Absorptive Capacity and Technology:
Influences on Innovative Firms

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Abstract

We use data from 1,861 Spanish industrial firms to study if high-agile firms have greater absorptive capacity than low-agile firms. At the same time our research studies whether agile firms with greater absorptive capacity are more innovative and better performers than other firms. The results of our multivariate analysis indicate that absorptive capacity moderates positively the relationship between the level of agile production technology and firm performance. We discuss implications for managing agile production systems.

Introduction

There is a growing need for firms to respond quickly to market changes as well as to keep updated their technology and knowledge portfolio, either through in-house R&D or by managing adequately the use of external knowledge. Two very important dynamic capabilities that become sources of sustainable competitive advantages are absorptive capacity and agile production.

On the one hand, absorptive capacity 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). Consequently this dynamic capacity allows the firms to keep technologically updated and adapted to market changes from the perspective of knowledge and innovation.

On the other hand, agile production has attracted increasing attentions of researchers and practitioners. Agility conveys the ability to efficiently change operating states in response to uncertain and changing market conditions. Agility means an organization with top internal capabilities (i.e. flexible hard and soft technologies, high skill employee training, and integrated flows of information) to meet dynamic needs of the marketplace.

Both 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 like, for instance, advanced machinery manufacturers. Agile firms develop and adopt production technologies more intensively than lean or mass production firms (Narasimhan et al., 2006). However the literature of agile production does not include variables or concepts related to absorptive capacity. Although new products are usually the most important output of innovation activities, process and organizational innovations are also sometimes relevant. Agile firms 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 R&D centres are necessary to leverage the firm´s capability to do unplanned & new activities in response to unforeseen shifts in market demands or unique customer requests.

Then the main purpose of this paper is to analyse if agile production firms have greater absorptive capacity than other firms. At the same time our research studies if agile firms with greater absorptive capacity are more innovative than other firms. This means that absorptive capacity would moderate positively the relationship between agility and innovation performance. Both analyses contribute to the literature of agility and absorptive capacity and have important managerial implications. Firms seeking agility should focus 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 perspectives contribute to explain the competitive implications of absorptive capacity 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 but 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). Although innovation is very important for firms to compete and improve performance, innovation management is not the only success factor. 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 the absorptive capacity (Wang and Ahmed 2007; Lin et al., 2016).

Absorptive Capacity

The concept of absorptive capacity (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) proposed four dimensions that have been mostly used thereafter: acquisition, assimilation, transformation and exploitation of new knowledge. 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 goals that compensate the effort and resources invested in the previous phases.

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 that they may improve their organizational routines and management practices which contributes positively to enhance firm performance (Lane et al., 2006; Dobrzykowski et al., 2015).

Agile Production

The manufacturing practices have undergone paradigm shift from the mass production to agile production. Agile production (AP) evolved as a response to the drastic changes in the manufacturing processes by discarding the traditional processes that are no longer valid to thrive in this competitive age, making an organization flexible and responsive to market changes. 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 AP concept and is an integral component of an AP framework (Dubey and Gunasekaran, 2015). Empirical studies on agile production are not very frequent but in the case of Spanish industry they are very scarce (Vázquez-Bustelo and Avella, 2006; Vázquez-Bustelo et al., 2007).

Technology, Absorptive Capacity and Agile Production

Absorptive Capacity is closely related to technology. AC manages knowledge to transform ideas and proposals into innovations. Technology is also 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. 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:

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

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

Methodology

To analyze the relationships between AC, innovation and agile production technology we used the 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 Spanish industrial firms. The SBS is an annual survey 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 industrial firms operating in Spain and with more than 10 employees, with representativeness being one of its characteristics. We use data available from 1,861 industrial firms in the year 2012.

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. *Flexible production technology* 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, & STIN (Scientific and Technical Information Network). A higher value of this variable indicates that the firm´s Operations have evolved to a greater agile environment. 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, 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 AC-potential 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 AC-realized since both dimensions show the realization of

[1] The SEPI Foundation is responsible for the survey design and control through the Economic Research programme.

outputs with the resources accumulated in the two previous stages of acquisition and assimilation.

The dependent variable in our multivariate analysis is innovation performance. The explanatory variables are the firm´s level of flexible production technology and internal R&D. The moderator variables are the two aggregate measures of absorptive capacity: AC-potential and AC-realized. We control for firm size and industry.

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.

Secondly 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.

Figure 1 shows the determinants of flexible production technology. 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 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 absorptive capacity. There are two models: IP1 (utility models and patents) & IP2 (product innovations and IP1). Flexible technology is positively related to innovation performance in both models and there is a moderator effect of AC on this relationship. AC-potential is a positive moderator: for firms with greater AC-potential the positive impact of agility increases in both models. AC-realized does not moderate the relationship although is positively related to innovation performance in model IP2.

Discussion

Our research demonstrates that agility and absorptive capacity are two interrelated dynamic capabilities. Agile production requires the investment in flexible technologies at the same time than 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 absorptive capacities mainly related 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 production processes competitive and technologically updated. Absorptive capacity may complement the positive impact of in-house R&D and contribute to improve the positive impacts of flexible production technology on firm performance. Then, 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.

Conclusions, Limitations and Future Research

The main conclusion of the paper is that absorptive capacity moderates the positive relationship between flexible production technology and innovation performance. The limitation of the research design has been to use constructs of absorptive capacity and the cross-sectional statistical analysis. Future studies could use real measures of absorptive capacity and longitudinal data.

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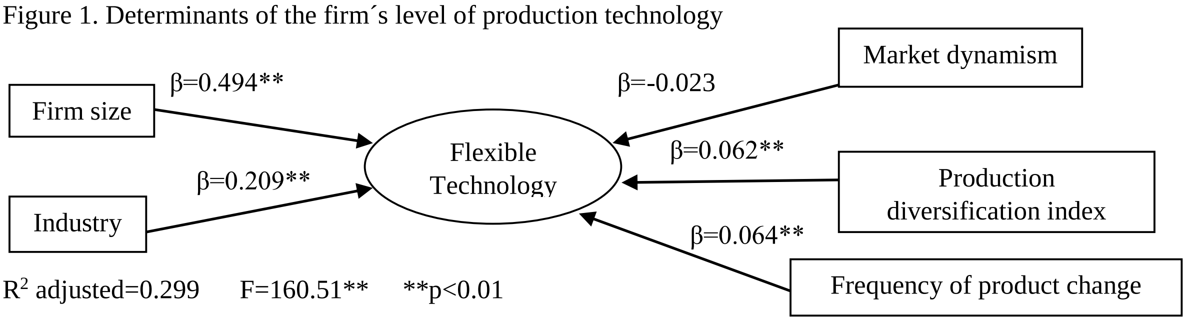
Table 1. Indicators of Absorptive Capacity	
ACQUISITION	
R&Dext	Percentage of sales invested in external R&D
Mac-Tech	Percentage of sales invested in machinery and incorporated technology
Imp-Tech	Percentage of sales invested in imported technology
AC-acq	Construct based on the sum of dummy variables (External R&D personnel with private experience; External R&D personnel with public experience; Technological cooperation with customers; Technological cooperation with suppliers; Technological cooperation with competitors; Technological cooperation with Universities and Technology Centers; Participation, shares or investment, in innovative firms; R&D European Union projects; Scientific and technical information activities; Use of technological advisers and consultants; Contracted design; Acquisition of machinery to improve products; Market studies). This variable may take values from 0 to 13.
ASSIMILATION	
R&Dper	Percentage of R&D personnel in the workforce
EngSci	Percentage of engineers and scientists in the workforce
TRAI	Percentage of sales invested in employees´ external training
AC-assim	Construct based on the sum of dummy variables (Incorporate young engineers and scientists; R&D executive department; Forecast technological change; Investment in assimilate external technology; Evaluate alternative technologies; Elaborate innovation performance indicators; Elaborate annual plans of innovation activities; External training in foreign languages; External training in engineering and technology; External training in information technology and software; External training in marketing; Other external training). This variable may take values from 0 to 12.
TRANSFORMATION	
AC-transf	Construct based on the sum of dummy variables (Forecast technological change; Evaluate alternative technologies). This variable may take values from 0 to 2.
EXPLOITATION	
AC-explo	Construct based on the sum of dummy variables (National patents; Foreign patents; Utility models; Product innovation; Process innovation; Market innovations in product design; Market innovations in sales channels; Innovations in organizational methods; Innovations in work organization; Marketing collaborations for products). This variable may take values from 0 to 10.

Figure 1. Determinants of the firm´s level of production technology



R^2 adjusted=0.299 F=160.51** **p<0.01

Table 2. Mean differences of firm indicators of Absorptive Capacity according to innovative firms

	Innovative firms (n=706)	Non-innovative firms (n=1,158)
Percentage of sales invested in external R&D	0.48**	0.09
Percentage of sales invested in internal R&D	1.31**	0.19
Percentage of sales invested in machinery and incorporated technology	1.05**	0.08
Percentage of sales invested in imported technology	0.0001**	0.00005
Percentage of R&D personnel in the workforce	4.30**	1.36
Percentage of engineers and scientists in the workforce	8.80**	5.43
Percentage of firms that incorporated young engineers and scientists	30**	8
Percentage of firms that hire R&D personnel with private experience	11**	1
Percentage of firms that hire personnel with R&D public experience	4**	1
Percentage of sales invested in employees´ external training	7.64**	3.45
Level of external technological cooperation (categorical, 0 to 4)	1.21	0.26
Percentage of firms with a R&D executive department	44**	9
Percentage of firms that acquired machinery to improve products	37**	4
Percentage of firms that carried out or contracted design activities	47**	19
Percentage of firms that carried out market studies	27**	9
Percentage of firms that forecasted technological change	44**	11
Percentage of firms that invested to assimilate external technology	17**	5
Percentage of firms that evaluated alternative technologies	43**	11
Percentage of firms that elaborate innovation performance indicators	36**	6
Percentage of firms that elaborate annual plans of innovation activities	47**	8
Percentage of firms that invest in innovative firms	12**	2
Percentage of firms with R&D European Union projects	3**	0
Percentage of firms that carried out scientific and technical information activities either in-house or contracted	36**	10
Percentage of firms that used technological advisers and consultants	36**	9

Level of significance +p<0.1 *p<0.05 **p<0.01

Table 3. Mean differences of firm indicators of Absorptive Capacity according to the level of flexible technology

	High-Flexible Technology (n=723)	Low-Flexible Technology (n=1,141)
Percentage of sales invested in external R&D	4.19**	1.24
Percentage of sales invested in internal R&D	0.98**	0.38
Percentage of sales invested in machinery and incorporated technology	0.57*	0.37
Percentage of sales invested in imported technology	0.00017**	0.00005
Percentage of R&D personnel in the workforce	3.49**	1.61
Percentage of engineers and scientists in the workforce	8.14**	5.58
Percentage of firms that incorporated young engineers and scientists	28**	9
Percentage of firms that hire R&D personnel with private experience	9**	2
Percentage of firms that hire personnel with R&D public experience	3*	1
Percentage of sales invested in employees´ external training	6.83**	3.90
Level of external technological cooperation (categorical, 0 to 4)	1.03**	0.36
Percentage of firms with a R&D executive department	39**	12
Percentage of firms that acquired machinery to improve products	23**	12
Percentage of firms that carried out or contracted design activities	43**	20
Percentage of firms that carried out market studies	26**	8
Percentage of firms that forecasted technological change	40**	13
Percentage of firms that invested to assimilate external technology	17**	4
Percentage of firms that evaluated alternative technologies	38**	14
Percentage of firms that elaborate innovation performance indicators	30**	10
Percentage of firms that elaborate annual plans of innovation activities	41**	12
Percentage of firms that invest in innovative firms	9**	4
Percentage of firms with R&D European Union projects	2*	1
Percentage of firms that carried out scientific and technical information activities either in-house or contracted	36**	8
Percentage of firms that used technological advisers and consultants	32**	11
Percentage of firms that have patented in Spain	6.74**	2.45
Percentage of firms that have patented in foreign countries	4.54**	2.02
Percentage of firms that have developed utility models	3.16**	0.61
Percentage of firms with product innovation	27**	12
Percentage of firms with process innovation	46**	22
Percentage of firms with market innovations in product design	13**	9
Percentage of firms with market innovations in sales channels	10**	6
Percentage of firms with innovations in organizational methods	31**	17
Percentage of firms with innovations in work organization	29**	16
Percentage of firms with marketing collaborations for products	6.66*	4.53
AC acquisition	2.89**	1.05
AC assimilation	4.28**	1.57
AC transformation	0.78**	0.26
AC exploitation	1.77**	0.91

Level of significance +p<0.1   *p<0.05   **p<0.01

The level of flexible technology is a categorical variable from 0 to 6 according to the number of flexible technologies implemented in the production process: CAD, robots, flexible manufacturing systems, LAN (Local Area Networks), Numerically Controlled Machines, & STIN (Scientific and Technical Information Network). The sample is divided in two groups: high-flexible technology firms (value over 2.11) and low-flexible technology firms (below 2.11).

Table 4. Lineal regression of innovation performance

	IP1	IP2
Firm size	0.052 (1.631)	0.038 (1.205)
Industry	-0.006 (0.254)	-0.008 (0.355)
TecFlex	0.111** (3.064)	0.079* 2.205)
R&Dint	0.095** (3.873)	0.083** (3.436)
AC-potential	0.185** (2.600)	0.144* (2.051)
TecFlex x AC-potential	0.291** (3.444)	0.247** (2.942)
AC-realizated	0.054 (0.893)	0.164** (2.766)
TecFlex x AC-realizated	0.027 (0.355)	-0.012 (0.166)
Model statistics	Adjusted R^2 =0.038 F = 10.071 p = 0.000 n = 1,864 firms	Adjusted R^2 =0.058 F = 15.293 p = 0.000 n = 1,864 firms

IP1: number utility models + number national & international patents. IP2: number product innovations + number utility models + number national & international patents

Standardized β values (t-values between parentheses)