Absorptive capacity and technology: influences on innovative firms

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Introduction

Firms compete nowadays in increasingly changing markets. In this kind of environment, firms need to react proactively to market and technology changes, and therefore, a growing attention has been paid to management capacities such as agility and knowledge absorption. These capacities offer strategic contributions to update and adapt the firms' technology, knowledge and innovation to environmental changes. Even though the competitive implication of agility and absorptive capacities is not new, and there is a growing literature about them, the interactions between both topics remains underdeveloped.

On the one hand, absorptive capacity (AC) is relevant because it assesses the firm's ability to identify, assimilate, transform, and exploit valuable external knowledge to their own processes or operations in order to obtain a competitive advantage (Escribano et al., 2009). On the other hand, agility conveys the ability to efficiently change operating states in response to uncertain and changing market conditions; agile organizations are intensive in flexible technologies, innovation and skilled employees. Both absorptive and agility capacities can be related from a theoretical and practitioner perspective. High-innovative firms invest heavily on in-house R&D but they also use external sources of technology and make efforts to assimilate and integrate them within in-house technical capabilities. Similarly, agile production firms need top internal capabilities, but they also require technological cooperation with members of the supply chain and others such as advanced machinery manufacturers. Agile firms develop and adopt production technologies more intensively than lean or mass production firms (Narasimhan et al., 2006). Nevertheless, the literature of agile production does not include specific variables or concepts related to AC and vice versa. Innovation appears in the conceptualization of agile production because agile firms must innovate to compete in highly customized and changing markets (Gunasekaran and Yusuf, 2002). Therefore, firms in need of agility have to innovate in products more frequently and faster than other firms. However, agile firms also need process (and organizational) innovations to keep Operations efficient and flexible. Since in-house efforts may not be enough to keep production processes updated, the use of external consultants or technological centres are necessary to leverage the firm's capability to do unplanned and new activities in response to unpredictable shifts in market demands or unique customer requests.

The literature of agile production recognizes the value of innovation as an output that enables firms to compete in high-unpredictable changing markets, but does not include innovation inputs as agility drivers. Technological cooperation is implicitly mentioned among agility facilitators like, for instance, supplier partnerships that allow introducing new technology and knowledge into the agile firm (Narasimhan et al., 2006). The technological importance of this and other agility facilitators could be assessed by

incorporating measures of AC into quantitative studies of agile production. Firms with greater AC could benefit more from supplier partnerships or technological centres because they would be able to assimilate, transform and exploit the new external knowledge faster and better. However, AC cannot be categorized as a direct agility facilitator because of its intrinsic nature and, therefore, does not appear in check-lists of agility drivers or facilitators (e.g., Narasimhan et al., 2006; Vázquez-Bustelo et al., 2007; Vinodh et al., 2012). Nevertheless, there is another way to take into account the effect of AC on agile production: if greater AC is able to improve the efficiency and efficacy of Operations, then firms with more need of agile technologies related to production processes could benefit more from external flows of knowledge and as a consequence would become more innovative.

Based on this proposition our paper is aimed to contribute to the literature in two different ways. First, we will analyse if agile production firms have greater AC than other firms. Second, our research will study if agile firms with greater AC are more innovative than other firms; that is to say even though AC cannot be categorized theoretically as agility facilitator it may act as a moderator in the relationship between agility and innovation performance. Both contributions may have important managerial implications: firms seeking agility should focus simultaneously on both internal and external sources of innovation and technology to keep ahead of competitors in dynamic and uncertain environments.

The paper is structured as follows. First, we review the literature and develop the research hypotheses. After that, we explain the methodology of the empirical study followed by the results and their discussion with managerial implications. Finally, we end with conclusions and limitations.

Theoretical foundation and hypothesis development

The resource-based view of the firm and the dynamic capabilities perspective

To theoretically develop our arguments, we rely on the resource-based view of the firm (RBV) augmented with the dynamic capabilities perspective, since both contribute to explain the competitive implications of AC and agile production. On the one hand, the basic premise of the RBV is that a firm's competitive advantage lies primarily in the application of bundles of resources that are valuable, rare, in-imitable and non-substitutable (Barney, 1991). The RBV has received considerable attention by scholars in business management, and its popularity has also been increasing in the field of production and innovation management research.

On the other hand, the dynamic capabilities perspective considers that accumulating resources is not enough. To be competitive firms need capabilities to integrate, reconfigure, develop and apply resources (Teece et al., 1997). More precisely firms need: the ability of employees to learn quickly and to build new strategic assets, the integration of these new strategic assets into company processes, and lastly the transformation or reuse of existing assets which have depreciated. A firm for Teece et al. (1997) is capable of shifting its capability portfolio in times of change through innovation. Nevertheless, although innovation is very important for firms to compete and improve performance, innovation management is not the only success factor. Arndt and Pierce (2018) identify the firm's management as drivers of dynamic capabilities by their shaping of rules, decision-making procedures, and capabilities.

For instance, dynamic routines that seek new product, process, and business model innovations are heavily influenced by the firm's extended technology acquisition

activities and R&D investments that difficult imitation by competitors through AC. However, dynamic capabilities are more than just routines. Dell's success in the PC business and Walmart's success in retailing are based on their ability to design and implement superior organizational arrangements for going to market and cooperating with suppliers. Thus, firms also need dynamic capabilities that allow them to create, expand or modify their resource bases (Kohlbacher, 2013). Effective dynamic capabilities contribute to a firm´s competitive advantage by enabling temporary advantages, which allow a firm to stay ahead of competitors and maintain a competitive advantage (Teece, 2007). As such, the possession of dynamic capabilities, enabling for example the speedy reconfiguration of a firm's Operations, promises to hold great potential, especially in today´s dynamic and fast-changing environment. Similar arguments can be found in relation to AC (Wang and Ahmed 2007; Lin et al., 2016).

Absorptive Capacity

The concept of AC was initially proposed by Cohen and Levinthal (1990). They showed that companies cannot benefit from external flows of knowledge, simply by being exposed to them. Instead, companies must develop the ability to recognize the value of external knowledge to assimilate and use it afterwards for commercial purposes. Their initial typology of three dimensions (identify, assimilate, and exploit knowledge) was later expanded by other scholars. For instance, Zahra and George (2002) categorised AC into two main subsets: potential and realised with two dimensions each: acquisition and assimilation for potential AC, and transformation and exploitation of new knowledge for realised AC. In this typology, the phase of acquisition refers to the identification of new knowledge and how it is transferred from one firm to another; the assimilation indicates the firm´s ability to use its resources, skills, and routines to assimilate the acquired knowledge; the transformation implies the combination of external and in-house knowledge to suit the firm´s needs; and finally, the exploitation means to achieve firm's goals that compensate the effort and resources previously invested.

AC becomes a firm's dynamic capability that it is valuable and difficult to imitate by competitors because it depends heavily on the trajectory and prior knowledge of each firm (Volberda et al., 2010). This capability becomes then something scarce, difficult to imitate and replace that contributes to obtain competitive advantages ahead of competitors. The four dimensions of AC -acquisition, assimilation, transformation, and exploitation- coexist and reinforce each other to make AC a dynamic capability that encourages innovation and improves performance (Patterson and Ambrosini, 2015). Thus, firms with a high AC may react much more effectively to customer's needs with new or adapted products. At the same time, they may improve their organizational routines and management practices that contribute positively to enhance firm's performance (Lane et al., 2006; Dobrzykowski et al., 2015).

Agile Production

A review of the literature indicates shows agility as an emerging and gradually dominating concept that explains the strategies for thriving in uncertain environments and responding to change (Swafford et al., 2006). An examination of agility concept and theories in the light of dynamic capability theory (Teece et al., 1997) leads to two important insights: (1) first, agility is a capability that enables a firm to respond to uncertain and changing business environment, and to sustain its position in the market, and (2) agility, as a dynamic capability, entails the exploitation of existing internal and

external firm-specific capabilities, developing new ones, and renewing them to respond to shifts in the business environment.

Even though there are several definitions of agile production in the literature, some authors like Gunasekaran and Yusuf (2002) have summarized them to indicate that the researchers viewed agile production paradigm as the post-mass production concept which focuses on meeting the global competition by quickly responding to the dynamic demands of the customers. Agile production enables a company to be flexible enough to quickly respond to the dynamic demands of the customers by manufacturing products with many varieties and innovative features. In other words, agile production aids the company to manufacture different varieties of products based on the dynamic changes in customer needs in a shorter period of time. Production is agile if efficiently changes operating states in response to uncertain and changing demands placed upon it.

Agile environments demand technologies that enable people and machines to share information effectively and efficiently to respond to market needs with speed. The use of robotics, real-time communication systems, etc. has redefined the agile production concept and is an integral component of an agile production framework (Dubey and Gunasekaran, 2015). Empirical studies find that firms in highly dynamic environments use agile technologies (design, production, and management) more intensively and obtain better performance (Narasimhan et al., 2006; Vázquez-Bustelo et al., 2007). However, given that agile production is an integrated production approach, studies should pay nowadays more attention to the relationships between the core of agile manufacturing and the other management capabilities such as production, innovation or cooperation that also facilitate agility through the flows of knowledge.

Hypotheses development

The concepts of AC and agile production can be combined under the RBV and dynamic capabilities' framework to analyze their interrelationships and the influence on innovation performance. From the three categories of dynamic capabilities (processes, position, and paths) our paper focuses on processes, the managerial and organizational processes that enable changes in the firm's resources and strategic assets. Dynamic capabilities literature makes a conceptual distinction between ordinary capabilities and the firm's broad resource base, on the one hand, and dynamic capabilities, on the other. Ordinary capabilities enable operational effectiveness, whereas dynamic capabilities enable the firm to change.

Teece et al. (1997) suggest that dynamic capabilities are unique to the firm. In contrast, Eisenhardt and Martin (2000) state that dynamic capabilities are relatively similar across firms (so-called 'best practices'). This second approach enables to build a dynamic capability 'profile' for each firm by identifying a set of practices and then look at which firms employ which ones. Such a dynamic capability profile also allows studying dynamic capabilities as multidimensional constructs (Barreto, 2010).

For our study, we are going to consider the firm's level of flexible production technology as a proxy for the ordinary capability of the firm's operational effectiveness. The higher the adoption of flexible production technology (level of technology agility) the greater the firm's performance (Vázquez-Bustelo et al., 2007). Technology is a key component of agile production. Narasimhan et al. (2006) found that firms evolving to the agile production paradigm -from mass or lean manufacturing systems- have to invest more in flexible production technologies like robots. At the same time, agile production needs more deployment and access to knowledge than other production systems because they have to accommodate changes in the business environment and the increasingly

demanding needs of well-informed customers. This process of deployment and access to knowledge that agile production needs is going to be the dynamic capability that could leverage the positive influence of agile/flexible technology on innovation performance.

Thus, AC may be considered as a pivotal foundation of agility for companies. Creating new knowledge and integrating the knowledge with the existing capabilities through having flexibility within the firm´s activities are of vital importance for confronting environmental changes. Agile organizations are knowledge-intensive because intellectual capital is the main factor of production and because they innovate in response to changing environments (Pérez-Bustamante, 1999). Knowledge acquisition and combination can enhance a firm's ability, i.e. the agility of the firm, to exploit productive opportunities. For example, Matthyssens et al. (2005) suggested that building and enhancing a firm's flexibility also involves the enhancement of the ability of companies to obtain, assimilate, and utilize external (and internal) knowledge and technology.

AC is closely related to technology. AC manages knowledge to transform ideas and proposals into innovations. Agile firms also need to invest in adaptation and continuous improvement. Buying flexible production technologies in the market is not by itself a source of sustainable competitive advantage, because it can be easily imitated by competitors. The customization of that flexible technology is what makes production a competitive advantage. Then, the development and implementation of flexible production technologies may need the access to external experts and consultants at the time of implementing or later on when improving the production line. AC will support the assimilation and transformation of external knowledge into in-house knowledge to manage production systems in an agile and competitive way. Thus, we propose the following hypothesis:

H1. High-agile manufacturing firms have greater absorptive capacity than low-agile manufacturing firms.

Our review shows that no study, to the best of our knowledge, has involved the role of AC, as an internal capability, to influence the relationship between agile/flexible technology and innovation performance. We are interested in innovation performance instead of overall firm performance because innovation can be signified as an intermediate variable between business processes and firm performance to get a clearer picture of actions and effects at the firm level (Alegre et al., 2006). It is also argued that a firm's AC is not just a goal, but it moderates some organizational outputs as well (Fosfuri and Tribó, 2008). In fact, AC is increasingly regarded as a moderator in recent agility studies (Tavani et al., 2014). Firms with a greater level of AC can provide stronger organizational mechanisms in terms of recognizing, communicating, and assimilating relevant external and internal knowledge that would allow them to have well shaped communication with technology suppliers through knowledge exchange processes. This communication process, in turn, may inspire new ideas for process innovations and product designs. Flexible production technology is able to reduce time to market for product innovations and enhance the level of newness of firm's new products. For instance, rapid prototyping and 3D printers increase the number of options that can be tested in a shorter period of time which enhances the probability of new product success. Faster new product development and greater newness of firm´s new products mean better innovation performance. If greater AC is able to improve the efficiency and efficacy of Operations through the adoption and improvement of new technologies, then firms with more need of agile technologies related to production processes could benefit more from

external flows of knowledge and as a consequence become more innovative. Thus, we propose the following hypothesis:

H2. Absorptive capacity moderates positively the relationship between the level of flexible production technology and innovation performance.

Methodology

To analyze the relationships between AC, innovation and agile production technology we used the Spanish Survey of Business Strategies (SBS) questionnaire which contains a set of statements that permit the study of production and innovation for a great number of manufacturing firms. The SBS is an annual survey undertaken since 1990 and conducted by the SEPI Foundation[1] in collaboration with the Spanish Ministry of Industry with the objective of knowing the evolution of the characteristics and strategies of Spanish industrial firms. This survey contains information about markets, customers, products, employment, technological activities, and economic-financial data of the firms. The reference population comprises the group of industrial firms operating in Spain with 10 or more employees, classified by their main activity belonging to the divisions 10 to 32 of NACE-2009, excluding division 19 (industrial activities related to petrol refine and fuel treatment). The SBS uses a systematic and stratified random sample from the Spanish Social Security directory. Representativeness is one of its characteristics (the firm´s response rate is high, around 91%), and as Almodóvar and Rugman (2014) argue, "it assures anonymity; it asks mostly for non-perceptual measurements; and Foundation SEPI carries out different criteria for content validity (if there is a failure to comply with the consistency controls the company is required to submit documental justification)".

We use data available from 1,864 industrial firms in the year 2012 (nevertheless the statistical relationships we found for this year are nevertheless consistent for the previous two years that were also available at the time of our research). The distribution of surveyed firms by size indicate that 21.2% have more than or equal to 200 employees and 78.8% less than 200 employees. In terms of economic activity, the sample is highly diversified because none of the industries exceeds 15% of total firms.

We differentiate our descriptive statistics between innovative and non-innovative firms: innovative firms are those that had developed at least a product innovation, a process innovation or a patent. We also differentiate basic AC indicators according to the agility level of production which we operationalized with a construct as a categorical variable: FlexTec. This variable assesses the use of production technologies in the firm´s Operations that are basically needed for agile production. This variable takes value from 0 to 6 according to the number of flexible technologies implemented in the production process: CAD (Computer Aided Design), robots, flexible manufacturing systems, LAN (Local Area Networks), Numerically Controlled Machines, and STIN (Scientific and Technical Information Network). A higher value of this variable indicates that the firm's Operations have evolved to a greater level of agile production. To explain the level of firm's agility we use the level of market dynamism, the firm's level of production diversification, and the firm's level of product change; we control for firm size and industry.

We have elaborated several indicators to assess AC. Table 1 indicates the single variables and constructs for each AC dimension: acquisition, assimilation,

[1] The SEPI Foundation is responsible for the survey design and control through the Economic Research programme. More information about the SBS can be found in the webpage https://www.fundacionsepi.es/investigacion/esee/en/spresentacion.asp

transformation, and exploitation. Some of these indicators are used for descriptive statistics and others for the multivariate analysis. We have aggregated AC-acquisition and AC-assimilation into the variable Potential Absorptive Capacity (PAC) because both dimensions indicate the potential to transform external knowledge into in-house innovations, according to Zahra and George (2002). Similarly, we aggregated AC-transformation and AC-exploitation into the variable Realized Absorptive Capacity (RAC) since both dimensions show the realization of outputs with the resources accumulated in the two previous stages of acquisition and assimilation. Our methodology of AC assessment is not similar to those studies that employ homogeneous Likert scales to measure managerial perceptions (such as, for instance, Camisón and Forés, 2010) but all indicators are based anyway on the AC concept. AC assesses how firms act to access and use external knowledge in-house. Nevertheless other authors have also used quantitative measures like for example the in-house R&D effort to estimate the AC of the firm. Our paper explores the Spanish SBS in relation to AC for the first time and this is relevant because the SBS is the largest database of Spanish industrial firms that include strategic decisions. Besides, this assessment of AC allows to differentiate firms acoording to their specific processes of accessing, assimilating, transforming, and exploiting external knowledge. This methodology provides a capability 'profile' for each firm by identifying a differentiated set of practices that it is a more adequate measure of dynamic capability than the traditional perceptual measures of AC.

The dependent variable in our multivariate analysis is innovation performance. We use mostly dummy variables for innovation performance in order to assess a dynamic change for a firm from being non-innovative to innovative firm. The explanatory variables are the firm´s level of flexible production technology (FlexTec) and in-house R&D effort (inR&D). The moderator variables are the two aggregate measures of absorptive capacity: potential (PAC) and realized (RAC). We control for firm size (logarithm of sales).

Results

Descriptive statistics of the SBS' 1,864 firms indicate that in the year 2012, 37.9% were innovative firms: 17.7% of firms developed at least a product innovation, 31.5% obtained at least a process innovation, and 5.8% filed at least a utility model or a patent. Regarding the performance of R&D activities, 18.9% of firms outsourced R&D at the same time that carried out R&D in-house, 12.1% of firms carried out R&D in-house but not outsourced, and 4.2% of firms contracted R&D activities externally but not in-house (64.7% of surveyed firms did not carry out any R&D activity).

We have analyzed several indicators that can be used to assess AC in the surveyed firms. These firm indicators are related to the four AC dimensions: acquisition, assimilation, transformation, and exploitation. First, we have analyzed the mean differences between innovative and non-innovative firms. The information displayed in Table 2 clearly demonstrates that innovative firms show greater AC than non-innovative firms and all the differences are statistically significant, either the individual indicators or the four AC constructs.

Second, we have also analyzed the mean differences of AC indicators according to the level of flexible production technology in the firm's Operations (Table 3). All AC indicators (single and aggregated measures) are significantly greater in firms with more flexible technology in their production systems. This result suggests that agile manufacturing firms are more in need of AC than firms in less dynamic and changing

production environments. AC indicators show greater values either for acquisition, assimilation, transformation or exploitation. These results support H1.

Figure 1 shows the determinants of flexible production technology (*FlexTec*). The firm's production diversification index and the frequency of product change are positively related to the level of flexible technology. Thus, high-agile firms have a more diversified production and change products more frequently than low-agile firms. Market dynamism is not significantly related to the level of flexible technology but the model is statistically significant which means that the relationship between the type of production and agility are valid either for expanding or stable markets. However, firm size and industry (control variables) are significantly related to flexible technology.

Finally, Table 4 shows the results of the multivariate analysis to explain innovation performance according to the firm's level of flexible production technology and AC. There are two models: IP1 (utility models and patents) & IP2 (product innovations and IP1). Both models indicate that the variables *inR&D* and *FlexTec* are positively related to innovation performance. There is a moderator effect of AC on the relationship between *FlexTec* and innovation performance. The variable PAC (Potential Absorptive Capacity) is a positive moderator: for firms with greater PAC the positive impact of agility increases in both models. The variable RAC (Realized Absorptive Capacity) does not moderate that relationship although is positively related to innovation performance in model IP2. These results support partially H2.

Even though we report data from the year 2012, data from previous years 2010 and 2011 also support the same significant relationships: (1) innovative firms show greater AC values than non-innovative firms, (2) all AC indicators are greater in high-agile firms, and (3) PAC moderates positively the relationship between TecFlex and innovation performance.

Discussion

Our research demonstrates that agility and AC may be interrelated. From the theoretical perspective of RBV and dynamic capabilities, this study indicates that a dynamic capability such as AC may enable the firm to change and be innovative by adopting flexible production technology. Flexible production technologies may improve the firm's ordinary capability of Operation effectiveness but they may also contribute to improve quality and develop innovations faster. By creating an AC 'profile' for each firm, we have demonstrated that firms which develop a comprehensive profile and adopt more agile/flexible production technology are innovative, whereas firms without a comprehensive AC profile are not innovative. Thus, the process of developing a dynamic capability like AC may positively contribute to a firm's competitive advantage and to enhance the positive influence of production resources on that advantage.

Our research also has managerial implications. The results show that all AC indicators are significantly greater in high-agile firms, and that the level of flexible production technology is positively related to innovation performance. This means that agile production requires the investment in flexible technologies, but at the same time agile firms need to develop product innovations to compete in highly demanding markets. In order to obtain sustainable competitive advantages, firms in search of agility should invest in AC mainly related, according to our study, to the acquisition and assimilation processes. The adoption of flexible production technologies is not a single action in time but a continuous process that goes beyond implementation. Firms need innovations to keep Operations competitive and technologically updated. AC may complement the positive influence of in-house R&D and contribute to improve the positive impacts of

flexible production technology on firm performance. A managerial implication is that agile production systems should be integrated into the firm's innovation system because the continuous improvement of agile production has to be reinforced by the outputs of external knowledge and in-house innovation activities.

The results of our study also support that higher levels of AC enhance innovation performance through a privileged range of advantages from a particular cluster of external knowledge. This enhancement would allow companies to have a stronger exchange and employment of novel ideas, relevant knowledge, and experience regarding the key issues such as product design, technical issues, and even management practices. Another managerial implication is that firms should also use external sources of knowledge to improve production processes and technology. Thus, firms could leverage much better the benefits from that improvement, not only in Operations but also in innovation performance.

More recent theories of organisational learning have also employed AC to explain the learning process in the organisation (Fosfuri and Tribó, 2008). Learning processes that lead to better performance in the innovation process, and hence responding to the market needs and environment changes, require existence of AC (Pérez-Bustamante, 1999). Our study is more specific because it indicates that potential absorptive capacity (PAC) is a positive moderator of flexible production technology: the greater the firm's level of flexible production technology the greater the innovation performance if, at the same time, the firm has greater capacity to access and assimilate external knowledge. The adoption of flexible technology cannot be kept apart from the firm´s organisational learning processes based on external knowledge because, as a consequence, innovation performance could be lower than what is needed to compete in market environments with unpredictable changes.

We have not found a significant relationship for the hypothesized moderator effect of realized absorptive capacity (RAC). On the contrary than PAC, RAC is more related to the exploitation of knowledge for product innovations. In our study this would mean that the hypothesis was not supported because PAC is more related to the use of knowledge for continuous improvement and process innovation. Thus, our result would remark the need that firms with agile production systems reinforce the AC dimensions of acquisition and assimilation because these are the phases where tacit knowledge, that it is key to processes improvement, is generated.

Finally, from an industrial policy perspective, our results suggest that training support in clusters that coordinate supply chain agents would facilitate improvements of firms' AC, and therefore, the implementation of agile production systems. Agile production not only needs flexible production technologies, but a continuous improvement in the firms' stock of knowledge because they have to innovate more intensively than other firms in less unpredictable environments. Production systems in agile firms have to be more updated and customized than in other firms. This requires in-house R&D efforts, but mainly the access and assimilation of the best external available knowledge. Clusters of firms are a mechanism to structure such access.

Conclusions, limitations, and future research

Our paper has analysed data from Spanish industrial firms to study the relationship between absorptive capacity and the level of flexible production technology. Both are positively related to innovation performance but the main conclusion of the paper is that absorptive capacity moderates the positive relationship between flexible production technology and innovation performance. From a managerial perspective, firms should

pay attention to the best practices to access and assimilate external knowledge in relation to production process improvement.

These results must be regarded according to the limitations of our research design. The main limitation is that our analysis is cross-sectional although the results are also valid for the two previous years of this study. Future studies could use real measures of absorptive capacity and longitudinal data in order to test dynamic capabilities. We also recognize the difficulty to generalize conclusions based only on Spanish firms, and therefore, larger databases with European firms would be needed to extend our propositions.

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