Different contexts for competitiveness: performance, technology, production strategy and contingencies

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Abstract

This paper examines the relationship among production strategy, technology, performance and contingencies, through bivariate and holistic fit models, by an empirical data (12 questionnaires from 330 plants worldwide). Findings show support for existence of differences in paths followed by plants, depending on the context for attaining competitiveness (i.e. suboptimal equifinality).

Keywords: Technology, Production strategy, Performance

Introduction

Paths to competitiveness may be different for manufacturing plants because of both plant context and manufacturing practice relationships. POM research still needs more clarification on why implementations of the same manufacturing practices foster high performance in some plants, but not in others. Poor success may be partially due to faulty relationships between manufacturing practices. This study therefore examines relationships between two practice sets (production strategy/PS and technology/T) and performance/P (Ortega et al., 2012).

Managers may be confused, and no wonder why. Firstly, management researchers, consultants, and practitioners often disagree on how plants should implement tech-enabled strategy, and many read papers contradict one another (Gilbert Jr et al. 2012; Glass 2011; Althonayan and Sharif, 2010; Bowonder et al. 2010).

Some theorists claiming to have answers to strategic management are argumentative and confusing, with conclusions that lack empirical support and/or that are justified with selective case studies. But as a manager, the ability to assess strategy and understand its probability of sustainability is one of the most valuable, yet difficult skills to dominate. As far as technology, it is not only seen as a key enabler to nearly every production strategy, but also often thought of standard equipment easily purchased from vendors. This may be why some plants struggle at the linkages where strategy and technology interact. Many managers who have operationalized this interaction incorrectly may have meant a contributing factor to their plants going out of business.

Drawing linkages and contingency-based approaches, this paper argues that the study of performance (P) in these settings can be enhanced by considering the fit between P, PS and T. Hence, this study adds to research in this area by proposing multiple fit models that examines the combined effect of PS and T on P within a single theoretical framework. It is true that such approaches have been used for some time for many researchers (see Drazin and Van de Ven 1985). However, fewer researchers have looked on multiple PS practices with internal consistency among multiple practices of T and their impact on P.

Therefore, this paper sets out as its objectives an empirical and descriptive discussion of some PS and T practices that should be implemented for competitiveness, and to test whether plants are seeking higher performance dimensions related to these practices.

The remainder of the paper is structured as follows. The following section defines the theoretical background of this study and present relevant hypotheses. The process of data collection and data analysis is then detailed in the third section. The results of the study are presented and discussed in the fourth section. The last section contains concluding remarks, implications, and directions for future research.

Theoretical background and hypotheses

Performance (P)

Establishing links between manufacturing practices and competitive performance is, perhaps, the most critical and interesting aspect of a study on manufacturing practices, particularly when studying situations, where plants need to perform well in a multidimensional level. However, some existing literature still ignores the role of manufacturing goals and uses a one-dimensional performance measure in the models and empirical tests.

Drawing on the above, in order to examine relationships between practices and competitiveness, this study focuses on multidimensional performance, by considering cost, quality and responsiveness, all three closely linked to plant operations. For the verification of the existing practices, being followed by plants to get these competitive priorities is necessary to identify their drivers of high performance and sustainability. POM researchers have contributed to literature by examining conditions under which specific practices, resources or structural arrangements are valuable (Bernardes and Hanna 2009; Skinner, 1969).

These priorities are built by dimensions and by indexes as follows: Responsiveness priority has three dimensions (time, dependability and flexibility). For time, two different indexes are considered: speed of new product introduction and cycle time. The dimension of dependability has two indexes: on time new product (NP) launch and on time delivery. The indicators of flexibility are also two: flexibility to change product mix, and flexibility to change volume. Quality dimension has an index based on conformance to product specifications. The index of cost dimension may be estimated through unit cost of manufacturing.

Production strategy (PS)

There is still enough broad empirical research in POM literature documented (and even less in high performance manufacturing (HPM) papers) addressing clearly the implementations of production strategy.

There are clear signs that manufacturing strategies play a fundamental role in the assessment of new technologies, since an analysis of appropriate technology can eliminate many risks, given that high performing technology is a key factor in global competitiveness (Machuca et al 2011).

In other regards, according to the classic conception defined in strategy literature which distinguishes between processes and content (e.g. Kandemir et al. 2012; Swamidass and Newell 1987), it can be said that the formal strategic planning process, which is successfully aligned with the business strategy, is key to the formulation of production strategy. The alignment of the external coupling (market) and the internal coupling (technology and organization) 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 (Yarbrough et al. 2011; Bates et al. 1995). 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, production 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 (Ortega et al. 2011; 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 production strategy in a plant should include aspects such as the *anticipation of new technology*, and *a link between production strategy and business strategy*, a *formal strategic planning process* that involves the plant management, and *communication of the production strategy* to plant personnel. Thus, we shall consider these four production strategy practices dimensions in this study.

Technology (T)

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 criticized for not creating the desired results, i.e. technology initiatives 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 by a more complete view of technology. However, the plant has to have a more progressive and dynamic vision yet 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 of hardware systems, but also human and organizational aspects of the way the plant operates (Heim and Peng, 2010). Thus, this focuses on the following two aspects of technology.

Product technology. International HPM research (Schroeder and Flynn 2001, McKone and Schroeder 2002) considers some relevant dimensions that are used to develop product technology. This paper focuses on *interfunctional design efforts*.

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 four dimensions: e*ffective process implementation*, *proprietary equipment*, *group technology-cellular manufacturing*, and *anticipation of new technologies*.

Fit: multiple contingencies

Fit means consistency of two or more factors and a good fit between relevant factors should improve performance (Venkatraman 1990). Since fit may explain why different practices may affect specific outcome measures, this paper conceptualizes it from a multiple contingencies model research model, which is extended to include the combined effect of PS and T variables on P. That is, it addresses the question of which P's are most likely to be used in each combination of PS and T.

The model adopts a holistic approach and assumes that effects placed on P by multiple PS and T practices (i.e. contingencies) may conflict (i.e., attempts to satisfy implementation level of one practice may mean that implementation level of another practice cannot be satisfied). Also, that the need for high performance can be met by several alternative, and equifinal, implementation levels of practices. This may be justified by the fact that practices may not only complement each other but also substitute for each other (Betts 2011).

Drawing on the above, this paper focuses on the following hypotheses:

H1: Levels of practices are associated with performance

H1: High performers (HPs) have higher implementation levels of both manufacturing practice sets (PS and T).

Thus, this paper takes on a bivariate fit perspective (i.e. PS and T as independent variables and P as the dependent variable), from a holistic view set out below.

Research setting

Data collection

The data were collected by using a standard set of questionnaires to 21 different informants (from manager to work laborer), together with site visits to 330 plants from 11 countries worldwide (Austria, Canada, China, Brazil, Finland, Germany, Italy, Japan, South Korea, Spain, Sweden, USA). The respondents for the PS practices and T practices variables, and control variables included managers, engineers, supervisors and workers from the entire plant. As for plant performance, the informants were plant managers.

The selection of the plants to participate in the study was based on several criteria. First, about half of the plants were randomly selected from lists of "world class reputation" plants that had been publicized as high performer in the literature or by industry experts. This was done to ensure that the sample contained a good representation of some of the best plants in the world. The other half of the plants was selected randomly from lists of the general population of plants. This provided a comparison group consisting of the more traditional and ordinary plants. The selection also included plants from three industries in each country (electronics, machinery, and automobile suppliers. These industries were selected because of two reasons: 1) these are industries in transition and have intense global competition; and 2) they are industries having a substantial number of plants in America, Asia and Europe.

Variable measurements

This paper uses both objective measures, as well as perceptual scale measurements with several questions (items). Perceptual questions were answered using seven-point likert scale for manufacturing practices and five-point scale for performance. Content validity was ensured through not only a comprehensive review of the extant literature but also by a test construction method (questionnaire preparation, pilot testing, structured interviews, translation, and back translation when the questionnaires were administered in native languages).

Scales had to pass both the reliability and unidimensionality tests to be considered for subsequent analysis. First, all scales used in the analysis exceeded the criterion level for reliability (i.e. internal consistency), which was measured by Cronbach (1951)'s alpha of 0.6 or more for a reliable scale at the plant level (Nunnally 1967). Construct validity was done by performing within scale factor analysis to verify dimensionalities. The items of each factor were checked to see if they loaded onto just one factor, if they didn´t they were deleted. More detailed measures will be sent upon request.

All PS and T practices are conceptualized and defined as multidimensional constructs with factor loadings of the scales above the cut-off value of ±0.40, showing that all the items contributed substantially to their respective scales (Hair et al. 1998). Each dimension (scale) represents one facet of both broad constructs (super scales) and all pertinent dimensions together define a super scale as a whole. After the scales were checked for reliability and validity, the next step was to aggregate them into super scales to represent the three broader concepts mentioned above. A set of scales can be aggregated to represent a super scale if these scales load onto a single factor. A second-order factor analyses was performed for each of the super scales to ascertain that the set of scales form corresponding unidimensional measures as shown in Table 1 (Hunter and Gerbing 1982). Table 2 presents averages of the three performance dimensions defined, since no super-scale was formed, in order to keep performance multidimentional.

Table 1- Reliability and unidimensionality analyses for the super scales and scales

Practices (SCALES)	**Cronbach Alpha**	**Factor Loadings**	**Cronbach Alpha (super scale)**
Group technology-cellular manufacturing (T1)	0.727	0.480	0.728 Technology (T)
Interfunctional design effort (T2)	0.728	0.621	
Anticipation of New Technologies (T3)	0.793	0.672	
Effective Process Implementation (T4)	0.806	0.842	
Proprietary equipment (T5)	0.757	0.824	
Manufacturing-business strategy linkage (PS1)	0.810	0.908	0.814 Production strategy (PS)
Manufacturing strategy strength (PS2)	0.629	0.762	

Practices (SCALES)	Cronbach Alpha	Factor Loadings	Cronbach Alpha (super scale)
Communication of manufacturing strategy (PS3)	0.778	0.663	
Formal strategic planning (PS4)	0.847	0.869	

Table 2 - Descriptive statistics for the three performance dimensions.

Variable	Mean	Std.
Cost (P1)	3.267101	0.8931433
Quality (P2)	3.880645	0.6980877
Responsiveness (P3)	3.596195	0.5650743

As for the class effect, it is clear that responsiveness (main reconfigurable characteristic) along with cost and quality were key factors in establishing the group classification. Thus, an analysis was carried out to distinguish between two plant types (high performer and standard performer) based on the classification higher-than-average and lower- than-average performance on the three performance measures, the scores for the drivers (PS and T manufacturing practices) for the two groups remain consistent with their overall performance. The plants with the lowest performance on the three performance measures are weakest in implementation of the drivers, and those with the best performance on the three performance measures are strongest in implementation of the drivers. Such analysis allowed identifying a group of 74 plants as high performers, which represent close to 24% of the total (not included missing values).

Method of analysis

Since the main objective of this study is to describe P as a dependent variable with internal consistency among multiple practices of both PS and T, cluster analysis is used to explore how the elements combine. Cluster analysis provides a sophisticated means of determining how they combine insofar as it groups observations into clusters such that each cluster is as homogeneous as possible with respect to the characteristics of interest and the groups are as different as possible.

Results and discussion

As a first step, the plants were divided into homogeneous groups based on their values for the three variables. Then, cluster analysis was used to develop categories of P, PS and T. Figure 1 shows the dendograms that resulted from the hierarchical cluster procedures. A critical issue in cluster analysis is the determination of the appropriate number of clusters.

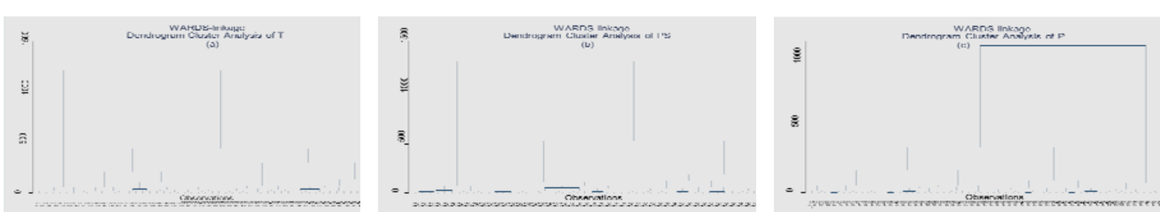

Figure 1 - Dendograms with results of hierarchical cluster analysis: (a) T, (b) PS, (c) P

K-means algorithm was used and the best result was K=2 (F=11.50681318, P-value=8.36826730344e-55). The results from the hierarchical clustering procedure were used as cluster seeds in the nonhierarchical clustering. Table 3 shows the results from the K-means clustering. Bold numbers denote the highest scores on each design element.

Table 3- Results of the K-means clustering[a]

	Group 2	Group 1		Group 2	Group 1		Group 2	Group 1
T1	**0.4210**	-0.489	**MS1**	**0.780**	-0.575	**P1**	**0.954**	-0.350
T2	**0.4205**	-0.476	**MS2**	**0.690**	-0.506	**P2**	**0.631**	-0.237
T3	**0.6171**	-0.719	**MS3**	**0.616**	-0.461	**P3**	**1.036**	-0.402
T4	**0.5124**	-0.600	**MS4**	**0.740**	-0.551			
T5	**0.4137**	-0.484						
Observations	178	155		143	192		84	221

Since data were standardized, positive signs mean that the centroid values of the objects contained in the cluster are above average while negative signs denote the opposite.

Then, a linear discriminant analysis was used for each cluster analysis to substitute reclassification for the division of high (HP) and standard (SP) performer explained in last section and similarly for implementation levels (low and high) of both PS and T. Figure 2 shows results of cluster vs. discriminant analysis, and, from Table 4, one can see bold numbers in groups 1 as low implementation and in groups 2 as high implementation for both T (Table 4a) and PS (Table 4b). Also, bold number in group 1 represents SP and in group 2, HP.

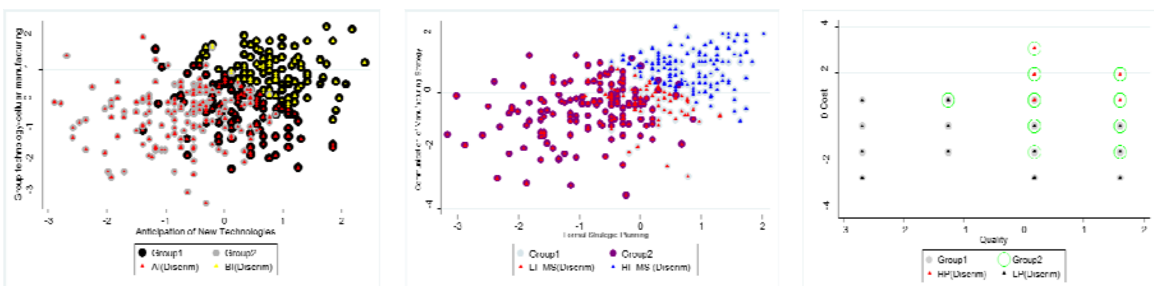

Figure 2-Cluster vs. discriminant analyses: (a) T, (b) PS, (c) P

Table 4- Linear discriminant analysis: re-substitution classification ((a) T, (b) PS, (c) P)

(a)

True	gr1	gr2	Total
gr1	**229**	60	289
%	79.24	20.76	100
gr2	6	**39**	45
%	13.33	86.67	100
Tot	235	99	334
%	70.36	29.64	100
Prior	0.5	0.5	

(b)

True	gr1	gr2	Total
gr1	**199**	54	253
%	78.66	21.34	100
gr2	3	**80**	83
%	3.61	96.39	100
Total	202	134	336
%	60.12	39.88	100
Prior	0.5	0.5	

(c)

True	gr2	gr1	Total
gr2	**74**	0	74
%	100	0	100
gr1	24	**208**	232
%	10.34	89.66	100
Total	98	208	
%	32.03	67.97	100
Prior	0.5	0.5	

These results confirmed HP and SP for P, as well as low and high implementation of both T and PS as key characteristics for each group. Hence, as a second step, plants were categorized with respect to low and high levels of implementation for PS and T. For each of the five T practices, it was then examined the extent to which the two performance classes (HP and SP) were used. Table 5 exhibits the observed P proportions and the observed frequencies within each context. All Ps were significant.

Table 5- Proportion of PS and T in different performance contexts

	High Implementation PS		**Low implementation PS**	
HIGH IMPLEMENTATION *T*	Frequency	* Proportions	Frequency	* Proportions
Group technology-cellular manufacturing				
HP	22	**48.89**	23	**51.11**
SP	25	**21.55**	91	**78.45**
Interfunctional design effort				
HP	33	**67.35**	16	**32.65**
SP	30	**27.03**	81	**72.97**
Anticipation of New Technologies				
HP	32	**56.14**	25	**43.86**
SP	36	**33.64**	71	**66.36**
Effective Process Implementation				
HP	34	**61.82**	21	**38.18**
SP	35	**31.53**	76	**68.47**
Proprietary equipment				
HP	27	**55.10**	22	**44.9**
SP	26	**22.81**	88	**77.19**
LOW IMPLEMENTATION *T*				
Group technology-cellular manufacturing				
HP	15	**53.57**	13	**46.43**
SP	17	**14.41**	101	**85.59**
Interfunctional design effort				
HP	4	**16**	21	**84**
SP	12	**9.68**	112	**90.32**
Anticipation of New Technologies				
HP	5	**29.41**	12	**70.59**
SP	6	**4.69**	122	**95.31**
Effective Process Implementation				
HP	3	**15.79**	16	**84.21**
SP	7	**5.65**	117	**94.35**
Proprietary equipment				
HP	10	**40**	15	**60**
SP	16	**13.22**	105	**86.78**

* $p<0.05$

Results from Table 5 give some support to both H1 and H2, since except for Group technology-cellular manufacturing (but just below with almost 49% of HPs when implementing high levels of it and PS), all T practices with high implementation level facing high implementation levels of PS had the higher proportion of HP, with Interfunctional design effort and Effective Process Implementation as the first and second highest respectively. Interestingly, all other combinations other than high-high implementation give HP’s. The concept of equifinality may help to explain these findings. That is, plants may get high performance by other ways, which may need further research, especially if they remain even if plant environment changes.

The findings presented above provide some support for the expected relationships between PS and T and P on plants on four out five T practices used in the study. However, an interesting and unexpected finding is that of Group technology-cellular manufacturing since plants here do not face any single dominant imperative, but a suboptimal equifinality. In other words, there is a trade-off between PS or T requirements. What T or P should look like is determined by the factor considered most important. Notably, this type of equifinality is always sub optimizing because one or several of the requirements are not met. Additionally, since no single dominant imperative exists, there is also an enhanced likelihood of variation among these plants. The fact that both HP’s can be found in approximately equal proportions (50%) in this context may be consistent with this argument.

Conclusions and future directions

This paper stated that there is still lack of research that examines simultaneously effects of multiple levels of implementation of both PS and T practices on performance. Findings from this study support roughly the notion of a combined effect of PS and T on P.

A variety of future research studies are possible including more cluster analyses for exploring the way in which a wide range of dimensions combines. The P class effect used in this paper provide a broader picture of how different PS and T practices make up a system, where the different practices may complement as well as replace each other.

There is also room for longitudinal studies and more detailed examination of the relationships among PS and T. Such studies may help examine the causal linkages among practices. More detailed studies could pinpoint the exact nature of the interaction among practices. While this study provides a foundation for examining PS, T and P within a single framework, it is only through further research that a full understanding of the relationship among them will be obtained.

Results also suggest that it may be important not to assume automatically that there is a one-to-one pre-establish (e.g. high-high implementation level) relationship between PS and T on P to get HPs. Instead, for high performance there may be different practices available in PS that may well combine in different ways with a particular T practice. Many researchers from different fields have taken up the concept of equifinality in their studies. However, there is need for more in POM research, such as studying inclusion of multiple practices, because it may help explaining contradictions and unexpected patterns. Hence, a logical extension of this study would be to examine more systematically the way in which these and other manufacturing practices improve P, and to investigate the existence of alternative and functionally equivalent interrelationships of manufacturing practices.

Finally, it is important to consider the limitations in this paper, since the research design used does not have enough statistical rigors, nor does the clear notion of fit as compared with fits between single factors of PS, T and P. Therefore, this is an opportunity for another future direction of research, which is to apply even more systemic models.

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