DO TECHNOLOGY AND MANUFACTURING STRATEGY LINKS ENHANCE OPERATIONAL PERFORMANCE? EMPIRICAL RESEARCH IN THE AUTO SUPPLIER SECTOR[+]

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ABSTRACT

Although much of the literature on manufacturing strategy (MS) and technology studies the implementation and impact of these manufacturing programs in isolation, this paper goes further by assessing the joint implementation and effect of these two manufacturing programs on performance, even when some contextual factors are present. Thus, this paper investigates how plants from the auto supplier sector make use of some operations practices from Manufacturing Strategy (MS) and from both Product and Process Technology, by testing the effectiveness of both sets of practices, with the ultimate goal of enhancing operational performance. The results suggest that there are only very minor differences between high and standard performers on the aggregated level for technology practices, which may be the reason why technology does not result in significant performance differences between the two plant types. On the other hand, on the aggregated levels there are somewhat greater differences for MS practices than for technology in both plant types, leading to larger differences in performance. While this study provides a foundation for examining MS, technology and context within a single framework, it is only through further research that a full understanding of the relationship between them will be obtained.

Keywords: High Performance Manufacturing (HPM), Technology, Manufacturing Strategy

1. INTRODUCTION

Traditionally, the management trend with which most companies are familiar is to recommend that manufacturing managers adopt almost every new manufacturing technique, practice or scheme that emerges in any industry. However, this study differs from this familiar way of doing things by using a dynamic perspective for manufacturing plants which focus on adopting only the manufacturing practices (with adaptations) that produce high performance when interconnected with those already in place (Schroeder and Flynn, 2001).

At the same time, previous studies on manufacturing practices (MPs) shed little light on the reasons why the implementation of any given manufacturing practice set leads to high performance in some plants but not in others (e.g. Crawford et al., 1988; Nassimbeni, 1996). Theoretically, before manufacturing practices are selected, adapted (as required), implemented and interconnected, a well-conceived strategic plan based on the circumstances of the plant (contingency) also needs to be put in place. If this is not done, manufacturing initiatives will not have the desired effect: the attainment of high performance. All of the above should be linked to a planned path of continuous improvement. These three elements (contingency, links between practices and continuous improvement) are, in general terms, the approach of the High Performance Manufacturing (HPM) conceptualisation.

In this search of high performance and continuous improvement, the effective use of technological resources should be essential for achieving a sustainable competitive advantage and for increasing the performance of the plant. However, although technology practices may in principle increase competitive advantage, it is necessary to analyse them in combination with the MS within plants, since there seems to be a clear influence between them (Porter, 1983, 1985; Schroeder and Flynn, 2001). For this reason, this paper stresses the need to investigate the combined impact of both sets of practices on performance.

Besides, this article focuses on auto suppliers as a first stage on a sequent of sector and intersector studies. However, this selection makes sense in itself since the automotive sector is one the most dynamic, influential and important industries in the world in terms de production, commercial exchanges, employment and generation of wealth. It also has a great multiplying effect with regard to other sectors of production. Its relative importance in industrial production in Western Europe in 2006 stood at 10% and it generated direct and indirect employment for almost 10 million workers (BEFC, 2006). Of the 100 major transnational companies other than in the financial sector by volume of foreign assets, thirteen are in this sector (UNCTAD, 2009). Thus, it uses data on manufacturing strategy practices, technology practices and operational performance dimensions collected from 90 auto supplier plants that responded to a survey from research teams located in ten countries selected as a major part of the industrialised world in North America, Europe, and Asia

Drawing upon the previously mentioned approach, this article takes a set of manufacturing strategy practices and a set of technology practices as a starting point to investigate how auto supplier plants make use of MPs, by testing the impact of both of these sets on operational performance. Thus, next (Section 2), this paper discusses the concepts and constructs used in this study. A brief review is made of bibliography related to possible impacts on performance, and some possible relationships from the framework of this study are presented, the models are proposed and the respective hypotheses described. Subsequently (Section 3), the research methodology used in this article is described and the analytical methodology discussed. The results are given in Section 4. Finally, in Section 5, the conclusions and final considerations are set out, highlighting the implications and limitations of the research.

2. THEORETICAL BACKGROUND AND HYPOTHESES

This study shall consider and define some operational performance dimensions, a set of some manufacturing strategy practices and a set of some technology practices through some of the constructs defined in Operations Management (OM) literature, as the focus of the present paper will be the possible impact of these two sets of practices on performance.

We do not purport the manufacturing practices (MPs) and dimensions in this study to be "best practice" (the paradigm par excellence of research into manufacturing in the nineteen-eighties and –nineties (e.g. Wheelwright and Bowen, 1996)). In addition, it is our opinion that practices adopted in imitation of high performers might contribute to achieving competitive parity though not competitive advantage. MPs could not and, in fact, due to contingency (context), cannot be generally recommended for any and every plant, so a review of manufacturing strategy is required, as each practice, or combination of practices, could be appropriate for different environments. Better performance might be achieved if key MP features are conscientiously analysed and their concepts adopted (and adapted) and carefully incorporated, there being different ways of achieving the same results in different environments (Sahin, 2000). In this regard, the typical way of measuring an MPs impact on competitiveness is usually through the comparison of some type of performance with the competition, whether it be financial (e.g. Return on Asset (ROA), Return on Investment (ROI), Return on Equity (ROE)) or operations-related (quality, cost, etc.).

The following selection of dimensions and practices is neither comprehensive nor exclusive to this research, but they are representative of MPs, operational performance and plant context in the OM literature and currently in widespread use in plants, and they are also appropriate for presenting theoretical arguments.

2.1. Operational performance

Manufacturing plants do not directly control measures of performance indicators such as profit, sales or market outcomes because they are mainly cost centres and do not have specific accounting records of this kind at the plant level; therefore, the use of financial measures may be inappropriate except in the case of plants that are profit centres. Therefore, this research uses basic production measures controlled at plant level, such as the competitive priorities: costs, quality, delivery (speed and dependability) and flexibility (see Hayes and Wheelwright, 1984; Ferdows and De Meyer, 1990; Ketokivi and Schroeder, 2004).

Specifically, this study will make use of some of the plant competitive performance indicators from the OM literature (Skinner, 1969; Hayes and Wheelwright, 1984; Schroeder and Flynn, 2001), such as unit cost of manufacturing, standard product quality, on-time delivery, fast delivery, flexibility in changing the product mix, flexibility in changing volume, etc. These six indicators represent different measures of the four above-mentioned basic production measures (Skinner, 1969; Ferdows and de Meyer, 1990) and can be measured from two perspectives, internal and external. The *internal perspective* represents measures that are useful for the control and internal management of the production process, whereas the *external perspective* entails customer-related dimensions. We will use a combination of both types. To conclude this sub-section, some remarks are made on the basic goals/dimensions and on the six measures that are used in this paper. In general terms, the measures selected are those that are most frequently used in OM (see Skinner, 1969; Hayes and Wheelwright, 1984; Ferdows and de Meyer, 1990; Cua et al., 2001; Schroeder and Flynn, 2001; Ahmad et al., 2003).

Cost. For many authors, the most important of all the operational performance measures is cost performance (e.g. Schroeder and Flynn, 2001; Slack and Lewis, 2002; Hallgren, 2007). This research focuses on unit cost of manufacturing.

Quality. Although quality is a very broad term, in production operations the most influential measure is conformance, which means the process' ability to manufacture products that conform to predefined reliability and consistency specifications (Garvin, 1987; Ward et al. 1996; Slack and Lewis, 2002; Hallgren, 2007). This research therefore focuses on product conformance with specifications.

Delivery. The two basic delivery measures are reliability and speed (Berry et al., 1991; Ward et al., 1996; Hallgren, 2007). This study focuses on both: the former through on-time delivery (i.e. the ability to complete the delivery as planned), and the latter through fast delivery.

Flexibility. Flexibility has many measures, but the two most influential in the operations area are the ability to change volume and product mix (Slack, 1983; Olhager, 1993; Hallgren, 2007; Hutchison and Das, 2007), and both are included in this study.

2.2. Manufacturing strategy

More and more companies are recognising production as a potential source for gaining a competitive advantage and as a way of differentiating themselves from competitors. Despite the importance of defining and clearly implementing manufacturing strategy, there is not much broad empirical research in OM literature documented (and even less in international HPM research) addressing the impact of manufacturing strategy on plant performance.

There are clear signs that manufacturing strategies play a fundamental role in the assessment of new technologies (Bates et al., 1995; Pretorius and Wet, 2000), as an analysis of appropriate technology can eliminate many risks, given that high performing technology is a key factor in global competitiveness. In other regards, according to the classic conception defined in strategy literature which distinguishes between processes and content (e.g. Swamidass and Newell, 1987; Weir et al., 2000; Dangayach and Deshmukh, 2001), it can be said that the formal strategic planning process, successfully aligned with the business strategy, is key to the formulation of manufacturing strategy. The alignment of the external coupling (market) and the internal coupling (technology and organisation) through a strategy is so important that the literature suggests that a company can only survive if the correct production and business advantages are interconnected (Bates et al., 1995; 2001; Sun and Hong, 2002). The formal planning perspective is clearly distinguished from the concept of strategy solely as a model (guideline) for decision-making based on past actions.

Furthermore, manufacturing strategy must be communicated to the plant personnel for it to be used as a guide in decision-making, as this is crucial to it being successfully implemented (Bates et al., 1995). In this way, the production function is capable of providing appropriate support to business strategy. Consequently, properly implemented and well-aligned manufacturing strategy in a plant should include aspects such as the *anticipation of new technology,* and *a link between manufacturing strategy and business strategy,* a *formal strategic planning process* that involves the plant management, and *communication of the manufacturing strategy* to plant personnel. Thus, we shall consider these four manufacturing strategy practice dimensions in this study.

2.3. **Technology**

There is a general trend towards an increase in the use of technology in manufacturing plants due to the belief that it will improve some performance measures (e.g. reductions in costs or human resources, improved quality or flexibility). However, these investments are often criticised for not creating the desired results, i.e. technology investments often lead to neither effective deployment of new practices nor the desired performance outcomes being reached fast enough. For this to be understood, it is necessary to take into account that the interconnection between technology and performance is influenced by a number of factors, some of which can be controlled, and others which cannot, but, nonetheless, they are all important for the final result.

Thus, when dimensions from both product and process technology are widely applied in a factory, it can be said that the plant is on a path to high performance through having a more complete view of technology. However, the plant has to have an even more progressive and dynamic vision of the development of technologies in manufacturing which takes into consideration sets of other manufacturing practices. Therefore, this paper assumes an open definition of technology comprising not only hardware systems, but also human and organisational aspects of the way the plant operates.

2.3.1. Product technology

International HPM research (Schroeder and Flynn, 2001, McKone and Schroeder, 2002) considers some relevant dimensions that are used to develop product technology. Our study focuses on *Product Design Simplicity* and *Interfunctional Design Efforts*. The former is often put forward as a feature of plants that are leaders in technology (McKone and Schroeder, 2002). The second dimension is considered to have great importance for the development of new product technologies, as the more business functions that are involved, the faster and more successfully new product technologies can be introduced.

2.3.2. Process/production technology

The emphasis that a plant puts on manufacturing technology can be described by a number of dimensions (see for example Schroeder and Flynn, 2001; McKone and Schroeder, 2002). This research focuses on the following two dimensions: a) *Effective process implementation*, which assesses whether the factory appropriately implements a new manufacturing technology after obtaining it; and b) *working with technology suppliers (supplier involvement)*, which serves to evaluate whether the factory is working closely with suppliers in developing new and appropriate technologies. This last dimension embraces not only process technology but also product technology.

2.4. Contextual factors: control variables

There are many other factors that influence a plant's performance apart from manufacturing strategy and technology which cannot be identified and eliminated in their entirety due to data limitations. Nonetheless, according to the OM literature (Im and Lee, 1989; Primrose, 1992; Groenevelt, 1993; Ahmad et al., 2003), contextual factors such as plant size, plant capacity utilisation and product customisation might have an impact on plant performance. This paper includes such factors merely as control variables and shall not carry out a comprehensive study of them as they are outside the scope of this research. Those used here are merely used to test the effectiveness of both MS and technology when present. That is, it is hoped that the influence of both practice sets in question should remain significant after such control variables have been included, thus making the results more robust. This is the reason why it is believed that the practices and techniques adopted by a plant can reduce the effect of contextual factors on performance.

2.5 Working hypotheses

Taking the above constructs and claims from both Porter (1983, 1985) and Schroeder and Flynn (2001) about the importance of both strategy and technology on the outcome of an organisation, two main types of relationship are examined in this study:

- How Manufacturing Strategy (MS) operations practices affect Operational Performance.
- How Technology operations practices influence Operational Performance.

In order to test these relationships, it may be of great benefit to this study to use the concept of fit/adjustment between two variables. In general, the term "fit" describes the congruency between two or more factors that leads to a better result (see Venkatraman and Prescott, 1990; Cua et al., 2001). Propositions for the two main relationships studied here are therefore first described and then the respective hypotheses are presented. Thus, the combined effect of both practice sets on performance are conceptualised from the universal perspective of the fit concept (Delery and Doty, 1996; Ahmad et al., 2003). This perspective assumes that one or both selected practice sets (related to MS and/or to technology) are positively associated with plant performance. According to this, researchers have tried to identify "best practices" that have a positive effect on performance (e.g. Delery and Doty 1996, Lee et al., 2004). Therefore, a two level approach is proposed next.

2.5.1. Manufacturing strategy-operational performance relationship

International HPM research literature maintains that MS affects operational performance positively (e.g. Bates et al., 2001; Milling et al., 1999). Several more general focal points in OM literature have been created around the joint MS-operational performance relationship. Hayes and his fellow authors (Hayes, 1985; Hayes and Clark, 1985; Hayes and Jaikumar, 1988; Hayes and Pisano, 1994; Hayes and Upton, 1998) have consistently argued that production capabilities play an important role in competitiveness. Ferdows and De Meyer (1990) concentrated on explaining production processes with an expandable group of capabilities when pursuing a specific sequence of improvement initiatives. The International Manufacturing Strategy Survey (IMSS) is another empirical project a that tests the Ferdows and deMeyer approach (i.e. Demeter 2003, Größler and André Grübner, 2006).

Others authors have demonstrated a positive link between strategic decision-making and performance (Swamidass and Newell, 1987; Roth and Miller, 1990). Demeter (2003) has summarised thirteen studies from as many different experts who evaluated different elements in the MS-performance relationship. Although their results are not always conclusive, a link does seem to exist to some degree. However, as there is still no broad body of empirical MS research, more evidence is needed to test the following hypothesis:

> H1: *Implementation levels of manufacturing strategy are positively associated with operational performance in the presence of technology implementation.*

Contingency fundament states that plant contexts may also influence their performance (Lawrence and Lorsch, 1967; Hayes and Wheelwright, 1984). Furthermore, some managers often suggest that manufacturing practices cannot be implemented in the context of their plant. This paper explores whether some contextual factors used as control variables contribute to performance. Thus, apart from the two manufacturing practice areas being implemented, this study also considers some contextual variables. As a result, considering the control variables, this paper also proposes that a higher level of operational performance is expected from manufacturing plants that are larger, have lower plant utilisation and are more process-oriented. However, it also expected that the internal practices of the plant —common practices and basic MS techniques— provide more explanation of operational performance than the context of the plant. Therefore, we propose that:

> H2: *Implementation levels of manufacturing strategy maintain its positive association with operational performance when both technology implementation and contextual factors are also present.*

2.5.2. Technology-operational performance relationship

According to the OM literature, technology improves operational performance (Maier, 1997a, 1997b; 1998a, 1998b; Maier and Schroeder, 2001; Heine et al., 2003; Matsui, 2002). Furthermore, some empirical support exists for this statement. Bates and Flynn (1995) have shown that high manufacturing performance results from the use of technological innovations. Regarding the production benefits to be gained from information systems, Matsui and Sato (2001) have revealed some positive results; Mallick and Schroeder (2003) have empirically studied product development performance. Meanwhile, Heine et al. (2003) have reviewed 16 models from the literature on the impact of technology on performance and have proposed a seventeenth model. These models represent some of the foremost current academic opinion on the role of technology and they provide reasonable (empirical and theoretical) justification for the relationship between technology and performance.

However, there is also literature that presents empirical support for the hypothesis that technology does not influence plant performance. For example, Das and Jayaram (2003) summarise seventeen publications which maintain that a significant and positive relationship does not exist between technology and performance. Similarly, even when testing the technology-performance relationship with the "flexibility" dimension, Swink and Nair (2007) state that there is contradictory evidence to this relationship, despite the fact that flexibility is one of the most common links in this type of relationship in the literature. In this respect, they mention seven publications in favour of the positiveness of this relationship and five publications against.

Therefore, although the empirical literature has examined the technology-performance relationship, the results are not yet definitive, and even less so regarding operational performance, since most of these studies analyse the relationship from the perspective of company performance and not operational performance.

However, although the effects of technology on performance are not yet clear, the following hypothesis will be tested:

> H3: *Implementation levels of technology have positive links with operational performance in the presence of manufacturing strategy implementation.*

Moreover, as with manufacturing strategy, we assume that:

> H4: *Implementation levels of technology maintain its positive association with operational performance when both manufacturing strategy and contextual factors are also present.*

3. RESEARCH METHODOLOGY

3.1. Data collection

The basic technique this research uses to obtain data is the survey. This has been an integral part of the ongoing HPM international project for several years. In total, there are 12 types of questionnaires used, directed at a variety of respondents in each plant (from plant manager to workers) and submitted to 21 informants.

All the scales and measures of all manufacturing practices considered in the HPM international project are covered in these questionnaires, along with roughly two thousand different practice items (in almost 250 dimensions). Additionally, the questionnaires gather a substantial amount of objective and subjective data on performance and plant characteristics, as well as diverse exogenous variables. Many of the scales are included in at least two different questionnaires, with the objective of being able to triangulate information for greater reliability. The information required for data analysis in this research is restricted to MS, technology and performance.

While some objective measures were used in this study, most of the measurements were performed using perceptual scales, each consisting of several questions (items).The items and scales used as measurement instruments in the international HPM study were developed from an extensive review of current literature on manufacturing practices. To ensure the validity of their content, they were reviewed by a panel of experts, bibliographical review and structured interview, and piloted in several plants (Nunnally, 1967). They have also been subject to an analysis for reliability and construct validity through the usual statistical (amongst them: inter-correlation matrixes, Cronbach’s alpha, factor analysis and canonical correlation). Moreover, throughout the international HPM research project, the questionnaires have been reviewed on the basis of the data collected and lessons learned from analyses, so that invalid scales were eliminated or modified to improve the reliability and validity of the data, whilst other scales were added to evaluate new concepts. As a result, the internal consistency, the content validity and the construct validity have high values on the scales finally used (e.g. Flynn, et al., 1995; McKone et al., 1999; Sakakibara, et al., 1997; Cua et al., 2002; Ahmad and Schroeder, 2003). The questionnaires were reviewed in the various participating countries to test whether they were wholly appropriate to the industrial context of the country concerned, as well as for their translation (where necessary) and -to the extent possible- for adaptation to the uses and terminologies of the industrial sectors that were the object of the study.

With regard to the sample, the unit of analysis is each individual plant, rather than each company, since pronounced differences may exist between practices, performance and contextual factors from one plant to another in the same company. Furthermore, since some of the practices analysed may not be applicable to small plants, it was established prior to the study that these plants were to have a minimum of 100 workers. In total, the international sample of the entire HPM project consisted of about 270 plants located in ten countries: Austria, Canada/USA, Finland, Germany, Italy, Japan, Korea, Spain and Sweden. In each country, the plants were selected from the following three industries: auto suppliers, electronics and machinery. A stratified sampling design was used to obtain an approximately equal number of plants for each industry-country combination. Additionally, one of the aims of the project was that half of the plants in the sample should be considered High Performers (HP). This study analyses the results of the ninety plants in the international auto suppliers' sample. Table 1 provides a profile of the sample.

Take in Table 1

The response rate was approximately 65% in each country, thereby reducing the need to check for any no-respondent bias (Flynn et al., 1990).

3.2. Description of the sample

Using an international database from the auto supplier sector, the analysis that is the object of our study was performed by means of plant comparison. The sample of ninety plants was distributed throughout the ten countries mentioned above. The use of all contextual factors affecting performance is not possible, so we have limited them to three, following on Ahmad et al (2003). Table 2 provides descriptive information on the three contextual factors considered in this study. Table 3 shows various other contextual variables, as a more complete description of our sample.

Take in Table 2

Take in Table 3

Furthermore, an analysis was carried out to distinguish between two plant types (high performer and standard performer) based on the position of the plants in each of the performance dimensions (cost, quality, delivery and flexibility)[1]. On this basis, following Schroeder et al. (2005), the criterion used to consider high performers was those plants with a high ratio between total sales and manufacturing cost (in the top quartile) and that were strong in some other performance dimension (in the top quartile). The mentioned ratio was used due to possible differences in product types and their respective

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[1] This analysis is designed specifically to identify high performers using objective performance measures, whereas the six performance measures defined in section 2.1 used in the rest of this paper are measured by perceptive scales.

manufacturing costs. With regard to the other dimensions, the following measures were used: quality (measure of customer satisfaction and percentage of products passing final inspection without reprocessing), delivery (percentage of orders dispatched on time) and flexibility (product customisation). An analysis of the objective data used allowed us to identify a group of ten plants as high performers, which represent 11.11% of the total. This is in line with results from previous HPM rounds (Schroeder et al., 2005).

Once the high performers had been identified, data analysis continued with a series of tests aimed at linking either, or both, of the manufacturing practice sets with plant performance.

The analysis was done using two techniques (multiple regression and subgroup variance analysis) which have been used previously in earlier analyses for other issues in HPM research in other countries (e.g. JIT linked to other MPs, as in Cua et al., 2001; Ahmad et al., 2003). These types of techniques are especially useful for our study given the possible multi-colinearity of the variables involved.

3.3. Data measurement

As was previously stated in Section 2, a group of scales/practices was used to measure operational performance, manufacturing strategy practices, and technology practices.

Although some of the data constitutes objective measures (e.g. the contextual variables, plant type classification criterion variables, etc.), most are perceptual scales. For this reason, the reliability and validity of performance operational indicators, manufacturing strategy and technology practice sets were checked for the data analysis. The reliability analysis was conducted at the plant level for each scale to evaluate internal consistency. Reliability was measured by Cronbach's alpha, where the criterion for a reliable scale was higher than 0.7 (Nunnally, 1978), and all scales finally used in the analysis exceeded this criterion.

For the construct validity, the items loaded on a second factor/scale were eliminated (cut-off value of less than ± 0.40 as assessed by Hair et al., 1998). Thus, the following scales were withdrawn since their items did not meet the requirements in their measures (see Table 4 for scales finally used): “communication of manufacturing strategy” (an MS related practice) and “simplicity of product design” (a technology related practice). Detailed analysis will be provided upon request.

Take in table 4

Therefore, both MS and technology are conceptualised and defined as multidimensional constructs. Each dimension/practice (scale) represents one facet of these broad constructs (super-scales) and all pertinent dimensions together define a super-scale as a whole. After the individual scales (dimensions) were checked for reliability and validity, the next step was to aggregate (average) them into super-scales or sets to represent the two broader concepts mentioned above. Following Hunter and Gerbing (1982), a second-order factor analysis was performed for each of the two super-scales to ascertain that the set of scales formed corresponding unidimensional measures, as in Table 4. As seen here, the super-scale measuring MS is reliable and unidimensional with all of its three scales contributing significantly to its formation.

A similar procedure was used to construct the technology super-scale from the three dimensions/practices described earlier. Table 4 shows the results of the reliability and unidimensionality analyses. With respect to operational performance, a composite measure reflecting a plant’s achievement in the six measures from section 2.1 was constructed in order to observe the total effectiveness of all four competitive priorities. Table 4 also shows that the composite performance measure is reliable and unidimensional.

In addition, Table 4 also summarises the way the measures (included contextual factors as the control variables) were distributed by respondent (or by group of respondents) in the plant. The natural numbers in the body of the Table indicate the number of responses for each category at each plant. Tables 5, 6 and 7 show the descriptive statistics of operational performance, MS and T measures and super-scales used in the research, respectively.

Take in table 5

Take in table 6

Take in table 7

3.4. Methods of analysis

Once the data was finally processed, it was analysed using the methods in the proposed universal perspective by means of the additive model, where each independent variable has an effect on the dependent variable that is not conditional on the value of any other independent variable, and the value of the independent variable itself is not conditional on the dependent variable or on any other independent variable. This model is operationalised by the use of multiple regression analysis to test the impacts of the two manufacturing practices sets on performance taking into consideration some contextual factors. Thus, equation (1) will be used to test hypotheses H1 and H3 (see Figure 1), and equation (2), hypotheses H2 and H4 (see Figure 2), where P is performance, T, Technology, and S, Manufacturing Strategy. Three independent variables are also included as control variables, specifically plant size (ps), product customisation (pc) and plant capacity utilisation (cu). The various β_i are the coefficients associated with the respective variables whilst ε is the error term. The statistical significance of coefficient β associated with the interest independent variable will provide support for a universal perspective between this variable and P.

$$\mathbf{P_1 = \beta_{01} + \beta_{11}S + \beta_{21}T + \varepsilon_1} \qquad \mathbf{(1)}$$

Take in Figure 1

$$\mathbf{P_2 = \beta_{02} + \beta_{12}S + \beta_{22}T + \beta_{32}ps + \beta_{42}pc + \beta_{52}cu + \varepsilon_2} \qquad \mathbf{(2)}$$

Take in Figure 2

In addition to the foregoing regression methods we used a *sub-group variance analysis* as a confirmatory method. This analysis is also used in this study to reveal major differences between the high and low performer group members, not to predict group membership of manufacturing plants. The method involves subdividing a sample of plants into two sub-groups (high and standard performers), as explained in Section 4.1, and then comparing their characteristics.

4. RESULTS

Multiple linear regression was used to test all the hypotheses (H1 to H4). As already stated, equation (1) (Section 3) was used to test hypotheses H1 and H3 (Figure 1 above) and equation (2) (Section 3), which includes the control variables, was used to test hypotheses H2 and H4 (Figure 2 above). Table 8 sets out the results of the first model (H1 and H3). It can be seen that Manufacturing Strategy alone is positively and significantly related to performance ($P \leq 0.01$).

Take in table 8

Therefore, this supports hypothesis H1 and rules out hypothesis H3 regarding an association between Technology and Performance.

The same is true for the second model (see Table 9, below), where Manufacturing Strategy retains its positive and significant relationship ($P < 0.05$) with the control variables present whereas, as before, Technology bears no significant relationship. Our review of papers employing regression analyses to test universal hypotheses in HPM research suggests that the P-values that we obtained in our study provide adequate support for such hypotheses (Ahmad et al., 2003).

Take in table 9

In order to study the characteristics of the different types of plants and thus obtain a more complete perspective, we used the variation sub-group analysis explained in the previous section. The averages for each variable for high (HP) and standard performers (SP) are shown in table 10.

Take in table 10

The averages for both groups (HP and SP) are practically identical for all the variables (Box test with significance >>0.05 confirms the same statistical covariance for both groups). This demonstrates that none of the MPs presents significant differences between the two plant groups, possibly indicating iso-performance between MS and technology, perhaps due to a congruency fit (i.e., fit to low levels of both technology and MS significantly produces the same performance as the fit to higher levels). Thus, it can be seen that the averages for each of the variables in both groups were practically the same, and there were no significant differences between any of the MPs. However, high performers have a slight advantage in performance; they may apply slightly higher levels of MS and technology practices, which may lead to better results.

It should be noted that the smallest differences between both groups can be found in technology, which could be taken as an indication that the technology practice set has been implemented in both plant groups to a very similar degree. Consequently, as had already been shown in the regression model, the technology set does not significantly affect performance. Thus, sub-group analysis was a confirmatory method to regression.

Going beyond the objectives of this paper, a simple (besides the multiple) linear regression was used to test whether there was a relationship between T and P, when not in the presence of MS. Results showed that T was indeed positively significant at 0.03 to P. Thus, in order to investigate further this study used partial correlations and observed that there are strong selection forces between T and MS (positively significant correlation at 0), with both T (0.03) and MS (0) positively correlated to P. However, when we tested the partial correlation between T and P, removing the influence of MS on both T and P, the correlation was found to be no longer significant (0.508).

This means that the significant simple linear relationship between T and P is due to the influence of MS on both T and P. This is the reason why T was not significant when we used multiple linear regression to test whether both T and MS explain P. In other words, only MS is relevant.

From all the above results, it can be stated that with the universal fit model, manufacturing strategy is positively associated with performance and that this association remains positive even when control variables are included. This indicates that manufacturing strategy explains operational performance better than the contextual control variables in which the plants operate.

In other regards, the universal model seems to show that technology (as measured here) has no apparent relationship with performance in the sector under study. Although at first sight, this may seem a little strange, it should be remembered that some of the literature also states that technology is not significantly linked to performance. Four reasons might explain this:

1. Technology is implemented to similar levels in both types of plant, which means that the MP has gone from being an *order-winner* to an *order-qualifier* (Hill, 1993). This is consistent with the sector under study, as the auto suppliers sector is so technologically competitive that it is impossible to survive in it without cutting-edge technology and, in general terms, it may be that companies remain on such a similar level that it is virtually impossible to distinguish between them.
2. The technology measures used in this study measure the Management's efforts to implement technology operations practices but do not measure the quality of their implementation.
3. Selection forces are strong between both independent variables, with the especially strong influence of manufacturing strategy on technology, which may indicate that the latter will not operate properly without MS. This opens up a line of research on selection fit to test for congruency between MS and T
4. This might be attributable to a problem with the data used. As a result it might be necessary to test this relationship in the future using different data sets both in an aggregated and a disaggregated way, to shed more light on this.

To sum up, while the implementation of MS manufacturing practices provides significant association with performance, we have also tested whether technology and some contextual factors may also contribute to the explanation of performance variation. However, neither technology nor contextual factors, such as plant size, plant capacity utilisation and product customisation, seemed to affect performance. Therefore, this stage of the analysis indicates that the MS internal practices and techniques of a plant provide a better explanation of plant performance than technology and the context in which a plant operates.

5. CONCLUSIONS AND FINAL CONSIDERATIONS

Using the universal perspective of fit, this paper examined whether manufacturing strategy and/or technology were *per se* effective in improving operational performance in a two stage approach: 1) in the presence of each other; and 2) when contextual factors are present. The results show that manufacturing strategy has a positive relationship with performance, and continues to do so even when contextual factors are present. However, technology does not have a positive relationship with performance in either case.

Despite the above, it is necessary to continue testing the hypothesis in the future with different data and a different level of dimensions in order to preclude any doubt about whether the results reflect the true state of the technology-performance relationship or not. With regard to the sector under study, it can be stated that it is fairly homogeneous as far as type of plant, and the degree to which manufacturing strategy and technology are concerned. This may in part be due to the dynamic and drastic changes that the sector is currently experiencing. This is leading plants to continuous improvement on the road to high performance, as reflected in the results of our analysis and in the few differences that can be appreciated in the sector (Ortega, 2007).

In other regards, it is important to evaluate the entire study critically, since, as with all research work, this paper has limitations. However, some of these limitations may be seen as fertile fields for future research on the same topics. As is the case with any empirical research, the results and conclusions of studies like this should be welcomed with caution due to the restraints imposed by the techniques and constructs on which they are proposed, as explained in more detail on the next paragraph. Similarly—and being mindful that this is a sector study (the sample consists of auto supplier plants)— the results may provide some inferential benefits for the population analysed, but their extrapolation to any other group may well be futile. Therefore, this leaves room for research to test for industry differences as a contingency. Thus, in a work in progress, the models are being tested with the samples from two other industrial sectors (electronics and machinery) in order to analyse and compare the interrelationship by sectors before doing an intersectoral study. Likewise, it is necessary to remember that the size of the plants analysed (more than 100 workers) may make the results of the study invalid for smaller companies.

As far as the limitations of the obtained results are concerned, while they suggest that the implementation of manufacturing practices from only MS and not from technology can mask the possible effect of contextual factors on performance, future studies should investigate the possible interaction effects of other contextual factors and manufacturing practices on performance. For instance, a future research study could be a more detailed examination of the relationships between the two programs and other contextual factors, which may identify the exact nature of the interaction between practices and context.

Furthermore, the international HPM Project is a cross-sectional research project (with very little longitudinal data): a snapshot tailored to the sample. This limits the possibilities of analysing dynamic changes in the sample plants. Also, it is important to remember that the correlation between two variables does not necessarily mean that there is causality between them. Two variables may be highly correlated without there being any logical explanation for this (Richardson and Pugh 1981; Norusis, 1997). Therefore, although the perspectives discussed here have been based on static cross-section approaches, specifying and testing fit and interrelationship between practices is a never-ending dynamic job, where the plant is continuously aiming at a moving target. Hence, no plant enjoys a perfect state of dynamic fit, but may be moving towards such a state. Although a small number of conceptual papers on the dynamic perspective of fit exist, no empirical studies can be found, either with the perspectives of this study or of others that would prove such theories. Regardless of the fact that this paper does not attempt to study dynamism, we acknowledge that this is a promising area for research and for the development of appropriate mechanisms in order to test fit within a longitudinal perspective.

Finally, the universal model used here imposes a linear correspondence between manufacturing strategy or technology and the respective direct result of their links with performance. This fit form—primarily of linear correspondence—does not take more complex relationships into account, such as manufacturing practice links: that is, it includes no explicit recognition that the effect of one variable depends on the presence or magnitude of other variables. Additive models can limit understanding of management by representing its causes and effects (e.g. MS and/or technology causes and performance effects) as universal rather than conditional on a context of other variables such as other manufacturing practices. Moreover, universalistic theories of organisation claim that there is only “one best way” to organise, meaning that maximum organisational performance comes from the maximum level of one or both variables with no conditions between them . However, this limitation may be overcome by future research using contingency theory, which asserts that maximum performance results from adopting the appropriate level of one of the variables that fits the other. This could extend this study from another perspective, such as selection or interaction, in order to outline hypotheses regarding the dependencies between the fit of both manufacturing practices and the link between fit and performance. This would allow us to answer the question whether improved operational performance might result from the interaction between manufacturing strategy and technology to be explored.

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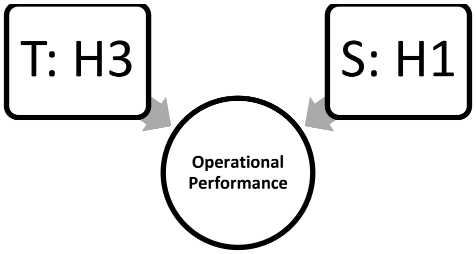

Figure 1. Manufacturing strategy and technology on operational performance

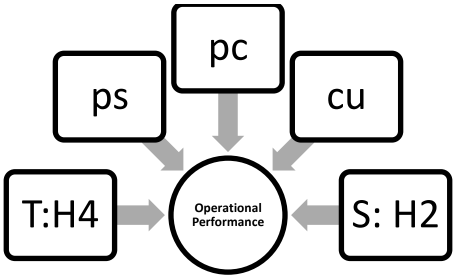

Figure 2. Manufacturing strategy, technology and contextual factors on operational performance

Table 1. Sample profile

COUNTRY	PLANTS
Austria	4
Finland	10
Germany	19
Italy	7
Japan	13
Korea	11
Spain	10
Sweden	7
USA/Canada	9
Total	**90**

Table 2. Contextual factors as control variables

Variable	Av.
Plant size (number of persons employed-per hour and permanent staff)	867
Average percentage of plant capacity utilisation (%)	84.45
Percentage degree of product customisation	
• ***Ad hoc* design activities (%)**	27
• **Customised manufacture (%)**	28
• **Customised assembly (%)**	23
• **Customised delivery (%)**	10
• **Standardised products (%)**	12

Table 3. Sample description: other contextual factors

Variable	Av.
Types of manufacturing processes in plants	
• **Projects (model) (%)**	7
• **Small lots (%)**	17
• **Large lots (%)**	28
• **Repetitive/lines (%)**	26
• **Continual (%)**	22
Types of equipment and processes used in plants	
• **Standardised equipment purchased from suppliers (%)**	40
• **Equipment from suppliers modified for own use (%)**	30
• **Patented equipment designed by own company (%)**	20
• **Equipment patented, designed and manufactured by own company (%)**	10
Length of equipment time is in service in plants	
• **2 years or under (%)**	14
• **3 - 5 years (%)**	25
• **6 - 10 years (%)**	32
• **11 - 20 years (%)**	21
• **Over 20 years (%)**	8

Table 4. Study scales and measures in questionnaires

Super scales and scales	Acc	PD	PM	PRM	PE	SU	Load Factor	Cronbach’s Alpha
Manufacturing strategy								**0.83**
Anticipation of new technologies			1	1	1		0.78	
MS-BS link			1	1	1		0.91	
Formal strategic planning			1	1	1		0.90	
Technology								**0.73**
Interfunctional design efforts		1			1	6	0.88	
Effective process implementation				1	1	6	0.79	
Supplier involvement		1					0.60	
Performance								**0.73**
Unit cost of manufacturing			1				0.53	
Product conformance to specifications			1				0.60	
On-time delivery performance			1				0.77	
Fast delivery			1				0.74	
Flexibility in changing product mix			1				0.56	
Flexibility in changing volume			1				0.71	
Control variables (objective measures)								
Product customisation					1			
Plant size	1							
Plant capacity utilisation					1			

Acc: Accounts; PD: Product Develop. PM: Plant Manager; PRM: Production Manager; PE: Process Engineer; SU: Supervisor

Table 5. Average values of manufacturing performance measures

Measure	Av.	S.D.
Unit cost of manufacturing	3.25	0.85
Conformance to product specifications	3.88	0.71
On-time delivery performance	3.90	0.82
Fast delivery	3.70	0.80
Flexibility in changing product mix	3.89	0.70
Flexibility in changing volume	3.83	0.80
Composite performance	**22.20**	**3.15**

N =79; 5 point Likert scale

Table 6. Average values of manufacturing strategy measures

Measure	Av.	S.D.
Anticipation of New Technologies	5.13	0.74
Formal Strategic Planning	5.46	0.72
MS-Business Strategy link	5.49	0.63
Manufacturing strategy	**5.36**	**0.60**

N =89; 7 point Likert scale

Table 7. Average values of technology measures

Measure	Av.	S.D.
Effective process implementation	5.05	0.62
Interfunctional design efforts	4.76	0.64
Supplier involvement	4.91	1.20
Technology	**4.90**	**0.62**

N =79; 7 point Likert scale

Table 8. Manufacturing Strategy, technology and performance

Measure	Composite performance
MS	2.504***
Technology	0.407
F	5.77***
R^2	0.273
Adj. R^2	0.255

N=84; **P ≤ 0.05; *** P ≤ 0.01

Table 9. Manufacturing strategy, technology, context and performance

Measure	Composite performance
MS	1.955**
Technology	0.563
Plant size	0.596
Product customisation	0.003
Plant capacity utilisation	-0.017
F	5.084***
R^2	0.361
Adj. R^2	0.290

N=51; **P ≤ 0.05; *** P ≤ 0.01

Table 10. High vs. standard performers

Plant group	Performance	MS	Technology
High performers	22.8	5.39	4.69
Standard performers	22.12	5.35	4.68