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Organizational Ambidexterity, Manufacturing Performance and Environmental Dynamism

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Abstract

Purpose - This research examines the relationship between organizational ambidexterity, the ability of companies to explore new and to exploit existing processes simultaneously, and manufacturing performance as represented by the sand cone model. Moreover, the paper analyses the impact of stable and dynamic environments on this relationship.

Design/methodology/approach – A set of research questions are tested using structural equation modelling (SEM) on a sample of 231 Spanish manufacturing companies.

Findings - Results illustrate a significant relationship between ambidexterity as the basis and enabler for manufacturing performance improvements, building on the sand cone model and its dimensions of quality, delivery, cost, and flexibility. This relationship is further emphasized when companies work in a dynamic environment.

Practical implications – The study contributes to practice by investigating the important and yet under-explored relationships of ambidexterity, the sand cone model, performance, and a company's wider market environment. Findings suggest a positive relationship between the sand cone model and ambidexterity capability.

Originality/value - This study adds to the limited theoretical and empirical understanding of the relationships between ambidexterity, the sand cone model, environmental dynamism, and performance. It also contributes through a set of empirical data derived from Spanish manufacturing companies.

Keywords - *Ambidexterity, Capability, Sand Cone Model, Manufacturing Performance; Environmental Dynamism; Spain; Survey*

Paper category - Research paper

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1. Introduction

Today's globally competitive markets mean that the practice of Operations Management (OM) increasingly addresses both traditional cumulative approaches to improvement and the more disruptive innovation and adaptation processes necessary to create and cope with radically different tasks, technologies, and territories (Lavie and Rosenkopf, 2006; Raisch *et al.*, 2009). In more theoretical terms, the fundamental challenge inherent in balancing exploitation/exploration (March, 1991) can be helpfully framed using the debate regarding resource-based (e.g. Wernerfelt 1984, Barney, 2001) and dynamic capabilities (Teece *et al.*, 1997: 516) related advantage. Resource-based theory (RBT) argues that cumulative resource factors, as typified in OM by the layers (i.e. quality, delivery, cost, flexibility) of the 'sand cone' (Nakane, 1986; Ferdows and De Meyer, 1990; Corbett and Whybark, 2001), are critical to the sustainability of any competitive advantage because they create barriers to imitation that prevent advantages being 'competed away' too quickly (e.g. McGee and Thomas, 1986; Mahoney and Pandian, 1992). Conversely, others in this debate have argued that it is the mechanism whereby an organization can purposefully create, extend, or modify its resource base (Helfat and Peteraf, 2003), its dynamic capabilities (DC), that especially in "high velocity" markets are the key to competitive survival via adaptation and experimentation (Patel *et al.*, 2012).

Those organizations that manage to balance both approaches have been called ambidextrous (O'Reilly III and Tushman, 2013). Although this concept has been widely discussed in the management literature, key questions remain (e.g. the relationship between ambidexterity and environmental dynamism: Jansen *et al.*, 2005) and, critically for this paper, its application within OM is under-developed. This represents an opportunity to make a relevant contribution to the OM field and, given that the specific relationship between ambidexterity and manufacturing performance (Sabella *et al.*, 2014) has received surprisingly limited attention (Raisch and Birkinshaw, 2008; Junni *et al.*, 2013), to the broader literature as well.

This paper reports on a study that used a dataset of 231 questionnaires collected from Spanish manufacturing companies to explore (a) the relationship between organizational ambidexterity and manufacturing performance (as represented by the sand cone model),

and (b) the impact of environmental dynamism on this relationship. In addition to offering further empirical support for the cumulative sand-cone, rather than trade-off (Narasimhan and Schoenherr, 2013) approach to capability development (i.e. quality, speed, cost, and flexibility), our findings suggest a positive relationship between the sand cone model and ambidexterity capability. In other words, simultaneously driving exploration and cumulative exploitation activities leads to increased manufacturing performance. The analysis also shows these relationships are more significant in the presence of dynamic environmental conditions.

The remainder of the paper is structured as follow: Following the introduction, the literature review discusses and synthesizes extant studies regarding ambidexterity, and the sand cone model. The study's research questions are then developed before section 3 addresses key methodological considerations. Section 4 describes the results of the research, while section 5 presents the discussion of the results, addresses key limitations and recommendations for future research avenues. Finally, section 6 outlines conclusions and practical implications.

2. Conceptual background

As noted above, this study can be usefully linked to questions of resource-based (exploitation) and/or DC-based (exploration) advantage. RBT has been particularly influential in OM (e.g. Lewis, 2000; Pandza *et al.*, 2003; Miller and Ross, 2003; Rungtusanatham *et al.*, 2003; Holcomb and Hitt, 2007) but, as Teece (2006) has argued, it is the distinct skills, processes, procedures, and decision rules underpinning DCs which allow managers to identify threats and opportunities for their firms and to reconfigure assets to address these threats and realize these opportunities. In other words, these perspectives appear to suggest very different interpretations of the challenge of competitive survival but each have their limitations. For example, it has been argued (e.g. Ahuja and Lampert 2001) that focusing on exploitation can improve performance in the short-term, but that these companies will not adapt easily to the changes of the environment (i.e. competency traps). Conversely, others have observed that companies with exploration capabilities may be able to change quickly but can struggle to properly exploit current strengths (Volberda and Lewin, 2003).

It is unsurprising that ambidexterity, with its promise of high performance (Junni *et al.*, 2013) by accommodating exploration and exploitation strategies in a single firm (cf. O'Reilly and Tushman, 2008; Birkinshaw and Gupta, 2013; Voss and Voss, 2013), is both practically appealing and, from an OM perspective, offers significant potential for further conceptual development. The following sections develop the key theoretical building blocks of the study with a particular focus, as DCs and ambidexterity have been related several times in the literature (O'Reilly and Tushman, 2008), on the link between ambidexterity and manufacturing performance in the specific guise of the sand cone model (Kristal *et al.*, 2010).

2.1 Sequential Capability Building and the Sand Cone model

Since Nakane (1986) first proposed that there was a sequential process associated with cumulative capability building, a number of studies have tested and developed this argument (Tables 1&2 outline exemplary studies) about how operations build what became known as the sand cone (Ferdows and De Meyer, 1990). Rosenzweig and Easton's (2010) meta-analysis illustrates the variety of contexts in which the concept has been studied, and concludes that the sand cone model offers a more accurate description of the capability process than the trade-off model. The majority of these early studies argued that the sequence of performance improvements followed a specific order - quality, delivery, cost, and flexibility – but more recently others have proposed alternative sequences. Some studies argue that product innovation and not flexibility is at the top of the sequence (Noble, 1995). Größler and Grübner (2006) found support for the idea of sequential capabilities but not for all dimensions, concluding that flexibility and cost are not clearly related. In this study, the Schroeder *et al.* (2011) model, which described the sequence as quality, delivery (stressing that work should continue on quality) and, once an appropriate standard for delivery had been reached, flexibility and then cost efficiency will be adopted as the sand cone template. This is a statistically validated sequence, subsequently supported by other studies (e.g. Narasimham and Schoenherr, 2013).

PLEASE INSERT TABLES 1&2 ABOUT HERE

2.2 The Sand Cone model, Ambidexterity and Performance

What is clear from this review is the strong link between the idea of the sand cone and the concept of organizational ambidexterity (cf. O'Reilly III and Tushman, 2013). The sand cone concludes that sequentially, cumulatively building quality and delivery performance underpins flexibility in the same way that ambidexterity suggests the synergistic fusion of exploration and exploitation can drive overall performance (Jansen *et al.*, 2009; Mom *et al.*, 2007; Chandrasekaran *et al.*, 2012, Junni *et al.*, 2013) – in turn leading to a higher and more sustainable financial performance (Lubatkin *et al.*, 2006; Simsek *et al.*, 2009). Some OM authors have observed this link. Narasimhan and Schoenherr (2013), for example, noting that environmental capabilities (Lee and Klassen, 2008) can improve the cumulative capabilities of manufacturing companies. Yet, despite these similarities, there have been relatively few explicit attempts to combine the sand cone model and the ambidexterity concept (Matthews *et al.*, 2015). The study by Liu *et al.* (2011, p. 1255), whilst missing consideration of the impact of environmental dynamism, is one of the few that addresses the relationship, concluding that increased knowledge and waste reduction “enable both exploration and exploitation in manufacturing, respectively; and in turn serves as the inputs for combinative capabilities development and the progression, in terms of its competitive capabilities, through the cumulative model”.

2.3 Developing Research Questions

Prior studies have drawn out specific relationships between ambidexterity and distinct dimensions of the sand cone. Matthews *et al.* (2015), for instance, linking explorative learning and flexibility (cf. Adler *et al.*, 1999) and exploitative learning and cost (cf. O'Reilly III and Tushman, 2013), quality and speed. In this study however, we sought to explore a more integrative perspective on the relationship and, in particular, the key aspect of the sand cone, the sequential nature of the capability building process. This leads us to our first research question.

RQ 1: What is the relationship between organizational ambidexterity and the sequential process of improved manufacturing performance (as represented by the Schroeder et al. (2011) version of the sand cone model)?

While ambidexterity has been explored at different levels of analysis (Birkinshaw and Gupta, 2013; Tamayo-Torres *et al.*, 2014), as a moderator to performance (Mudamhi and Swift, 2011), and in terms of its links to industry setting (Simsek *et al.*, 2009), the relationship between ambidexterity and environmental dynamics has not yet been sufficiently explored (Junni *et al.*, 2013). This is of particular interest to this study because, to date, exploration has usually been considered as important in dynamic environments (Kabadayi *et al.*, 2007; Chang *et al.*, 2011) and exploitation critical in a more static environment (Ward *et al.*, 1996).

Similarly, with regards to the sand cone model, environmental dynamics have rarely been treated in the round. Schroeder *et al.*, 2011 (pp. 4897) argue that "it is possible that contingencies such as different strategies or different external environments might explain why some plants follow the sand cone model and others do not". Quality and cost (Nandakumar *et al.*, 2010) performance, for instance, have usually been related to a stable environment (i.e. process standardization is more effective when not influenced by external changes). Conversely, flexibility has usually been defined as the best way to solve uncertainty (Beach *et al.*, 2000), arguing for a fit between flexibility and environmental dynamism as critical for a company's survival (Anand and Ward, 2004; Liao and Hu, 2007). Equally, speed is the measure of the company to react to important changes in the environment (Ferdows and De Meyer, 1990), suggesting a strong relationship between speed and environmental dynamism. But what is the impact of environmental dynamism (Jansen *et al.*, 2005) when developing both, exploration and exploitation, via a specific sequence of capabilities? This leads us to our second RQ.

RQ 2: What is the relationship between environmental dynamism and the relationship between organizational ambidexterity and manufacturing performance?

3. Research methodology

3.1 Target population and questionnaire procedure

The data used in this study were derived from a cross-sectional study. To measure each variable, the survey instrument asked CEOs or managers of manufacturing departments to specify their answers across different items using Likert-type 1- to 7-point scales (1=totally disagree; 7=totally agree). Telephone questionnaires were administered by a specialist private company. One of the authors explained the content of the questionnaire to and briefed the interviewers about the research study. To gather data, interviewers called respondents' landlines. This phase of the study lasted five days and was performed by seven highly trained interviewers. The interviews were recorded and then codified electronically to avoid possible errors during data analysis and interpretation phases.

The sample of Spanish manufacturing firms was taken from SABI, a database including detailed information on over 550,000 Spanish firms. Two conditions were applied to the set. First, companies with fewer than five manufacturing workers were excluded, as their characteristics (e.g. minimal operating structure, Hair *et al.*, 2004) differ substantially from those discussed in the theoretical argument. Second, it was vital that respondents possess sufficient in-depth knowledge of the questions asked to ensure that the responses obtained were reliable. After applying these two conditions, the resulting organizations were reduced through random sampling to obtain a final sample of 1,854 companies. From the final sample we obtained 231 valid questionnaires, a global response rate of 12.49%. Possible sample bias was investigated by comparing the mean of the size across all firms and of firms included in the study's sample, arriving at similar values in both cases. The sampling error was calculated (6.03%) and deemed acceptable against a generally agreed maximum level in social science studies of 10% (Scandura and Williams, 2000).

3.2 Sample demographics

All of the respondents in this study are based in Spain, although firms may operate in national and/or international territory. This choice ensured a similar economic, political, and legal framework for the studied firms, minimizing the importance of other international variables that cannot be controlled for in our empirical research (Adler, 1983). All investigated companies belong to the manufacturing sector, although they have different production configurations. We have included a table with detailed sample information in Appendix A.

3.3 Measures

Our model has two types of variables, six of them have been considered as reflective variables as related literature has treated them (Table 3). Exploration and exploitation strategies (Mom *et al.*, 2007), quality, flexibility, cost (Raymond and St-Pierre, 2005), and speed (Larso, 2004). The remaining variable is a second-level variable called ambidexterity (Patel *et al.*, 2012), a variable defined as the ability to explore and exploit simultaneously (please see Appendix B).

Please insert 'Table 3' about here

3.3.1 Exploitation and exploration strategies

We deploy the scale used by Mom *et al.* (2007) because they relate exploitation and exploration strategies to mechanisms of coordination and decision making which fits the focus of this study. Five items were selected and adapted from these scales to measure exploration strategy and six items to measure exploitation strategy, using 7-point Likert-type scales, of which two were finally eliminated because they did not fit with the statistical process. Exploration and exploitation activities were used to build a second-level variable. Both factors correlated significantly ($p < 0.01$) with this second-order factor, with standardized loads that ranged between 0.63 and 0.77. Both factors were therefore considered indicators of a single factor called "ambidexterity".

3.3.2 Manufacturing capability

Manufacturing capabilities are defined and were considered as following a pre-specified sequence. We adopted Schroeder *et al.*'s (2011) proposed sequence - quality, delivery, flexibility, and cost – to study manufacturing capabilities. We selected the scale developed by Raymond and St.-Pierre (2005) for three of the capabilities - perceived quality improvements, perceived flexibility performance, and perceived cost performance. Speed performance was measured through the scales proposed by Larso (2004).

3.3.3 Environmental dynamism

Environmental dynamism is defined as the degree of instability of the factors that affect the environment of the firm (Jansen et al., 2005). This study adopts the scale proposed by Miller and Friesen (1983) in which they analyze the rate at which products and services become outdated, considering low and high degrees of environmental dynamism. First, we evaluated low and high degrees of environmental dynamism. We defined low values as those with a standard deviation below the average and high values as those with a standard deviation above the average (following the recommendations by Jaccard, et al., 1990). Second, as our research sought to uncover potential differences in ambidexterity across static and dynamic environments, the sample needed to include firms characterized by operating in markets with low environmental dynamism or high environmental dynamism. As a result, we eliminated 59 firms because they were considered as operating in a medium environment (Jaccard *et al.*, 1990; Barrales-Molina *et al.*, 2010). Finally, we used Chow's Test, to measure whether there is structural change in the sample because of the type of environment. The test showed a 95% significance level, thus we rejected the null hypothesis that there is no structural change. The difference was located at 113, indicating the point at which the sample is divided between firms that compete in a dynamic environment (93 firms) or a static environment (79 firms). Both groups (static and dynamic environment) have the minimum sample size to run SEM (Hair *et al.*, 2004) and recent studies in OM used SEM with similar sample sizes (Gutiérrez-Gutiérrez *et al.*, 2012).

3.4 Tests for reliability and validity

This section analyses the reliability, unidimensionality, convergent validity, and discriminant validity of the scales used in this study. First, to determine the scales' reliability, the Cronbach α was calculated and all of them are higher than the recommended value of 0.7 (Nunally, 1978) (see Table 4). In order to test convergent validity, the average variance extracted (AVE) values were calculated and all the scales showed values higher than the minimums recommended (Gupta and Kim, 2008). We first utilized confirmatory factor analysis (CFA) to establish the psychometric properties of the model, and then used structural equation modelling (SEM) to evaluate the performance implications.

Please insert 'Table 4' about here

Next, all scales were subjected to a confirmatory factor analysis (CFA) using the software program EQS6.2 which demonstrated the scales' convergent validity. All of the scales show results higher than the established minimums. According to Hulland (1999), three conditions must be fulfilled for convergent validity to exist. First, the factor loadings must be significant ($t > 1.96$; $p < 0.05$). Second, they must be greater than 0.4. Finally, individual reliability (R^2) must be greater than 0.5. Figure 1 shows all of the values for the factor loadings, their significance, and their reliability. Finally, to complete validation, discriminant validity was analyzed following Howell (1987) and Szulanski (1996). We compared the correlation value observed in the CFA to the correlation value calculated for the case of perfect correlation. The correlation value calculated should be greater than the value observed. In all cases, the results show that the value calculated was greater than that observed, ensuring discriminant validity.

4. Results

In order to analyze the relationships between variables, Structural Equation Modelling (SEM) was used and the program EQS 6.2 was deployed. This methodology was used because it is considered "the most sophisticated statistical techniques in the group to find evidence in support of the sand cone model" (Schroeder *et al.*, 2011, p. 4885). Also, SEM was chosen because it allowed us to examine how the different dimensions of the sand cone are influencing one another. Moreover, we tested for Common Method Variance (common method bias) (Siemsen *et al.*, 2010) to address possible problems with systematic error variance shared among variables, and we checked that The Harman's single-factor had a very poor fit: GFI = 0.568, AGFI = 0.479, CFI = 0.41, NFI = 0.44, RMSEA = 0.147, showing no sign of common method variance. We conducted two different analyses. First, we have included the variables about ambidexterity and the sand cone model (Figure 1). Second, we contrasted this relation when considering different environments (Figures 2&3). The fit indices used to estimate the measurement models are presented in Table 5.

Please insert 'Table 5 and Figure 1' about here

The overall fit of the structural model for the total sample fits on absolute fit (χ^2 , degrees of freedom and RMSEA), incremental fit (CFI, NNFI and IFI), and parsimony fit suggested by Hair *et al.* (2004). Moreover, significant results of the influence of ambidexterity into the other variables are shown with a t-value significant at $p < 0.01$.

Figure 2 describes the SEM results of the influence of ambidexterity as basis for the sand cone model. Each path indicates the associated research question, the estimated path coefficients, and t-values (t-values for path coefficients greater than 1.645 are significant at $p < 0.1$; t-values for path coefficients greater than 1.96 are significant at $p < 0.05$; t-values for path coefficients greater than 2.58 are significant at $p < 0.01$).

Statistical analysis illustrates different aspects. First, we observe that the second-order variable, ambidexterity, is significant through the variables exploration and exploitation. Second, data show how this second-order variable is the first step of a significant sequence - quality, speed, flexibility, and cost, which addresses RQ1, that considered the relation between ambidexterity and sand cone model, considering an ambidextrous sand cone model. Third, we can observe how the impact of the sequence is increasing from 0,162 (quality to speed) to 0,691 (flexibility to cost improvements), which shows the sequential improvements of the sand cone model

Please insert 'Figures 2&3' about here

In order to address RQ2, as explained in section 3.3.2, we divided the sample in two: one, the set of firms operating in a dynamic environment (93) and another, those operates in a static environment (79). We used Chow's Test to show that the sample can be divided in two different sub-samples because there is structural change between them. We observed that the results were different for companies in dynamic when compared to static environments. Once we established that there are observable differences between both sets of firms depending on the environment, the following step was to compare whether there are significant differences in the relationship between ambidexterity and the sand cone model across both (static and dynamic) environments. The main results are shown in Figures 2 and 3.

We observed different and interesting key aspects. First, when investigating firms in a dynamic environment (Figure 2), we observed that ambidexterity (the significant and contrasted combination of exploration and exploitation) has a significant relationship with the sand cone model (Figure 2). Moreover, we observed that the significance levels increase the results when going through the sequence. Figure 3 shows the results for companies that compete in a static environment. Here, ambidexterity is less significant for performance improvements. Hence, we address RQ2 in which we considered that high environmental dynamism will influence the ambidextrous sand cone model.

5. Discussion

Based on a theoretically derived and empirically grounded study, this paper explored two key research questions: the relationship between organizational ambidexterity and manufacturing performance (in the guise of the sand cone model) and, the impact of environmental dynamism on this relationship. Before discussing each of these questions in turn it is important to note the following limitations of this study – which we hope will also offer fruitful avenues for future research. First, although we tested for common methods bias, the study relies on one key informant per firm. Future studies should seek out multiple informants per firm as suggested by Guide Jr. and Ketokivi (2015). Second, both ambidexterity and the sand cone are dynamic concepts and a cross sectional survey can only infer its temporal characteristics. Future longitudinal research, informed by the relationships uncovered in this study, would allow for direct inspection of the processual developments. Finally, different environmental characteristics should be considered, going beyond low and high environmental dynamism.

With regards to research question 1, although previous studies have implied that exploitation and then exploration are themselves sequential (i.e. exploitation via incremental, closed loop learning and exploration via innovation and double-loop learning) we find that organizational ambidexterity acts as an enabler across each of Schroeder *et al.*'s (2011) proposed stages for the sand cone (i.e. quality, speed, flexibility, and cost) and hence drives manufacturing performance. Previous ambidexterity literature has shown the link to each of the four constituent performance dimensions separately, but by integrating our analysis with the sand cone model we have an indication that managers should focus on

cumulative, sequential improvements to drive manufacturing performance. The findings support the sequential performance dimensions of the sand cone model - quality, speed, flexibility, and cost. When Ferdows and De Meyer (1990) argued in favor of a cumulative rather than trade-off model of capability development, they suggested that the traditional managerial approach for improving manufacturing performance should be changed. Our research results strongly support this argument and suggest ambidexterity should be a strategic aim regardless of the firm's stage of operational capability evolution (across the sand cone dimensions). A firm developing capabilities to drive ambidexterity and driving the development of the sand cone dimensions – quality, speed, cost, and flexibility – will drive manufacturing performance.

In answering our second research question, results emphasize the apparent universality of ambidextrous approaches. This balanced approach seems to have benefits for manufacturing firms in both static and dynamic environments, albeit the relationship between ambidexterity and performance is less pronounced in the static environment setting. In other words, companies working in a dynamic market environment need to ensure that not only ambidexterity capabilities are developed, but also support cumulative capability development via the sand cone dimensions. Returning to the RBT/DC concepts used as a framing device for the study, the findings for both research questions offer support for a partially contingent (on environmental dynamism) but largely integrative perspective on this debate. The centrality of a sequential, cumulative approach to performance improvement echoes much of the RBT position (with its emphasis on local, unique, incremental learning) but, at the same time, the positive impact of ambidexterity on this process – regardless of the competitive context - suggests that over time, competitive survival is indeed supported by a continuous reinvention of capabilities (Helfat and Peteraf, 2003).

6. Conclusions and implications

This study theoretically and empirically refines our understanding of the relationships between manufacturing performance via the sand cone model, environmental dynamism, and ambidexterity. Two research questions are addressed using structural equation

modelling (SEM) in a sample of 231 Spanish manufacturing companies. Findings illustrate a significant relationship between ambidexterity as the basis and enabler for manufacturing performance improvements, calling for an ambidextrous sand cone model. The study illustrates that this relationship is influenced by the company's wider environment. This relationship is further emphasized when companies work in a dynamic environment. Quality, speed, flexibility, and cost improvements are supported by a company's capability to drive ambidexterity.

The practical contributions of this study are twofold. First, we illustrate that manufacturing companies should drive to develop ambidextrous capabilities. This will have a positive impact on performance across the whole sequence stipulated by Schroeder *et al.*'s (2011) version of the sand cone model - quality, delivery, flexibility, and then cost. Second, this sequential development approach is even more significant for operations working in dynamic environments (i.e. those characterized by a constantly changing market and customer demands).

References

- Adler, N. J. (1983), "Psychological safety and learning behaviour in work teams", *Administrative Science Quarterly*, Vol. 14, pp. 350–383.
- Adler, P.S., Goldoftas, B., Levine, D.I. (1999), "Flexibility versus efficiency? A case study of model changeovers in the Toyota Production System", *Organization Science*, Vol. 10 No. 1, pp. 43–68.
- Ahuja, G. and Lampert, C.M. (2001), "Entrepreneurship in the large corporation: a longitudinal study of how established firms create breakthrough inventions", *Strategic Management Journal*, Vol. 22 No. 6-7, pp. 521–543.
- Amoako-Gyampah, K. and Meredith, J.R. (2007), "Examining cumulative capabilities in a developing economy", *International Journal of Operations & Production Management*, Vol. 27 No. 9, pp. 928–950.
- Anand, G., and Ward, P. T. (2004), "Fit, flexibility and performance in manufacturing: Coping with dynamic environments", *Production and Operations Management*, Vol. 13 No. 4, pp. 13369-13385.
- Avella, L., Vazquez-Bustelo, D. and Fernandez, E. (2011), "Cumulative manufacturing capabilities: An extended model and new empirical evidence", *International Journal of Production Research*, Vol. 49 No. 3, pp.707–729.
- Barney, J. (2001), "Is the resource based view a useful perspective for strategic management research? Yes", *Academy of Management Review*, Vol. 26 No. 1, pp. 41-56.
- Barrales-Molina, V., Benitez-Amado, J. and Perez-Arostegui, M.N. (2010), "Managerial perceptions of the competitive environment and dynamic capabilities generation", *Industrial Management & Data Systems*, Vol. 110 No. 9, pp.1355 – 1384.
- Beach, R., Muhlemann, A.P., Price, D.H., Paterson, A. and Sharp, J.A. (2000), "A review of manufacturing flexibility", *European Journal of Operational Research*, Vol. 122 No. 1, pp. 41-57.
- Birkinshaw, J. and Gupta, K. (2013), "Clarifying the distinctive contribution of ambidexterity to the field of organization studies", *Academy of Management Perspectives*, Vol. 27 No. 4, pp. 287-298.
- Bortolotti, T., Danese, P., Flynn, B. B. and Romano, P. (2015), "Leveraging fitness and lean bundles to build the cumulative performance sand cone model", *International Journal of Production Economics*, Vol. 162, pp. 227-241.

- Boyer, K.K. and Lewis, M.W. (2002), "Competitive priorities: investigating the need for trade-offs in operations strategy", *Production and Operation Management*, Vol. 11 No. 1, pp. 9–20.
- Byrne, B. M. (1998), Structural equation modeling with LISREL, PRELIS, and SIMPLIS: Basis concepts, application, and programming. *Mahwah*, Lawrence Erlbaum, NJ.
- Chandrasekaran, A., Linderman, K. and Schroeder, R. (2012), "Antecedents to ambidexterity competency in high technology organizations", *Journal of Operations Management*, Vol. 30, pp. 134–151.
- Chang, Y.Y., Hughes, M. and Hotho, S. (2011), "Internal and external antecedents of SMEs' innovation ambidexterity outcomes", *Management Decision*, Vol. 49 No. 10, pp. 1658-1676.
- Corbett, L.M. and Whybark, D.C. (2001), "Searching for the sand cone in the GMRG data", *International Journal Operations & Production Management*, Vol. 21 No. 7, pp. 965-80.
- Ferdows, K. and De Meyer, A. (1990), "Lasting improvements in manufacturing performance: in search of a new theory", *Journal of Operations Management*, Vol. 9, pp. 168-84.
- Ferdows, K. and Thurnheer, F. (2011), "Building factory fitness", *International Journal of Operations & Production Management*, Vol. 31 No. 9, pp. 916-934.
- Flynn, B.B. and Flynn, E.J. (2004), "An exploratory study of the nature of cumulative capabilities", *Journal of Operations Management*, Vol. 22 No. 5, pp. 439-57.
- Größler, A. and Grübner, A. (2006), "An empirical model of the relationships between manufacturing capabilities", *International Journal of Operations & Production Management*, Vol. 26 No. 5, pp. 458–485.
- Guide Jr., V.D.R. and Ketokivi, M. (2015), "Notes from the editors: Redefining some methodological criteria for the journal", *Journal of Operations Management*, Vol. 37, pp. v-viii.
- Gupta, S. and Kim, H. (2008), "Linking structural equation modelling to Bayesian networks: Decision support for customer retention in virtual communities", *European Journal of Operational Research*, Vol. 190 No. 3, pp. 818-33.
- Gutiérrez-Gutiérrez, L. J., Bustinza-Sánchez, O. F. and Barrales-Molina, V. (2012), "Six Sigma, absorptive capacity and organizational learning orientation", *International Journal of Production Research*, Vol. 50 No. 3, pp. 661–675.
- Hair, J.F., Anderson, R.E., Tatham, R.L. and Black, W.C. (2004), *Análisis Multivariante*, Prentice Hall, Madrid.

- Helfat, C.E. and Peteraf, M.A. (2003), "The dynamic resource-based view: capability lifecycles", *Strategic Management Journal*, Vol. 24 No. 10, pp. 997-1010.
- Holcomb, T.R. and Hitt, M.A. (2007), "Toward a model of strategic outsourcing", *Journal of Operations Management*, Vol. 25 No. 2, pp. 464-81.
- Howell, R.D. (1987), "Covariance structure modelling and measurement issues: A note on 'interrelations among a channel entity's power sources'", *Journal of Marketing Research*, Vol. 24 No. 1, pp. 119-126.
- Hulland, J. (1999), "Use of partial least squares PLS in strategic management research: A review of four recent studies", *Strategic Management Journal*, Vol. 20 No. 2, pp. 195-204.
- Jaccard, J., Turrisi, R. and Wan, C. (1990), *Interaction Effects in Multiple Regression*, Sage, Newburg Park, CA.
- Jansen, J., Van Den Bosch, F. and Volberda, H. (2005), "Managing potential and realized absorptive capacity: how do organizational antecedents matter?", *Academy of Management Journal*, Vol. 48 No. 6, pp. 999-1015.
- Jansen, J.J.P., Tempelaar, M.P., Van den Bosch, F.A.J. and Volberda, H.W. (2009), "Structural differentiation and ambidexterity: The mediating role of integration mechanisms", *Organization Science*, Vol. 20 No. 4, pp. 797-811.
- Junni, P., Sarala, R.M., Taras, V. and Tarba, S. Y. (2013), "Organizational ambidexterity: A meta-analysis", *Academy of Management Perspectives*, Vol. 27 No. 4, pp. 299-312.
- Kabadayi, S., Eyuboglu, N. and Thomas, G.P. (2007), "The performance implications of designing multiple channels to fit with strategy and environment", *Journal of Marketing*, Vol. 71 No. 4, pp. 195-211.
- Kristal, M.M., Huang, X. and Roth, A.V. (2010), "The effect of an ambidextrous supply chain strategy on combinative competitive capabilities and business performance", *Journal of Operations Management*, Vol. 28, pp. 415-429.
- Larso, D. (2004), *Manufacturing flexibility in new product development: Perceptions and implications of new product performance*, Oregon State University.
- Lavie, D. and Rosenkopf, L. (2006), "Balancing exploration and exploitation in alliance formation", *Academy of Management Journal*, Vol. 49 No. 4, pp. 797-818.
- Lee, S.Y. and Klassen, R.D. (2008). "Drivers and enablers that foster environmental management capabilities in small- and medium-sized suppliers in supply chains", *Production and Operations Management*, Vol. 17 No. 6, pp. 573-586.

- Lee, S.G., Koo, C. and Nam, K. (2010), "Cumulative strategic capability and performance of early movers and followers in the cyber market", *International Journal of Information Management*, Vol. 30 No. 3, pp. 239-255.
- Lewis, M.A. (2000), "Lean production and sustainable advantage", *International Journal of Operations & Production Management*, Vol. 20 No. 8, pp. 959-978.
- Liao, S.H. and Hu, T.C. (2007), "Knowledge transfer and competitive advantage on environmental uncertainty: An empirical study of the Taiwan semiconductor industry", *Technovation*, Vol. 27 No. 6-7, pp. 402-411.
- Liu, N., Roth, A.V. and Rabinovich, E. (2011), "Antecedents and Consequences of Combinative Competitive Capabilities in Manufacturing", *International Journal of Operations & Production Management*, Vol. 31 No. 12, pp. 1250-1286.
- Lubatkin, M. H., Simsek, Z., Ling, Y. and Veiga, J. F. (2006), "Ambidexterity and performance in small to medium-sized firms: The pivotal role of top management team behavioral integration", *Journal of Management*, Vol. 32 No. 5, pp. 646-672.
- Mahoney, J.T. and Pandian, J.R. (1992), "The resource-based view within the conversation of strategic management", *Strategic Management Journal*, Vol. 15 No. 5, pp. 363-380.
- March, J.G. (1991), "Exploration and exploitation in organizational learning", *Organization Science*, Vol. 2 No. 1, pp. 71-87.
- Matthews, R.L., Tan, K.H. and Marzec, P. (2015), "Organisational ambidexterity within process improvement: An exploratory study of four project-oriented firms", *Journal of Manufacturing Technology Management*, Vol. 26 No. 4, pp. 458-476.
- McGee, J. and Thomas, H. (1986), "Strategic groups: Theory, research and taxonomy", *Strategic Management Journal*, Vol. 7, pp. 141-160.
- Miller, K.D. and Friesen, P., (1983), "Strategy making and environment: The third link", *Strategic Management Journal*, Vol. 4 No. 3, pp. 221-235.
- Miller, S.R. and Ross, A.D. (2003), "An exploratory analysis of resource utilization across organizational units: understanding the resource-based view", *International Journal of Operations & Production Management*, Vol. 23 No. 9, pp. 1062-1083.
- Mom, T.J.M., Van Den Bosch, F.A.J. and Volberda, H.W. (2007), "Investigating managers' exploration and exploitation activities: The influence of top-down, bottom-up, and horizontal knowledge inflows", *Journal of Management Studies*, Vol. 44 No. 6, pp. 910-931.

- Mudamhi, R. and Swift, T. (2011), "Proactive R&D management and firm growth: A punctuated equilibrium model", *Research Policy*, Vol. 40 No. 3, pp. 429-440.
- Nakane, J. (1986), *Manufacturing Futures Survey in Japan, a Comparative Survey 1983-1986*, System Science Institute, Waseda University, Tokyo.
- Nandakumar, M. K., Ghobadian, A. and O'Regan, N. (2010), "Business level strategy and performance: the moderating effects of environment and structure", *Management Decision*, Vol. 48 No. 6, pp. 907-939.
- Narasimhan, R. and Schoenherr, T. (2013), "Revisiting the progression of competitive capabilities: results from a repeated cross-sectional investigation", *International Journal of Production Research*, Vol. 51 No. 22, pp. 6631-6650.
- Newman, W.R., Hanna, M.D., Gattiker, T. and Huang, X. (2009) "Charting supply chain management integration and initiatives: A framework to guide implementation", *American Journal of Business*, Vol. 24 No. 1, pp. 19 - 32
- Noble, M. (1995), "Manufacturing strategy: testing the cumulative model in a multiple country context", *Decision Sciences*, Vol. 25 No. 5, pp. 693-721.
- Nunally, J. (1978), *Psychometric Theory* McGraw Hill, New York.
- O'Reilly III, C.A. and Tushman, M.L. (2008), "Ambidexterity as a dynamic capability: Resolving the innovator's dilemma", *Research in Organizational Behavior*, Vol. 28, pp. 185-206.
- O'Reilly, C.A., III, and Tushman, M.L. (2013), "Organizational ambidexterity: Past, present and future", *Academy of Management Perspectives*, Vol. 27 No. 4, pp. 324-338.
- Pandza, K., Polajnar, A., Buchmeister, B. and Thorpe, R. (2003), "Evolutionary perspectives on the capability accumulation process", *International Journal of Operations & Production Management*, Vol. 23 No. 8, pp. 822-849.
- Patel, P., Terjesen, S. and Li, D. (2012), "Enhancing effects of manufacturing flexibility through operational absorptive capacity and operational ambidexterity", *Journal of Operations Management*, Vol. 30 No. 3, pp. 201-220.
- Raisch, S. and Birkinshaw, J. (2008), "Organizational ambidexterity: Antecedents, outcomes, and moderators", *Journal of Management*, Vol. 34, pp. 375-409.
- Raisch, S., Birkinshaw, J., Probst, G. and Tushman, M.L. (2009), "Organizational ambidexterity: Balancing exploitation and exploration for sustained performance", *Organization Science*, Vol. 20 No. 4, pp. 685-695.

- Raymond, L. and St-Pierre, J. (2005), "Antecedents and performance outcomes of advanced manufacturing systems sophistication in SMEs", *International Journal of Operations & Production Management*, Vol. 25 No. 6, pp. 514-533.
- Rosenzweig, E.D. and Easton, G.S. (2010), "Tradeoffs in manufacturing? A meta-analysis and critique of the literature", *Production and Operations Management*, Vol. 19 No. 2, pp. 127-141.
- Rosenzweig, E.D. and Roth, A.V. (2004), "Towards a theory of competitive progression: evidence from high-tech manufacturing", *Production and Operations Management*, Vol. 13 No.4, pp. 354-368.
- Rungtusanatham, M., Salvador, F., Forza, C. and Choi, T.Y. (2003), "Supply chain linkages and operational performance: a resource-based perspective", *International Journal of Operations & Production Management*, Vol. 23 No. 9, pp. 1084-1099.
- Sabella, A., Kashou, R. and Omran, O. (2014), "Quality management practices and their relationship to organizational performance", *International Journal of Operations & Production Management*, Vol. 34 No. 12, pp. 1487 – 1505.
- Scandura, T.A. and Williams, A. (2000), "Research methodology in management: Current practices, trends, and implications for future research", *Academy of Management Journal*, Vol. 43 No. 6, pp. 1248-1265.
- Schroeder, R.G., Shah, R. and Peng, D.X. (2011), "The cumulative capability 'sand cone' model revisited: a new perspective for manufacturing strategy", *International Journal of Production Research*, Vol. 49 No. 16, pp. 4879-4901.
- Siemsen, E., Roth, A. and Oliveira, P. (2010), "Common method bias in regression models with linear, quadratic, and interaction effects", *Organizational Research Methods*, Vol. 13 No. 3, pp. 456-476.
- Simsek, Z., Heavey, G., Veiga, J. F. and Souder, D. (2009), "A typology for aligning organizational ambidexterity's conceptualizations, antecedents, and outcomes", *Journal of Management Studies*, Vol. 46 No. 5, pp. 864-894.
- Szulanski, G. (1996), "Exploring internal stickiness: Impediments to the transfer of best practice within the firm", *Strategic Management Journal*, Vol. 17 No. 2, pp. 27-43.
- Takala, J., Leskinen, J., Sivusuo, H., Hirvela, J. and Kekale, T. (2006), "The sand cone model: Illustrating multi-focused strategies", *Management Decision*, Vol. 44 No. 3, pp. 335-345.

- Tamayo-Torres, J., Barrales-Molina, V and Perez-Arostegui, M.N. (2014), "The influence of manufacturing flexibility on strategic behaviours: A study based in certified quality management systems", *International Journal of Operations & Production Management*, Vol. 34 No. 8, pp. 1028-1054.
- Teece, K., Pisano, G. and Shuen, D. (1997), "Dynamic capabilities and strategic management", *Strategic Management Journal*, Vol. 18 No. 7, pp. 509-533.
- Teece, K. (2006), "Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance", *Strategic Management Journal*, Vol. 28 No. 13, pp. 1319-1350.
- Vokurka, R.J., Zank, G.M. and Lund, C.M. (2002), "Improving competitiveness through supply chain management: A cumulative improvement approach", *Competitiveness Review*, Vol. 12 No. 1, pp. 14-25.
- Volberda, H.W. and Lewin, A.Y. (2003). "Co-evolutionary Dynamics Within and Between Firms: from Evolution to Co-evolution", *Journal of Management Studies*, Vol. 40 No.8, pp. 2111–2136.
- Voss, C.A. (2003), "Rethinking paradigms of service: Service in a virtual environment", *International Journal of Operations & Production Management*, Vol. 23 No. 1, pp. 88-104.
- Voss, G.B. and Voss, Z.G. (2013), "Strategic ambidexterity in small and medium-sized enterprises: Implementing exploration and exploitation in product and market domains", *Organization Science*, Vol. 24 No. 5, pp. 1459–1477.
- Ward, P.T., Bickford, D.J. and Leong, G.K. (1996), "Configurations of manufacturing strategy, business strategy, environment, and structure", *Journal of Management*, Vol. 22 No. 4, pp. 597-626.
- Wernerfelt, B. (1984), "The Resource-Based View of the Firm", *Strategic Management Journal*, Vol. 5 No. 2, pp. 171–180.

Tables and Figures

Authors	Sample size	Dimensions	Type of study	Research method	Results
Ferdows and De Meyer, 1990	167 business units	Quality, dependability, speed and cost	Conceptual	Associative analysis	Sand cone was first proposed
Noble, 1995	561 plants	Flexibility, dependability, delivery and cost	Empirical	Regression analysis	Support for sand cone model
Boyer and Lewis, 2002	110 plants	Quality, delivery, flexibility, cost	Empirical	Correlations	Trade-off remains
Flynn and Flynn, 2004	165 plants	Quality, flexibility, delivery and cost	Empirical	Hierarchical regression analysis	No sequential progression
Rosenzweig and Roth, 2004	81 business units	Quality, delivery reliability, volume flexibility, and cost	Empirical	Path analysis	Evidence in support of the sand cone model
Amoako-Gyampah and Meredith, 2007	126 manufacturing firms	Quality, flexibility, delivery and cost	Empirical	Multiple regression analysis	Evidence supports the sand cone theory but in developing economies
Avella <i>et al.</i> , 2011	274 manufacturers	Quality, delivery, flexibility, environmental protection, and cost efficiency	Empirical	Structural equation model	Existence of cumulative effects amongst manufacturing capabilities
Schroeder <i>et al.</i> , 2011	189 manufacturing plants.	Quality, delivery, flexibility and cost	Empirical	Path analysis and structural equation modelling	Existence of cumulative effects but not for all the plants
Narasimhan and Schoenherr, 2013	180 manufacturing firms	Quality, flexibility, delivery and cost	Empirical	Repeated cross-sectional analysis	Sand cone model over time

Table 1 Exemplary studies focusing on main dimensions used in the sand cone model

Authors	Relation to SCM	Dimensions	Research/Sector	Results
Vokurka <i>et al.</i> , 2002	Supply chain management	Quality, dependability, flexibility, agility and cost efficiency	Conceptual	Supply chains improve their performance by competitive priorities
Voss, 2003	e-Commerce	Foundation of services, customer focus and value added	70 firms randomly selected	Sand cone as basis for e-commerce development
Takala <i>et al.</i> , 2006	Multi-focus strategy	Basic security pillars, operating philosophies and credibility	21 experts in strategy	A better fit for strategic decision making
Newman <i>et al.</i> , 2009	Supply chain management	Functional, cross-functional, supplier/customer and multi-tier effectiveness	Mid-level career supply chain managers of 4 different companies	Potential improvements to their supply chain from the sand cone model
Lee <i>et al.</i> , 2010	Porter's generic strategies	Focus, differentiation, cost and performance	135 firms from Korea	Early movers have more cumulative strategic capabilities
Ferdows and Thurnheer, 2011	Fitness	Design, launch, and management	42 factories of the Hydro Aluminum Extrusion Group	Factories, like athletes, can become fitter by strengthening a carefully planned sequence of capabilities
Bortolotti <i>et al.</i> , 2015	Lean practices	Quality, delivery, flexibility and cost	317 plants	Relation to performance through sand cone dimensions

Table 2 Exemplary studies focusing on sand cone model relating to other strategic variables

Variable	Number of items	Source
Exploration	5	Mom <i>et al.</i> , 2007
Exploitation	4	Mom <i>et al.</i> , 2007
Quality performance	3	Raymond and St-Pierre, 2005
Flexibility performance	3	Raymond and St-Pierre, 2005
Speed performance	3	Larso, 2004
Cost performance	3	Raymond and St-Pierre, 2005

Table 3 Variables and items used for the questionnaire

Variable	Cronbach's α	Mean	SD	Correlations						
Exploration	0.878	4,8586	1,20421	1						
Exploitation	0,798	5,2857	1,07045	,374**	1					
Quality improvements	0.769	5,5527	1,01248	,215**	,225**	1				
Speed improvements	0.827	4,4894	1,36746	,251**	,181**	,131*	1			
Flexibility improvements	0.769	4,9424	1,21046	,202**	,249**	,340**	,229**	1		
Cost improvements	0.755	4,8252	1,22022	,193**	,147*	,359**	,132*	,550**	,1	

* Correlation is significant at the 0.05 level (two tailed)

Table 4 Descriptive statistics and reliability analysis

Types of fit	Measures	Levels of acceptance	Summary for Robust Model		
			Total sample	Dynamic	Static
Absolute	χ^2 (sig.)	Significance level	455.592 (p=0.00)	371.752 (p=0.00)	286.816 (p=0.00)
	Degrees of freedom		176	176	176
	Root Mean Square Error of Approximation (RMSEA)	<0.08 ^a	0.061	0.057	0.049
Incremental	Comparative Fit Index (CFI)	>0.9 ^b	0.911	0.924	0.941
	Non-Normed Fit Index (NNFI)	>0.9	0.902	0.909	0.930
	Bollen's (IFI)	>0.9	0.918	0.926	0.944
Parsimony	Normed Chi-square χ^2 / df	<3.0 ^a	2.588	2.112	1.629

^aHair *et al.*, (2004) and Byrne (1998).

^bByrne (1998).

Table 5 Goodness of fit statistics of the structural mode

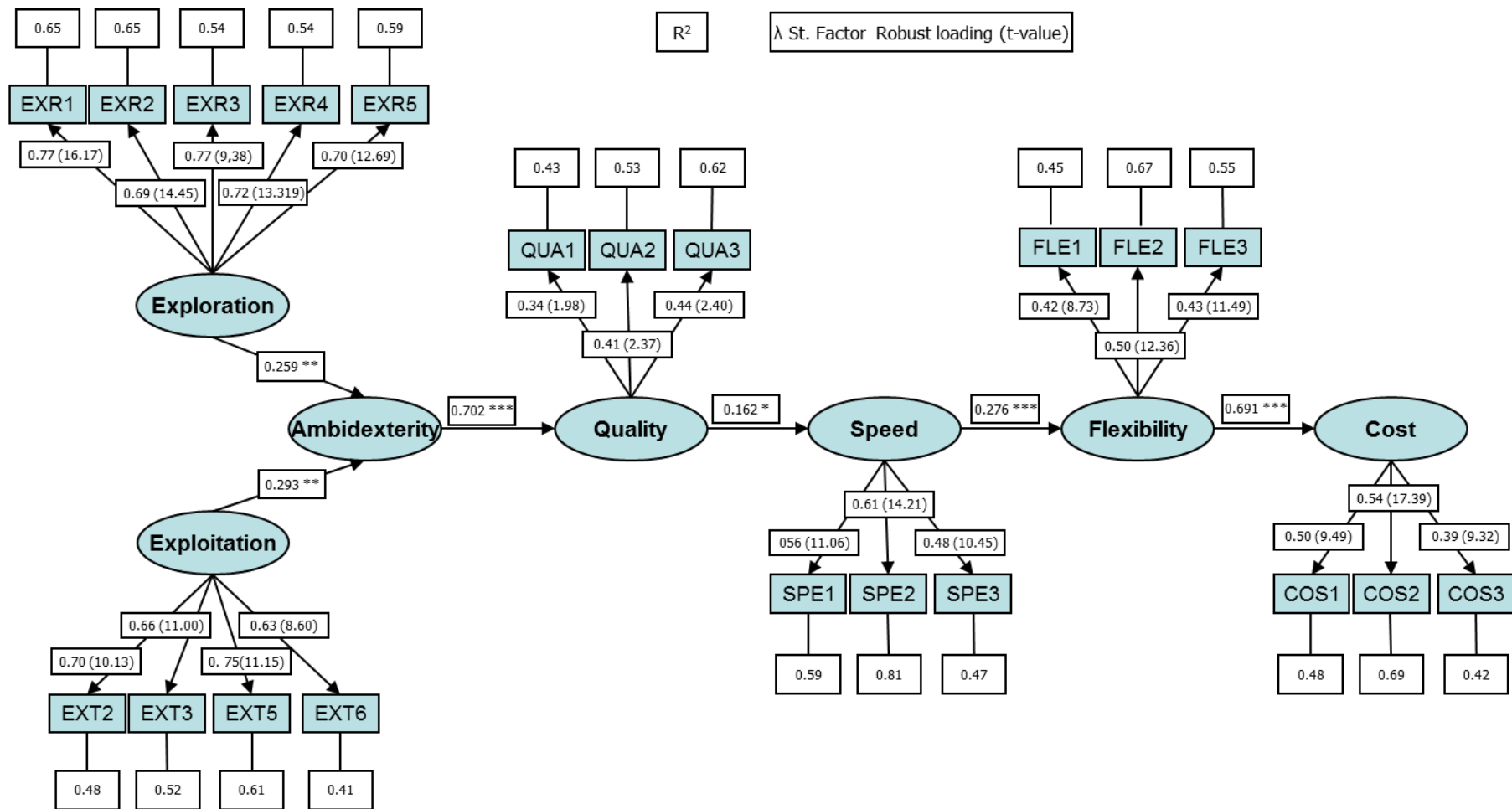


Figure 1 Structural modelling of the influence of ambidexterity and the sand cone model

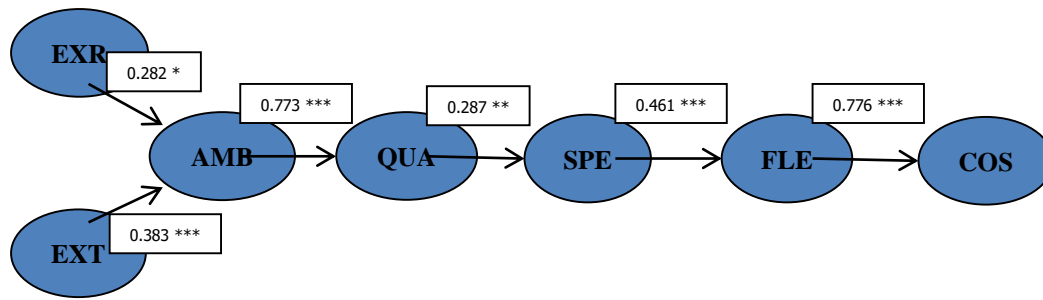


Figure 2 Structural modelling of the influence of ambidexterity and the sand cone model in a *dynamic environment*

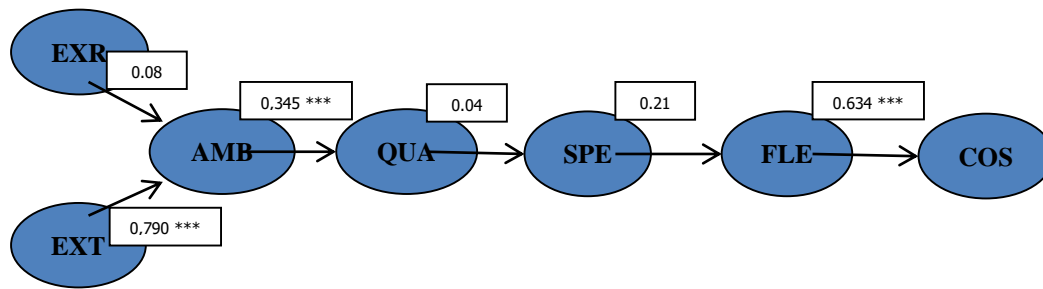


Figure 3 Structural modelling of the influence of ambidexterity and the sand cone model in a *static environment*

Appendix A: Sample details

Size	Fewer than 50 employees	34 cases
	50 to 250	100 cases
	250 to 1,000	76 cases
	More than 1,000	21 cases
Sales	Less than €1 million	11 cases
	€1 to €7 millions	16 cases
	€7 to €40 millions	177 cases
	More than €40 millions	27 cases
Production type	Job shop	9 cases
	Batch flow	60 cases
	Line flow	38 cases
	Continuous flow	33 cases
	Flexible Manufacturing System	74 cases
	Others	17 cases

Appendix B: Questionnaire

PART I: EXPLORATION AND EXPLOITATION ACTIVITIES

Strongly disagree	= 1	2	3	4	5	6	7=	Strongly agree
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1. Our activities search for new possibilities with respect to products/services, processes or markets.
2. Our activities try to evaluate diverse options with respect to products/services, processes or markets.
3. Our activities are focused on strong renewal of products/services or processes.
4. Our activities require quite some adaptability of ourselves.
5. Our activities require you to learn new skills or knowledge.

1. We develop activities of which a lot of experience has been accumulated by yourself.
2. We develop activities which serve existing (internal) customers with existing services/products.
3. We develop activities of which it is clear to us how to conduct them
4. We develop activities primarily focused on achieving short-term goals.
5. We develop activities which we can properly conduct by using our present knowledge.
6. We develop activities which clearly fit into existing company policy.

PART II: MANUFACTURING PERFORMANCE

Low =	1	2	3	4	5	6	7 = High
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Quality improvements

1. Increase product quality
2. Improve delivery delays
3. Preventive maintenance

Flexibility improvements

1. Reduce set-up times
2. Manage bottlenecks
3. Increase equipment flexibility

Cost improvements

1. Reduce production downtime
2. Reduce new product development time
3. Increase product standardization

Speed improvements

1. A route can quickly adjust process products/parts.
2. Products can be made quickly.
3. The manufacturing system can quickly changeover to a different product mix.

PART III: ENVIRONMENT DYNAMISM

Slow = 1	2	3	4	5	6	7 = High
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1. The rate at which your products and services become outdated is
2. The rate of innovation of new products and services is
3. The rate of innovation of new operating processes is
4. The tastes and preferences of customers in your industry are