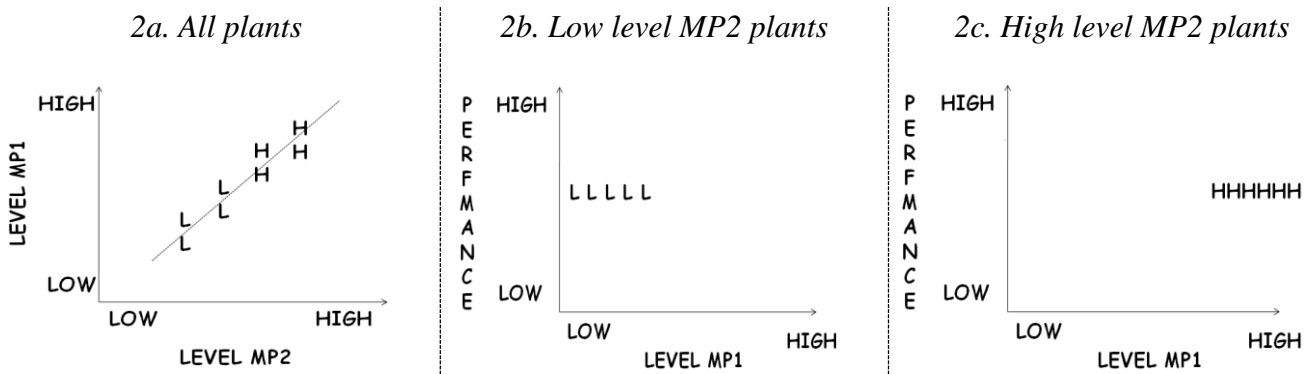


Figure 2. Relationship in a Selection Fit

(Adapted from Gerdin and Greve, 2004)

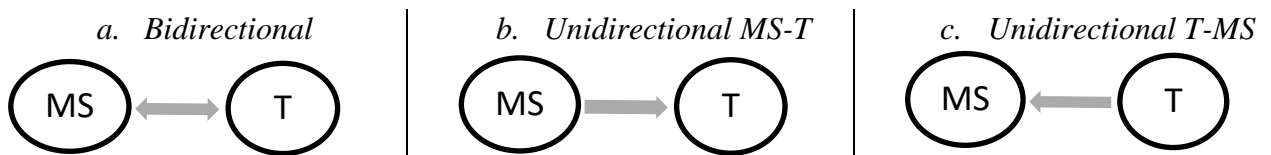


Figure 3. MS-Technology Relationship in a Selection Fit

Table 1. MS and T correlations

	First canonical pair
Canonical Correlation	0.7711
Likelihood ratio	0.3803
Significance	0.0000
Redundancy index: MS	0.4361
Redundancy index: T	0.3117
Correlations between manufacturing strategy practices and canonical variable of technology related practices (canonical cross-loadings)	
Anticipation of New Technologies (MS1)	0.665
Formal Strategic Planning (MS2)	0.627
Manufacturing - Business Strategy Linkage (MS3)	0.669
Correlations between technology practices and canonical variable of MS related practices (canonical cross-loadings)	
Interfunctional Design Efforts (T1)	0.490
Effective Process Implementation (T2)	0.743
Technology supplier Involvement (T3)	0.329

Table 2. MS set as predictor

a. Predictor regression: significance on multivariate tests

MS1 ^{***}	GL: 0.210, 0.790, 0.266, 0.266	F 6.478
MS2 [*]	GL: 0.096, 0.904, 0.106, 0.106	F 2.573
MS3 [*]	GL: 0.086, 0.914, 0.094, 0.094	F 2.297

b. MS to T: tests of between-subjects effects

	MS1	MS2	MS3
T1	*** ← F 7.922	⊗ F 0.444	** ← F 3.818
T2	*** ← F 16.863	* ← F 2.640	** ← F 5.633
T3	⊗ F 1.301	⊗ F 1.027	⊗ F 0.305

GL: Pillai's Trace, Wilks' Lambda, Hotelling's Trace and Roy's Largest Root respectively; * P ≤ 0.1, **P ≤ 0.05, *** P ≤ 0.01

Table 3. Technology set as predictor

a. Predictor regression: significance on multivariate tests

T1	GL: 0.053, 0.947, 0.057, 0.057	F 1.375
T2***	GL: 0.459, 0.541, 0.847, 0.847	F 20.609
T3**	GL: 0.107, 0.893, 0.120, 0.120	F 2.919

b. T to MS: tests of between-subjects effects

	MS1	MS2	MS3
T1	F 0.388 ⊗	F 2.770 ⊗	F 0.074 ⊗
T2	F 25.372 ↑ ***	F 39.187 ↑ ***	F 34.857 ↑ ***
T3	F 1.962 ⊗	F 7.658 ↑ ***	F 4.249 ↑ **

GL: Pillai's Trace, Wilks' Lambda, Hotelling's Trace and Roy's Largest Root respectively; **P ≤ 0.05, *** P ≤ 0.01