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Experience in R&D collaborations, innovative performance and the moderating effect of different dimensions of absorptive capacity

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Abstract

Using a multi-stage research design and insights from organizational learning theory, we investigate how experience in R&D collaboration with different types of domestic and foreign partners (customers, suppliers, competitors) influences the formation of new R&D collaborations with foreign partners, and how such collaborations in turn affect firms' innovative performance. Our framework, which is tested against a sample of 8800 firms over a 9-year period, explains how experience with certain types of domestic partners helps firms establish foreign collaborations, particularly with the same partner types. It further explains why experience in foreign collaborations is more important for the formation of new collaborations abroad in relation to experience with domestic partner types. Moreover, it shows that collaborations with foreign partners are more beneficial than domestic collaborations for a firm's innovative performance and identifies which types of foreign R&D partnerships are more advantageous for enhancing innovation performance. Finally, it demonstrates that the performance-enhancing advantages of foreign partnerships are not equal for all firms but are dependent on certain dimensions of absorptive capacity. The effect that foreign suppliers have on a firm's innovative performance is further enhanced if a firm has adopted appropriate organizational practices designed to enhance external collaboration and the internal dissemination of external knowledge. Finally, firms gain more from foreign competitors if they possess high levels of employee skills.

Keywords: Foreign R&D collaborations; organizational learning theory; experience; absorptive capacity

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1. Introduction

Access to external sources of knowledge is important for the innovative and overall performance of firms (Chesbrough, 2003; Gkypali et al., 2017). As the development of radical products requires knowledge from different scientific domains, it is unlikely for a single firm to possess the entire set of the capabilities needed for developing such products (Lawson et al., 2015; Kafouros and Aliyev, 2016; Khan et al., 2018). Radical products are also characterised by higher levels of risk and costs that stop many firms not only from completing but also starting such projects (Tether, 2002). To overcome these challenges, firms increasingly engage in open innovation (Kratzer et al., 2017; Meissner and Shmatko, 2017) and form R&D collaborations[†] with different types of domestic and/or foreign partners (i.e. customers, suppliers, competitors) (Hashai et al., 2018; Hsieh et al., 2018; Tsai, 2009; van Beers and Zand, 2014).

Given the importance of R&D collaborations, previous studies have provided valuable insights into what enables firms to collaborate with different types of partners and examined how partners affect a firm's innovative output (Tether, 2002; Roper et al., 2008; Love et al., 2011; Ganotakis and Love 2012; Un et al., 2010). The literature has also shown that collaboration with a certain type of partner (e.g., customers) provides experience that helps firms form collaborations with other types of partners (e.g., suppliers and competitors) (Roper et al., 2008; Gulati et al., 2009). Nevertheless, three significant gaps in our understanding remain unaddressed.

First, despite the above contributions, we have a rather limited understanding of the relationship that exists between the formation of domestic partnerships and foreign partnerships. We address this gap by examining how the experiential knowledge that firms accumulate in domestic R&D collaborations assists in the formation of foreign R&D

[†] Collaboration in this paper is defined as active participation in innovation activities/projects with different types of external partners, and it therefore excludes pure contracting out work (Tether and Tajar, 2008; De Marchi, 2012).

collaborations. Domestic partners provide firms with general experience and partnering skills (Roper et al., 2008). However, these skills might not be applicable in forming foreign collaborations because international partnerships involve cultural, institutional and organizational differences that increase complexity (Hashai et al., 2018; Barkhema et al., 1997; Eriksson et al., 1997). The importance of addressing this question lies in identifying potential complementarities between domestic and foreign partnerships and in the performance benefits of accumulating foreign vis-à-vis domestic knowledge (van Beers and Zand, 2014; Kafouros and Forsans, 2012; Majidpour, 2017).

Second, although prior studies have examined the relationship between foreign knowledge and innovative performance (e.g., Hsieh et al., 2018; Jiang et al., 2010), we still have a limited understanding of how prolonged experience with different types of partners (either domestic or foreign) affects a firm's innovative output. This is an important question because of two opposing forces on a firm's innovative performance that arise as firms accumulate experience in collaborating with a certain type of partner. On the one hand, as firms gather experience, they develop partner-specific mechanisms and routines that assist in coordination and knowledge exchange and enhance a firm's innovative output (Un et al., 2010; Reuer and Arino, 2007). On the other hand, it may also create learning rigidities as the firm accesses similar knowledge for a prolonged period (Belderbos et al. 2012; Lane and Lubatkin, 1998), reducing the chances of creating valuable combinations. This in turn may affect adversely the firm's innovative performance (Un and Asakawa, 2015).

Third, prior research has established that a firm's ability to assimilate external knowledge (absorptive capacity, AC) depends on its R&D intensity. We extend understanding of the relationship between R&D collaboration and innovation performance by examining how certain dimensions of AC such as employee skills and organizational practices for exchanging and transferring knowledge across and within the firm (Schmidt, 2010; Zahra and George,

2002) enable firms to integrate knowledge from different partners more effectively. Our overarching reasoning is that different partner types vary in the nature and type of knowledge they possess, their motivations for engaging in collaboration, their risk profiles and their structures and management styles (Belderbos et al. 2012; Un and Asakawa, 2015; Un et al. 2010; De Silva and Rossi, 2018). As a result, different dimensions of AC are more prominent for benefiting more from collaborations with different types of partners.

We test our framework and hypotheses against a sample of 8000 Spanish firms over 9 consecutive years. Our study makes a number of contributions to the innovation literature. First, it enhances understanding of the determinants of R&D collaborations by explaining the mechanisms through which experience with certain types of partners assist firms in establishing foreign collaborations. In this respect, our analysis shows that the benefits of experience are stronger for similar partner types (e.g., between domestic and foreign customers) than for different ones. Second, we explain why experience with foreign partners is more beneficial for a firm's innovative performance than experience with domestic partners. We also increase knowledge of why not all foreign partners contribute equally. Experience with foreign suppliers and competitors is more important than experience with foreign customers. Third, our analysis extends prior thinking about the role of AC in collaborations by showing that although certain AC dimensions (i.e., skills, internal R&D) matter more for benefiting from collaborating with competitors, different dimensions (i.e., organizational practices for knowledge exchange) are more important in enhancing the effects of collaborations with customers and suppliers on innovative performance.

The rest of the paper is structured as follows: first, following an overview of the baseline theoretical framework, we discuss our working hypotheses; second, we present our data, variables and methods; third, we report the results; fourth, we discuss the main research findings; and, fifth, we present our concluding remarks.

2. Theory

The theoretical foundation in this study relies on organizational learning theory (hereafter OLT) (Huber, 1991; March, 1991) and is complemented by work on AC (Cohen and Levinthal, 1990; Schmidt, 2010). The OLT suggests that firms obtain experience and knowledge from both internal and external activities. Internal activities include organizational experiments such as internal R&D whereas external activities (or otherwise focused search efforts) include inter-organizational linkages such as collaborations with different (domestic or foreign) partner types (Dodgson, 1993).

The type of external linkages firms choose depends on the perceived costs and benefits (Kafouros et al. 2015), but also on habitual forces and rigidities in managerial decision making (Hsieh et al., 2018). Accumulated experience and knowledge from those activities becomes part of the organization's memory and is transformed into routines, management practices and organizational structures (Huber, 1991; Dodgson, 1993). These practices and routines enhance communication and coordination with partners and are used to develop a shared context that facilitates knowledge transfer (Un et al., 2010; Reuer and Arino, 2007; Heimeriks and Duysters, 2007; Rothaermel and Deeds, 2006; Sampson, 2005). As firms accumulate experience with a certain partner type, these practices get further embedded within a firm's structure and can then be deployed in the formation of future collaborations.

OLT also suggests that the benefits that a firm can derive from each partner type depend on two mechanisms. First, they depend on how close a firm's organizational structures and basic knowledge are to those of different types of partners and second on how different (heterogenous) their specialised knowledge is (Gkypali et al., 2017; Lane and Lubatkin, 1998; Un and Asakawa, 2015). Partners that share similar organizational structures can coordinate internal functions through the existence of common practices and routines. This improves inter-organizational learning (Schmidt, 2010; Lane and Lubatkin, 1998). Basic knowledge

refers to the general understanding of the techniques upon which a discipline is based. Specialised knowledge refers to the niche/specific and tacit knowledge that different partners possess. Although OLT suggests that the basic knowledge between two partners has to be relevant to facilitate knowledge exchange and understanding, parts of partners' specialised knowledge have to be diverse enough to create valuable knowledge combinations (March, 1991; Lane and Lubatkin, 1998). Moreover, the literature on AC suggests that the ability of firms to successfully assimilate external knowledge, depends not only on their internal R&D intensity but also on the level of employee skills and on management practices for the transfer and dissemination of external knowledge (Schmidt, 2010; Kratzer et al., 2017).

Drawing on OLT, the next sections develop three hypotheses. The first concerns the relationship between experience in prior domestic and foreign R&D collaborations and the formation of new foreign collaborations with different partner types. The second focuses on the magnitude of the effect that experience with different types of foreign partners has on a firm's innovative performance and finally the third focuses on how various dimensions of AC moderate the effects of foreign collaborations on innovative performance for each type of foreign partner. The reasoning of these hypotheses relies on (1) the role of organizational practices and routines when firms develop experience in collaborating with external partners (Hsieh et al., 2018; Un et al., 2010), (2) the proximity between the organizational structures as well as between the basic and specialised knowledge of the focal firm and that of different partner types and (3) the role of knowledge rigidities and habitual forces in decision making (Lane and Lubatkin, 1998).

3. Hypotheses development

The role of experience in establishing foreign collaborations

When a firm collaborates with a certain partner type (e.g., customers), it gains two kinds of experiential knowledge that translate into organizational routines. The first refers to knowledge about collaborating with that specific type of partner (i.e., customer) and the second is general knowledge about the overall management of collaborations (Lhuillery and Pfister, 2009; Roper et al., 2008). The majority of the routines developed from collaboration are partner-specific and can be used in collaborations only with that certain type of partner (Lhuillery and Pfister, 2009; Hoang and Rothaermel, 2005; Muehlfeld et al 2012). Routines that result from *general* knowledge can be applied in the formation and management of collaborations with any type of partner (suppliers or competitors) (Roper and Arvanitis, 2012).

As a firm accumulates experience with a type of partner, partner-specific practices and routines become further embedded in its organizational structure. As a result, they may lead to path dependency, rigidities and habitual forces in decision making (Lane and Lubatkin, 1998). Relying extensively on such routines increases repetition of past action and persistence in collaborating with a certain type of partner (Belderbos et al 2012; Hoang and Rothaermel, 2005; Sampson, 2005; Levitt and March, 1988). Therefore, the type of prior collaborative experience can determine the firm's future collaborative path. Due to path dependency, they can even constrain collaboration with different types of partners. Because of this mechanism, experience in collaborating with a certain partner type increases the chances of repeating such collaborations whereas the likelihood of collaborating with different partner types decreases.

Moreover, experience in collaborating with domestic partners is not as useful in forming foreign collaborations. Foreign collaborations are characterised by difficulties that arise due to differences in national culture, language and institutions that can ultimately increase the complexity of forming foreign collaborations (Meuhlfeld et al 2012; Lhuillery and Pfister,

2009; Texeira et al., 2012; Parkhe, 1991). Such differences in turn may lead to differences in the organizational structures, routines and management practices between partners (Park and Ungson, 1997; Parkhe, 1991) and constrain coordination and knowledge transfer activities.

However, the above challenges and constraints might not be as severe when forming foreign collaborations with a type of partner (e.g., foreign customer), if firms have gained domestic experience in collaborating with the same partner type (e.g., domestic customer). For instance, prior research suggests that firms can learn some of the skills required to function within international JVs through domestic ones. This allows firms to build experience in their formation and management without having to deal with the additional complexities that arise due to variations in national cultures (Barkhema et al, 1997).

Building on this reasoning, we further posit that the practices and routines that a firm implements in order to collaborate with a specific type of domestic partner can be extended and used when collaborating with similar types of foreign partners. The same partner types have similar management practices, organizational structures and knowledge (Belderbos et al 2012; Un et al, 2010). Therefore, using mechanisms and routines that are already part of a firm's organizational memory help firms align their organizational structures closer to those of foreign partners. This can allow firms to overcome some of the difficulties associated with variations in national cultures (Park and Ungson, 1997; Parkhe, 1991; Pittaway et al 2004).

On the other hand, experience gained from different types of domestic partners in relation to the one a firm attempts to collaborate abroad will not be as useful in assisting the firm to overcome certain challenges because of differences in business systems and in firms' organizational structures across countries. The type of knowledge a firm will be able to transfer and apply in such cases will be general knowledge on the formation and management of collaborations (Roper et al., 2008). Such knowledge will not be as helpful as partner-

specific knowledge is in increasing organizational proximity between partners and therefore in reducing problems that arise due to cultural differences.

Firms that do not have experience with the same type of domestic partners have to develop new mechanisms to collaborate with foreign partners. Although this is possible, it requires additional cost as well as managerial time and effort which makes collaboration more difficult and less likely to occur compared with collaboration with similar types of foreign partners (Parkhe, 1991; Sampson, 2005; Nieto and Santamaria 2007).

In addition, firms that have accumulated experience in collaborating with foreign partners, also possess country-specific as well as general foreign knowledge about engaging in cross-country collaborations (Eriksson et al., 1997; van Beers and Zand, 2014). Country-specific knowledge includes understanding of a country's culture, laws and institutions but also dominant business practices and organizational structures (Sampson, 2005). This knowledge helps a firm to engage in future collaborations in that specific country either with the same or a different type of partner. General foreign knowledge on the other hand can be applied to collaborations in any country and it involves overall expertise in organizing and managing international collaborations (Eriksson et al., 1997; Sampson, 2005). It provides a firm with overall knowledge of how to adapt their organizational practices to match those used by a culturally different partner (van Beers and Zand, 2014; Lavie and Miller, 2008).

Through foreign collaborations therefore, apart from partner specific and general collaboration experience, firms also obtain country specific as well as general foreign collaboration experience. Foreign collaborations therefore are more useful than domestic collaborations in the formation of new foreign partnerships.

Accordingly, we introduce the following hypotheses:

Hypothesis 1a: Experience in domestic collaborations assist in the formation of foreign collaborations.

Hypothesis 1b: Prior collaboration experience with a domestic partner of a certain type correlates more strongly with the likelihood of engaging in a foreign collaboration of the same type than experience with different types of domestic partners.

Hypothesis 1c: Experience in foreign collaborations is more useful in the formation of new collaborations abroad in relation to experience in domestic collaborations.

Hypothesis 1d: Prior collaboration experience with foreign partners of a certain type correlates more strongly with the likelihood of engaging in a foreign collaboration of the same type than experience with different types of foreign partners.

Foreign collaborations and innovative performance

Extant literature shows that R&D collaborations with customers, suppliers and competitors improve a firm's innovative performance (Nijssen et al 2012; Harhoff et al 2014; Mention, 2011; Leiponen, 2010; Belderbos et al, 2004). However, each partner type may contribute differently to innovation performance (Gkypali et al., 2018). This is because when a firm collaborates with customers, suppliers or competitors, the proximity between the organizational structure, basic and specialised knowledge of the firm and each of the partner types differs (March, 1991; Lane and Lubatkin, 1998). Hence, the potential benefits of collaborating with each partner type also vary.

Given that competitors operate in the same industry, it is more likely that their organizational structures are more closely aligned and that they share a larger proportion of common basic knowledge in relation to customers or suppliers (Tsai, 2009; Un and Asakawa, 2015). Customers and suppliers tend to operate in different but yet closely related to the focal firm industries, given that firms receive inputs from suppliers and provide outputs to

customers (Porter, 1980). Hence, their organizational structures and basic types of knowledge share commonalities in relation to the focal firm, but not to the same extent as for the case of competitors (Un and Asakawa, 2015). Therefore, when firms start collaborating, the similarities in the structures and basic knowledge between competitors should make the transfer of knowledge easier in relation to collaborations with customers and suppliers.

However, as firms *accumulate experience* in collaborating with customers and suppliers, they introduce practices and organizational routines that improve coordination and communication, reducing differences in their organizational structures. When firms accumulate experience with competitors, these routines may still improve knowledge exchange but at a lesser extent in relation to when firms accumulate experience with other partner types, given that rival firms already share similar organizational structures.

When firms access heterogenous knowledge from different types of partners, we argue that this takes place at a greater extent for the case of suppliers, then for customers and finally for competitors. First, collaboration with suppliers provides access to specialist knowledge that creates new processes that enable the development of radical products or novel improvements in existing products (Megnuc et al., 2014; Lawson et al., 2015; Pittaway et al 2004; Gassman et al, 2010). Moreover, suppliers can make novel additions to the design or features of new products (van Beers and Zand 2013; Tsai, 2009; Pittaway et al, 2004) and increase their uniqueness. Finally, because suppliers develop technological solutions for the different problems their customers might face, they often transfer best practices that have been developed in past collaborations to new R&D collaborations with additional customers (Ganotakis and Love, 2012). Hence, through suppliers, firms gain indirect entry to various types of technological expertise that exists not only in their own industry but also in different sectors (Fine and Whitney, 1996). This makes the knowledge that exist within the firm more valuable and heterogenous and improves the chances of developing product innovations.

On the other hand, R&D collaborations with customers enable firms to refine the direction of their R&D effort and identify ideas for the development of products with strong market potential. Through such collaborations, firms gain knowledge regarding unmet customer needs (Nijssen et al 2012; Gassman et al, 2010; Barge Gil, 2010) and can access their customers' technological expertise by having members of customers' R&D and engineering personnel being part of the firm's new product development team (Tsai, 2009; Miotti and Sachwald, 2003). Hence, although firms access new knowledge, such knowledge is derived from a certain industry and it is specific to addressing particular technical issues for a certain customer. For those reasons the range of knowledge gained is less diverse in relation to that gained from suppliers.

Finally, firms collaborate with rivals when a strong joint interest in a risky and resource intensive project exists, when they have to deal with common problems and when they carry out basic or generic research that can lead to new industry standards (Mention, 2011; Nieto and Santamaria, 2007; Harhoff et al 2014). Although competitors share similar basic knowledge, they often possess their own technological specializations that lie beyond a focal firm's own knowledge range (Xu et al, 2013). Nevertheless, through competitors, firms access a smaller range of knowledge in relation to customers or suppliers because they operate in the same or in a similar industry and because competitors limit the amount of knowledge they make available to their rivals (Barge-Gill, 2010; Mention, 2011) in an attempt to reduce knowledge spillovers (Arranz and Arroyabe 2008; Nieto and Santamaria, 2007).

The next relevant question is how does the *accumulation of experience* with those types of partners affects the value of the different types of knowledge that firms obtain. As firms gain experience in collaborating with different types of partners, they are exposed to similar types of knowledge over a long period of time (Belderbos et al. 2012; Un and Asakawa, 2015), which reduces the chance of creating novel knowledge combinations. This may lead to

learning rigidities and make collaborations less beneficial for a firm's innovative effort. However, we argue that the rigidities that are developed by continuous collaboration with a certain type of partner are lower for the case of foreign collaborations.

This is because foreign R&D collaborations allow access not only to the specialized expertise of partners but also to country-specific knowledge (Kafouros and Forsans, 2012; Cincera et al 2003). Given that knowledge is spatially bounded and geographically constrained (Kafouros et al. 2018), only firms that engage in foreign collaborations can access it (Arranz and Arroyabe 2008; Narula and Duysters 2004). Collaborating with foreign partners provides access to heterogenous knowledge (not only partner but also country specific). Hence, engaging in collaborations with certain foreign partner types provides access to knowledge that is more diverse than that from domestic collaborations of a similar kind (Cincera et al 2003; Kafouros et al 2012; van Beers and Zand 2014; Ramadani et al., 2018). This in turn increases the chances of firms benefiting more from continuous collaborations with certain types of foreign rather than domestic partner types. Accordingly, we introduce the following hypotheses:

Hypothesis 2a: Experience in collaborating with suppliers enhances a firm's innovative performance at a greater extent in relation to experience with customers.

Hypothesis 2b: Experience in collaborating with customers enhances a firm's innovative performance at a greater extent in relation to experience with competitors.

Hypothesis 2c: Experience in collaborating with a certain foreign partner type (i.e., foreign suppliers) enhances a firm's innovative performance at a greater extent in relation to experience in collaborating with the corresponding domestic partner type (i.e., domestic suppliers).

The role of absorptive capacity

As discussed earlier, customers and suppliers (compared to competitors) have more diverse organizational structures in relation to the focal firm (Un et al., 2010). These differences constrain the effective coordination and communication among partners and hinder the transfer of knowledge (Schmidt, 2010). To collaborate with supply chain partners and to successfully assimilate external knowledge, significant adjustments and additions to firms' organizational practices must take place (Lane and Lubatkin, 1998; Islam et al., 2018).

We therefore expect the effects of collaboration with customers or suppliers on a firm's innovative performance to increase when new organizational practices designed to aid collaboration with external partners and/or to assist in the internal dissemination of externally acquired knowledge have been recently introduced by firms. Their adoption can help align their structures closer to those of their supply chain partners, enhancing therefore the flow and assimilation of knowledge. Examples of practices that aid collaboration between different partner types include integrated portfolio planning, interlocking product development process, co-located teams and IT tools such as software and project management systems that allow for concurrent engineering to take place between partners (Barczack et al., 2009).

The introduction of such new practices can also help firms escape competency traps that can arise from accumulating experience with a specific type of partner. These competency traps differ from those that arise because of firms accessing similar types of knowledge from the same types of partners, as discussed in Hypothesis 2. OLT suggests that experience in collaborations leads to the development of partner-specific routines (Huber, 1991; March, 1991). However, as firms accumulate experience with a certain partner type, habitual forces in the usage of practices are also developed. Hence, managers persist in using existing practices at the expense of introducing new and more efficient ones (Dodgson, 1993; Levitt and March, 1988). This in turn does not allow a firm to reach the possible (viable) maximum level of

efficiency in transferring and assimilating knowledge from external partners that could have been achieved if they had implemented new routines based for example on the adoption of new management practices that have been recently developed and diffused in the market, or on the adoption of information systems (Ganotakis et al., 2013; Barczack et al., 2007). By improving existing practices, firms can escape competency traps and improve the value of collaborations as recently implemented routines are more easily evoked by an organization and are more likely to be used in relation to older ones (Levitt and March, 1988).

On the other hand, firms from the same industry sector (i.e. competitors) share similar organizational structures. Hence, the adoption of the aforementioned practices and routines will not enhance, at least not to the same extent, the benefits that firms can gain from collaborating with competitors. However, we suggest that firms can benefit more from collaborating with competitors if they have a high level of internal capabilities in the form of internal R&D or employee skills. For several reasons, we also suggest that these capabilities are more important for collaborations with competitors rather than with customers or suppliers. The first involves the motivation for engaging in collaboration with rival firms. Although as mentioned in the development of hypothesis 2 firms gain access to a lower range of heterogenous knowledge types when collaborating with rivals, they still collaborate in order to tackle novel and risky technological problems that carry a high level of cost (Tsai, 2009). They do so when they have to find a technological solution to a problem that has a clear future benefit for both partners. This usually leads to the development of basic (or theoretical) scientific knowledge (Mention, 2011; Nieto and Santamaria, 2007; Harhoff et al 2014) that although might not always lead to the development of new products in the short term, it carries future commercial value.

Given the novelty of the projects but also the risk due to possible appropriation costs involved in such collaborations, competitors will engage in collaboration with each other only

if they can identify a clear potential for knowledge gain from their partners. This is more likely to be the case, only if their partners possess a high level of skills. Given the novelty of those projects, high capabilities also matter during the collaboration, because they allow firms to understand and assimilate the technological knowledge that the rival firm possess (Freel and Harisson 2006). Therefore:

Hypothesis 3a: The effect that foreign competitors have on a firm's innovative performance will be further enhanced if a firm is characterised by a high level of skills and internal R&D intensity.

Hypothesis 3b: The effect that foreign customers and suppliers have on a firm's innovative performance will be further enhanced if a firm has recently adopted new organizational practices for managing external relations or for the transfer of knowledge between departments.

4. Data and Methodology

Data and sample

The analysis is based on data derived from the Spanish Technological Innovation Panel (PITEC), an annual survey based on the Community Innovation Survey (CIS) framework. The survey is carried out by the Spanish National Statistics Institute (INE) in collaboration with the Spanish Science and Technology Foundation (FECYT) and the Foundation for Technological Innovation (COTEC). The PITEC data are organized as a panel dataset and contain information from successive waves of the Spanish innovation survey providing us a panel dataset of 9 years (from 2003 to 2011).

Measures

Dependent variables

For the dependent variables in the first stage of the analysis that concerns the type of foreign collaborations that firms establish, we followed previous studies (van Beers and Zand, 2014; Hsieh et al., 2018; Un et al., 2010) and used three different dummies, depending on whether a firm had formed collaborative agreements with foreign customers, foreign suppliers or foreign competitors.

For the second stage, we measure innovative performance as the number of patent applications that firms have made in the three year period between 2009 and 2011 (Hegedoorn and Cloodt, 2003; Artz et al, 2010; Acs and Audretsch, 1989). This variable captures the belief a firm has that it has innovated at a level beyond to what is currently available in the market (Salomon and Shaver, 2005). It has been used by several studies, either as a single measure (Garcia et al 2013; Salomon and Jin, 2010; Wirsich et al, 2016) or alongside product innovation in two separate equations (Salomon and Shaver, 2005; Hsieh et al., 2018). In those studies and others, a strong statistical overlap (and therefore a strong linkage) has been found between patents and product innovation.

Independent variables

The variables capturing experience in collaborations with customers, suppliers and competitors (domestic and foreign), measure the number of continuous years of experience that a firm had with a certain type of partner up to a maximum period of five years. All variables were lagged in order to improve causality. We took into account continuous years of experience because learning is a process that takes time to be developed and when firms stop certain activities, learning can be disrupted and firms can even unlearn knowledge and deconstruct existing routines (Hilmersson et al., 2017; Casillas et al., 2012). However, in

order to ensure robustness of findings, we also tried alternative specifications including using a shorter time frame (2 but also 3 years of continuous but also not continuous experience) and results overall remained unchanged[‡].

In regards to the different dimensions of AC, the level of skills that exist within a firm was measured with the percentage of employees with degrees within a firm (Ramadani et al., 2018), R&D intensity with the expenditure in internal R&D over the level of sales (Ramadani et al., 2018; Zouaghi et al., 2018) and finally we measure a firm's organizational practices by using two different dummy variables, the first on whether firms introduced new methods for managing external relations with external partners and the second on whether firms implemented new business practices in work organisation and company procedures regarding the transfer of knowledge between departments (Tavassoli and Karlsson 2015).

Control variables

In both stages we control for the age of the firm measured as the number of years since incorporation as well as for firm size measured in number of employees (while including its square term to account for non-linear effects) (Roper et al., 2008). We include those variables because older firms are more likely to have established long-term persistent partnerships and larger ones, because of their greater resource pool are more likely to generate needed knowledge internally and might not need to form external partnerships. Moreover, older but also larger firms are expected to have more rigid organizational practices that can constrain innovation. (Roper and Arvanitis, 2012). We also take into account whether a firm is foreign owned or not (value of 1 if it is a foreign firm and 0 if it is a local firm) (Hsieh et al., 2018) and whether it exports to a foreign market (value of 1 if the firm exports and 0 if the firm does

[‡] In all occasions all hypotheses were supported (1a to 3a) apart from hypothesis 3b where the coefficient of the interaction variable between suppliers and the adoption of new organizational practices was insignificant.

not export) (Ramadani et al., 2018). Foreign ownership and exporting activity can allow a firm to gain a better understanding of foreign cultures and related business practices, become familiar with potential foreign partners and to be exposed to foreign technological knowledge which can enhance its innovative performance (Love and Ganotakis, 2013; Golovko and Valentini, 2014). We also control for the training that employees have received in innovative activities by taking into account the amount of expenditure on training per employee. Training can allow employees to better understand firm level processes and practices, promotes openness to new ideas and the creation of new knowledge (Bauernschuster et. al., 2009).

In the second stage we also consider whether (yes =1, no = 0) firms have introduced a new process that can assist in the development of innovative products (Tavassoli and Karlsson, 2015). In order to improve causality, all the control variables are lagged by one year. Finally, industry fixed effects are included for a total of 56 sectors. Variables and their descriptions are summarized in Table 1. Descriptive statistics and correlations for both stages of the analysis can be found in the appendix.

*** Insert table 1 about here ***

Methods

In the first stage, given that our dependent variables are binary in nature and capture whether a firm has formed an R&D collaborative agreement or not with a certain partner type, we estimate our first stage based on a random-effects probit models in a panel data framework. In the second stage, given that our dependent variable is a non-negative integer count variable, we estimate our specification based on a random effects negative binomial regression model in a panel data framework (for a similar application of those models please see Un et al., 2010; Un and Azakawa, 2014). As in Un et al (2010) and Un and Azakawa

(2014) we use random effects models because fixed-effects estimates are less efficient for panels over short periods (Wooldridge, 2009) like ours, particularly when the variation over time of the relevant variables is small[§]. For all those models we have made the estimations by using 3 years of panel data. This is because we have data for 9 years, the experience-related variables cover experience in collaborations up to 5 years, and we lagged the variables. We also conducted robustness tests based on an experience variable that cover experience in collaborations up to 2 or 3 years. In these estimations, our panel dataset spans 6 years and 5 years, respectively. Results overall remained consistent across all tables and models. No issues related to multicollinearity were found.

5. Results

The results for the first stage are presented in Table 2. First, in terms of prior experience in collaborations and in models 2.1 and 2.2 there is a clear linkage between experience with a certain type of domestic partner and the formation of a foreign R&D collaboration agreement with a similar partner type. In more detail, experience in collaborating with domestic suppliers increases the probability of forming collaborations with foreign suppliers by 18.3%, whereas experience with domestic customers increases the probability of forming collaborations with foreign customers by 21.1%. On the other hand, the relationship between having experience with domestic competitors and collaborating with foreign competitors is marginally insignificant. Apart from the linkage between the same types of domestic and foreign partner types, the formation of R&D collaboration with foreign suppliers is also affected by having experience with domestic customers and the formation of R&D collaboration with foreign customers from having experience with domestic suppliers.

[§] Indeed, variation over time (i.e., within variation) for all variables that capture experience in different types of collaborations is very small (between 8.2% and 10.8% of total variation).

Moreover, Wald tests across models 2.1 and 2.2 show that having experience in collaboration with domestic suppliers and customers increases significantly more the chances of forming foreign collaborations with foreign suppliers and customers (respectively), in comparison to having prior experience with any other domestic partner type. Hypotheses 1a and 1b are therefore supported for the formation of collaborations with foreign suppliers and foreign customers but not for the case of foreign competitors.

Results also reveal that past experience in collaborating with foreign partners is useful in forming new collaborations with different types of foreign partners. The formation of new collaborations with foreign suppliers is significantly enhanced by having experience in prior collaborations with foreign suppliers or customers. Moreover, experience in prior collaborations with foreign customers, suppliers and competitors is useful when forming new collaborations with both foreign customers and competitors.

Moreover, Wald tests suggest that prior experience with different types of partners abroad, has a significantly higher effect on the formation of new collaborations with foreign suppliers, customers and competitors in comparison to prior experience with the same types of domestic partners[**]. This was the case for all three models (2.1 – 2.3); apart for the case of domestic and foreign suppliers in the foreign competitors model (2.3), results that strongly support hypothesis 1c. Finally, Wald tests across models 2.1 – 2.3 also showed that having experience in collaborating with a certain type of foreign partner increases significantly more the chances of forming new collaborations with the same type of foreign partner, in relation to having experience with different types of foreign partners. For example, having experience in collaborating with foreign customers has a higher effect on the probability of forming new

[**] For instance, experience in collaboration with foreign customers, suppliers and competitors has a higher impact on the formation of collaborations with foreign customers in relation to experience with domestic customers, suppliers and competitors respectively.

collaborations with customers abroad in relation to having prior collaborations with foreign suppliers or competitors. Hypothesis 1d is therefore strongly supported.

*** Insert table 2 about here ***

Regarding the second stage and in model 3.1 of table 3 (but also across all models in tables 3 and 4), experience in collaborating with domestic and foreign suppliers appears to enhance a firm's innovative performance at a greater extent in relation to domestic or foreign customers, in line with hypothesis 2a. No other domestic partner type, apart from suppliers was found to have a significant effect on a firms' innovative performance.

However, in contrary to our expectations stated in hypothesis 2b, foreign competitors appear to be more important for a firm's innovative activity in relation to foreign customers. Indeed, foreign customers is the only foreign partner type that does not have a significant effect on a firm's innovative effort. Results therefore do not support hypothesis 2b. Wald tests on the coefficients of the foreign partner types showed that there were significant differences between the effect that each partner type had on a firm's innovative performance. Finally, across all partner types, experience with foreign partners (i.e., foreign supplier) had a higher effect in relation to collaboration with the corresponding domestic partner type (domestic supplier), providing support for hypothesis 2c.

*** Insert tables 3 and 4 about here ***

Regarding hypothesis 3a, the interaction term between employee skills and different types of foreign partners is significant only for the case of competitors (model 3.4 of table 3). This indicates that high levels of human capital is more important for gaining a greater value from collaborations with competitors in relation to other partner types. However, the interaction terms between R&D intensity and foreign collaboration is insignificant across all three partner types (models 3.5-3.7 of table 3). In regards to hypothesis 3b and the moderating

effect that new organizational practices for (1) managing external collaboration as well as (2) for disseminating knowledge internally (between departments) have on a firm's innovative performance; models 4.1 and 4.4 in table 4 show that the interaction terms are significant for the case of foreign suppliers. This indicates that those practices are more important and need to be in place when firms collaborate specifically with foreign suppliers. Overall therefore, results partially support hypothesis 3b.

In order to ensure the robustness of our findings, we re-examined the relationship between similar types of domestic and foreign partner types (hypothesis 1b) by estimating the effect of domestic collaboration experience for the sample of firms with no foreign collaboration experience, i.e., firms that get engaged in a foreign collaboration for the first time. Results remained consistent with those reported in table 2. Hypothesis 1b is supported for the relationship between domestic and foreign suppliers as well as between domestic and foreign customers but the relationship between domestic and foreign competitors is marginally insignificant.

6. Discussion and conclusions

First, our study contributes to the literature on the formation of technological collaborations (Hsieh et al., 2018; Roper and Arvanitis, 2012; Van Bers et al., 2014; Un et al., 2010) by explaining how experience in domestic or foreign collaborations assists in the formation of new collaborations abroad. Drawing from organizational learning theory, our framework shows that experience in collaborating with a certain type of domestic or foreign partner (e.g., domestic or foreign customer) is more useful for the formation of new collaborations with the same partner type abroad (e.g., foreign customer) than experience in collaborations with other domestic or foreign partner types respectively. The strong

relationship between similar types of partners occurs because of the organizational practices and routines that firms implement as they accumulate experience in collaborating with a certain type of partner. Because experience in certain collaborations results in habitual forces and cognitive rigidities, firms over-rely on prior management practices and organizational routines to collaborate with a particular partner type (Huber, 1991; Dodgson, 1993), which can lead to repetition of past actions and to collaborations with similar types of partners. This effect is reinforced because such organizational practices are partner-specific and difficult to be transferred to other partner types.

The aforementioned relationship between similar partner types, was found to exist for all domestic and foreign types of partners but not for the case of domestic competitors. This suggests that experience in collaborating with domestic competitors might not be as useful in forming collaborations with foreign competitors. This might occur because the formation of collaborations with competitors is often based on the development of trust between the two parties (Hsieh et al., 2018). However, trust in collaborations is perceived and is developed differently between cultures (Ferrin and Gillespie, 2010). Hence, firms will have difficulties adopting the same process abroad, as they do domestically, in order to form a trusting relationship with a potential competitor. Moreover, because of country variations in IPR laws and their enforcement (Kafouros et al., 2012), the mechanisms that firms use to protect their IP when they engage in collaborations with domestic competitors might not work when they collaborate with foreign ones. This can force firms to change existing organizational practices to reduce knowledge leakage abroad.

Our study also contributes to the literature on the formation of collaborations by showing that when firms have experience in foreign partnerships, they form new collaborations abroad more easily in relation to having experience in domestic partnerships (Eriksson et al., 1997; Sampson, 2005; van Beers and Zand, 2014). The key explanation for this finding is that

foreign partnerships allow firms to obtain experience in managing collaborations in a certain foreign country as well as general experience regarding the management of *foreign* collaborations (Eriksson et al., 1997; Sampson, 2005; van Beers and Zand, 2014).

Second, we advance understanding of the relationship between R&D collaborations and innovative performance (van Beers and Zand, 2014; Hsieh et al., 2018; Tsai, 2009) by identifying which type of experience is more advantageous for the firm. In this respect, our framework shows that experience in foreign collaborations is more beneficial than experience in domestic partnerships. Our analysis also contributes to this literature by identifying which type of partners are more effective in enhancing innovative performance. More specifically, collaboration with suppliers is more important for a firm's innovative performance in relation to other partnerships. Collaboration with foreign suppliers has the strongest effect on a firm's innovative performance. From the domestic partners, only suppliers appear to matter, largely because of the greater diversity in the knowledge they can provide (Ganotakis and Love, 2012; Fine and Whitney, 1996). Contrary to our expectations, foreign competitors are more important than customers in enhancing a firm's innovative performance. Customers (foreign or domestic) do not appear to matter in enhancing a firm's innovative performance. This result can be justified by the different motivations behind such collaborations.

More specifically, not all customers that firms collaborate with do so in order to develop a novel product. This depends on whether firms collaborate with lead users rather than with mainstream customers (Hsieh et al., 2018). Lead users can fulfill needs that are not met from the available technological solutions and therefore form collaborations to explore new combinations of more diverse knowledge components (Nijssen et al 2012). On the other hand, mainstream customers focus on forming collaborations to improve their existing product range (and therefore to carry out incremental innovation). This involves the use of a lower range of knowledge (Hsieh et al., 2018).

Finally, we contribute to the AC literature (Schmidt, 2010) by showing that different dimensions of AC matter for benefiting from foreign collaborations. The explanation we put forward is that different partners possess different types of knowledge, collaborate for different reasons and vary in how proximate their organizational structure is in relation to the focal firm (Un and Asakawa, 2015; Un et al. 2010). This finding improves our understanding of what types of internal capabilities help firms to draw value from different partner types. Organizational practices designed to manage the collaborative process and disseminate knowledge internally are more important when firms collaborate specifically with foreign suppliers. On the other hand, higher levels of human capital (skills) human capital matters more for capturing value from collaborations with competitors.

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Table 1 Variable description

Variable	**Description/Measurement**
Dependent variables	
Foreign R&D collaboration with suppliers	Technology alliance with a foreign supplier.
Foreign R&D collaboration with customers	Technology alliance with a foreign customer.
Foreign R&D collaboration with competitors	Technology alliance with a foreign competitor.
Patents	Number of patent applications in the past three years
Independent variables	
Alliance experience with foreign suppliers	Prior experience (years) in having a technology alliance with foreign suppliers.
Alliance experience with foreign customers	Prior experience (years) in having a technology alliance with foreign customers.
Alliance experience with foreign competitors	Prior experience (years) in having a technology alliance with foreign competitors.
Alliance experience with domestic suppliers	Prior experience (years) in having a technology alliance with domestic suppliers.
Alliance experience with domestic customers	Prior experience (years) in having a technology alliance with domestic customers.
Alliance experience with domestic competitors	Prior experience (years) in having a technology alliance with domestic competitors.
New internal practices	Dummy variable that takes the value of one if the firm introduces new business practices in work organisation and company procedures' regarding the transfer of knowledge between departments (i.e., knowledge management system) during last three years, and zero otherwise.
New methods (external relationships)	Dummy variable that takes the value of one if the firm introduces 'new methods for managing external relations with other companies or public institutions' during last three years, and zero otherwise.
Skills	Percentage of employee with degrees
Firm age	Years since incorporation
Firm size	Number of employees
Firm size squared	Number of employees squared
Foreign ownership	A dummy variable that takes the value of 1 if the firm is a foreign owned firm and zero if locally owned firm.
Foreign markets	A dummy variable that takes the value of 1 if the firm exports and zero otherwise.
R&D intensity	Internal expenditure on R&D divided by sales

Training	Amount of expenditure on training per employee
Process innovation	Dummy variable that takes the value of one if the firm introduces any process innovations during last three years, and zero otherwise.
Concentration Ratio	Industry level concentration ratio, measured as the ratio of the total sales of the largest three firms in the industry over total sales with that industry

Table 2: Likelihood of foreign R&D collaboration (Probit models)

	Model 2.1 Foreign R&D Collaboration with Suppliers	Model 2.2 Foreign R&D Collaboration with Customers	Model 2.3 Foreign R&D Collaboration with Competitors
H1a&b: Alliance experience with domestic suppliers	0.183***	0.0942**	0.0675
	(0.0314)	(0.0374)	(0.0417)
H1a&b: Alliance experience with domestic customers	0.101***	0.211***	0.0491
	(0.0360)	(0.0401)	(0.0458)
H1a&b: Alliance experience with domestic competitors	0.0145	-0.0184	0.0804
	(0.0475)	(0.0571)	(0.0535)
H1c&d: Alliance experience with foreign suppliers	0.572***	0.194***	0.103**
	(0.0386)	(0.0446)	(0.0476)
H1c&d: Alliance experience with foreign customers	0.197***	0.480***	0.298***
	(0.0459)	(0.0476)	(0.0571)
H1c&d: Alliance experience with foreign competitors	0.0574	0.168***	0.560***
	(0.0544)	(0.0615)	(0.0550)
Skills	0.00246	0.00761***	0.00980***
	(0.00206)	(0.00244)	(0.00269)
Training	2.75e-05	-8.74e-05	0.000160
	(0.000140)	(0.000121)	(0.000131)
New internal practices	0.230**	0.135	0.250*
	(0.0995)	(0.118)	(0.135)
New methods (external relationships)	0.348***	0.242**	0.311**
	(0.102)	(0.122)	(0.133)
R&D intensity	-0.000109	-5.24e-06	-5.45e-06
	(0.000739)	(2.17e-05)	(2.12e-05)
Firm age	0.00430*	0.000887	0.00135
	(0.00220)	(0.00283)	(0.00312)
Firm size	0.000108**	7.48e-05	0.000344***
	(4.63e-05)	(8.17e-05)	(7.89e-05)
Firm size squared	-3.23e-09*	-3.90e-09	-1.52e-08***
	(1.78e-09)	(4.63e-09)	(4.74e-09)
Foreign owned	-0.0913	-0.153	-0.210
	(0.112)	(0.132)	(0.155)
Foreign markets	-0.0476	1.150***	0.782***
	(0.136)	(0.224)	(0.202)
Observations	6,356	6,356	6,356
Number of firms	2,834	2,834	2,834
Wald-chi2	486.2***	374.3***	269.6***
Log pseudolikelihood	-1344	-1089	-803.7

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Notes: Coefficients are marginal effects. For brevity, industry-specific fixed effects are not reported.

Table 3: Innovative performance estimation (Interactions with Skills) – dependent variable for innovation performance is number of patent applications.

	Model 3.1	Model 3.2	Model 3.3	Model 3.4	Model 3.5	Model 3.6	Model 3.7
H2a-c: Experience with foreign suppliers	0.166***	0.148***	0.168***	0.177***	0.170***	0.166***	0.167***
	(0.0303)	(0.0378)	(0.0302)	(0.0295)	(0.0298)	(0.0298)	(0.0296)
H2a-c: Experience with foreign customers	0.0372	0.0368	0.00237	0.0245	0.0366	0.0384	0.0363
	(0.0342)	(0.0342)	(0.0475)	(0.0337)	(0.0334)	(0.0359)	(0.0342)
H2a-c: Experience with foreign competitors	0.113***	0.114***	0.110***	-0.00729	0.112***	0.113***	0.110***
	(0.0368)	(0.0365)	(0.0371)	(0.0533)	(0.0359)	(0.0365)	(0.0372)
H2a-c: Experience with domestic suppliers	0.0481*	0.0474*	0.0485**	0.0467**	0.0487**	0.0478**	0.0487**
	(0.0246)	(0.0242)	(0.0246)	(0.0231)	(0.0227)	(0.0239)	(0.0243)
H2a-c: Experience with domestic customers	-0.0349	-0.0371	-0.0368	-0.0450	-0.0343	-0.0347	-0.0357
	(0.0290)	(0.0288)	(0.0290)	(0.0285)	(0.0282)	(0.0286)	(0.0288)
H2a-c: Experience with domestic competitors	-0.0179	-0.0185	-0.0194	-0.0274	-0.0173	-0.0181	-0.0171
	(0.0357)	(0.0354)	(0.0362)	(0.0348)	(0.0349)	(0.0353)	(0.0355)
Skills	0.00723***	0.00548***	0.00362***	0.00581***	0.00739***	0.00586***	0.00429***
	(0.00134)	(0.00140)	(0.00139)	(0.00136)	(0.00132)	(0.00134)	(0.00135)
H3a: Skills * Experience with foreign suppliers		7.18e-05					
		(0.000751)					
H3a: Skills * Experience with foreign customers			0.000535				
			(0.000974)				
H3a: Skills * Experience with foreign competitors				0.00337***			
				(0.000970)			
R&D intensity	7.45e-02	5.19e-03*	6.62e-03**	5.74e-03**	7.50e-02	5.16e-03*	4.70e-03*
	(0)	(2.66e-03)	(3.09e-03)	(2.80e-03)	(0)	(2.65e-03)	(2.61e-03)
H3a: R&D intensity* Experience with foreign suppliers					-0.282		
					(0.598)		
H3a: R&D intensity* Experience with foreign customers						-0.435	
						(0.385)	
H3a: R&D intensity* Experience with foreign competitors							-0.211
							(0.428)
New internal practices	0.296***	0.298***	0.297***	0.291***	0.296***	0.296***	0.295***
	(0.0629)	(0.0626)	(0.0635)	(0.0623)	(0.0615)	(0.0626)	(0.0630)
New methods (external relationships)	0.139**	0.143**	0.140**	0.152**	0.138**	0.139**	0.140**
	(0.0657)	(0.0656)	(0.0666)	(0.0644)	(0.0637)	(0.0653)	(0.0660)
Training	-0.000105	-0.000178**	-0.000157**	-2.25e-05	6.11e-05	-2.87e-05	-0.000160**
	(6.67e-05)	(7.67e-05)	(7.92e-05)	(5.47e-05)	(5.95e-05)	(6.27e-05)	(7.75e-05)
Firm age	0.00748***	0.00615***	0.00424**	0.00735***	0.00755***	0.00608***	0.00452***
	(0.00180)	(0.00176)	(0.00175)	(0.00178)	(0.00178)	(0.00176)	(0.00175)
Firm size	-0.000460***	-0.000152***	-0.000187***	-0.000148***	-1.18e-05	-0.000182***	-9.47e-05**
	(6.18e-05)	(4.33e-05)	(4.51e-05)	(4.27e-05)	(3.86e-05)	(4.46e-05)	(4.15e-05)
Firm size squared	1.80e-08***	4.86e-09***	6.07e-09***	4.67e-09***	1.38e-10	5.21e-09***	3.12e-09**
	(2.89e-09)	(1.53e-09)	(1.60e-09)	(1.53e-09)	(1.43e-09)	(1.53e-09)	(1.47e-09)
Foreign owned	-0.604***	-0.604***	-0.606***	-0.614***	-0.605***	-0.604***	-0.604***
	(0.0788)	(0.0784)	(0.0787)	(0.0780)	(0.0782)	(0.0784)	(0.0784)
Foreign markets	0.562***	0.563***	0.565***	0.586***	0.560***	0.562***	0.564***
	(0.0895)	(0.0890)	(0.0902)	(0.0885)	(0.0876)	(0.0891)	(0.0895)
Process innovation	0.0617	0.0582	0.0573	0.0472	0.0618	0.0624	0.0612
	(0.0787)	(0.0788)	(0.0794)	(0.0778)	(0.0777)	(0.0785)	(0.0792)
Concentration ratio	-0.0402***	-0.0406***	-0.0413***	-0.0386***	-0.0406***	-0.0409***	-0.0414***
	(0.0143)	(0.0142)	(0.0146)	(0.0138)	(0.0135)	(0.0142)	(0.0144)
Observations	7,849	7,849	7,849	7,849	7,849	7,849	7,849
Number of firms	3,176	3,176	3,176	3,176	3,176	3,176	3,176
Wald-Chi2	734.11***	719.6***	736.2***	784.7***	715.66***	736.1***	708.8***
Log likelihood	-6261	-6256	-6027	-6130	-6416	-6280	-6192

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Notes: For brevity, industry-specific fixed effects are not reported. Results are the second stage of negative binomial model

Table 4: Innovative performance estimation (Interactions with Organisational practices) – dependent variable for innovation performance is number of patent applications.

	Model 4.1	Model 4.2	Model 4.3	Model 4.4	Model 4.5	Model 4.6
H2a-c: Experience with foreign suppliers	0.103**	0.166***	0.169***	0.130***	0.166***	0.168***
	(0.0491)	(0.0296)	(0.0296)	(0.0338)	(0.0297)	(0.0298)
H2a-c: Experience with foreign customers	0.0360	0.0764*	0.0375	0.0361	0.0219	0.0399
	(0.0341)	(0.0459)	(0.0336)	(0.0340)	(0.0401)	(0.0339)
H2a-c: Experience with foreign competitors	0.116***	0.113***	0.0345	0.117***	0.115***	0.0935**
	(0.0364)	(0.0365)	(0.0700)	(0.0361)	(0.0362)	(0.0413)
H2a-c: Experience with domestic suppliers	0.0487**	0.0476**	0.0473**	0.0513**	0.0488**	0.0480*
	(0.0244)	(0.0243)	(0.0240)	(0.0230)	(0.0240)	(0.0247)
H2a-c: Experience with domestic customers	-0.0346	-0.0336	-0.0351	-0.0366	-0.0354	-0.0359
	(0.0289)	(0.0286)	(0.0286)	(0.0286)	(0.0287)	(0.0289)
H2a-c: Experience with domestic competitors	-0.0225	-0.0163	-0.0221	-0.0224	-0.0205	-0.0201
	(0.0356)	(0.0354)	(0.0352)	(0.0350)	(0.0352)	(0.0356)
New internal practices	0.255***	0.315***	0.274***	0.301***	0.297***	0.298***
	(0.0656)	(0.0646)	(0.0634)	(0.0619)	(0.0623)	(0.0624)
H3b: New internal practices * Experience with foreign suppliers	0.0808*					
	(0.0490)					
H3b: New internal practices * Experience with foreign customers		-0.0529				
		(0.0499)				
H3b: New internal practices * Experience with foreign competitors			0.0938			
			(0.0728)			
New methods (external relationships)	0.136**	0.143**	0.138**	0.0772	0.122*	0.123*
	(0.0660)	(0.0653)	(0.0646)	(0.0711)	(0.0681)	(0.0688)
H3b: New methods (external relationships) * Experience with foreign suppliers				0.0696**		
				(0.0345)		
H3b: New methods (external relationships) * Experience with foreign customers					0.0310	
					(0.0546)	
H3b: New methods (external relationships) * Experience with foreign competitors						0.0326
						(0.0480)
Skills	0.0054***	0.0059***	0.0071***	0.0073***	0.0072***	0.0067***
	(0.00134)	(0.00134)	(0.00133)	(0.00132)	(0.00133)	(0.00134)
R&D intensity	5.25e-03*	3.82e-03	4.89e-03*	7.36e-03**	9.45e-03*	5.15e-03*
	(2.68e-03)	(2.53e-03)	(2.58e-03)	(3.52e-03)	(5.16e-03)	(2.64e-03)
Training	-0.0002**	-0.0002**	-0.0002***	1.27e-05	-9.18e-05	-0.0005***
	(7.81e-05)	(7.62e-05)	(7.52e-05)	(5.57e-05)	(6.42e-05)	(0.000139)
Firm age	0.0055***	0.0061***	0.0073***	0.0077***	0.0075***	0.0070***
	(0.00176)	(0.00176)	(0.00178)	(0.00178)	(0.00178)	(0.00177)
Firm size	-0.0002***	-0.0002***	-0.0002***	-0.00010**	-0.0003***	-0.0002***
	(4.65e-05)	(4.53e-05)	(4.52e-05)	(4.10e-05)	(4.77e-05)	(4.56e-05)
Firm size squared	7.3e-09***	6.5e-09***	6.5e-09***	3.1e-09**	8.3e-09***	6.6e-09***
	(1.68e-09)	(1.62e-09)	(1.62e-09)	(1.46e-09)	(1.73e-09)	(1.61e-09)
Foreign owned	-0.601***	-0.606***	-0.601***	-0.599***	-0.601***	-0.601***
	(0.0785)	(0.0785)	(0.0782)	(0.0782)	(0.0784)	(0.0784)
Foreign markets	0.567***	0.559***	0.566***	0.570***	0.564***	0.562***
	(0.0898)	(0.0892)	(0.0887)	(0.0882)	(0.0888)	(0.0891)
Process innovation	0.0693	0.0592	0.0640	0.0726	0.0621	0.0624
	(0.0791)	(0.0788)	(0.0784)	(0.0779)	(0.0782)	(0.0788)
Concentration ratio	-0.0424***	-0.0406***	-0.0407***	-0.0400***	-0.0403***	-0.0405***
	(0.0144)	(0.0142)	(0.0140)	(0.0137)	(0.0140)	(0.0141)
Observations	7,849	7,849	7,849	7,849	7,849	7,849
Number of firms	3,176	3,176	3,176	3,176	3,176	3,176
Wald-Chi2	732.6***	743.6***	764.1***	792.7***	779.8***	749.4***
Log likelihood	-6185	-6228	-6202	-6258	-5972	-6252

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Notes: For brevity, industry-specific fixed effects are not reported. Results are the second stage of negative binomial model

Appendix: Descriptive statistics and correlation matrix

Stage 1: Likelihood of foreign R&D collaboration

	Variable	Mean	S.D.	Min	Max	Correlation coefficients																	
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Foreign R&D collaboration with suppliers	0.05	0.22	0	1																		
2	Foreign R&D collaboration with customers	0.04	0.19	0	1	0.38																	
3	Foreign R&D collaboration with competitors	0.03	0.17	0	1	0.28	0.33																
4	Alliance experience with foreign suppliers	0.18	0.79	0	5	0.64	0.29	0.24															
5	Alliance experience with foreign customers	0.14	0.7	0	5	0.29	0.63	0.31	0.37														
6	Alliance experience with foreign competitors	0.1	0.6	0	5	0.23	0.29	0.63	0.3	0.38													
7	Alliance experience with domestic suppliers	0.41	1.16	0	5	0.31	0.24	0.2	0.38	0.27	0.23												
8	Alliance experience with domestic customers	0.36	1.11	0	5	0.27	0.34	0.27	0.32	0.4	0.3	0.39											
9	Alliance experience with domestic competitors	0.2	0.81	0	5	0.17	0.18	0.3	0.18	0.24	0.37	0.27	0.37										
10	New internal practices	0.34	0.48	0	1	0.12	0.11	0.1	0.12	0.11	0.1	0.17	0.14	0.11									
11	New methods (with external relationships)	0.16	0.36	0	1	0.14	0.13	0.13	0.14	0.12	0.14	0.18	0.19	0.14	0.47								
12	Skills	25.32	28.33	0	100	0.03	0.07	0.11	0.03	0.05	0.1	0.02	0.14	0.15	0.09	0.13							
13	Firm age	23.9	20.18	0	547	0.05	0.02	0.01	0.05	0.02	0.01	0.1	-0.02	0.02	0.07	0.04	-0.17						
14	Firm size	326.18	1444.11	0	41509	0.08	0.01	0.05	0.11	0.02	0.08	0.14	0.02	0.07	0.06	0.06	-0.07	0.13					
15	Firm size squared	2.19E+06	3.87E+07	0	1.72E+09	0.04	-0.01	0.02	0.05	0	0.02	0.07	0.01	0.03	0.03	0.03	-0.03	0.06	0.87				
16	Foreign owned	0.31	0.46	0	1	0.03	0.03	-0.03	0.04	0.03	-0.02	-0.03	-0.01	-0.07	0.02	-0.01	-0.06	0.06	0.02	0			
17	Foreign markets	0.57	0.49	0	1	0.08	0.12	0.06	0.07	0.11	0.05	0.04	0.04	-0.01	0.14	0.07	-0.02	0.13	-0.04	-0.02	0.18		
18	R&D intensity	1.55	285.86	0	78216	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0	-0.01	-0.01	
19	Training	40.24	434.97	0	52246.02	0.03	0.03	0.04	0.05	0.06	0.06	0.05	0.09	0.06	0.04	0.04	0.08	-0.03	-0.01	0	-0.02	0	0

Stage 2: Innovative performance estimation

Variable	Mean	S.D.	Min	Max	Correlation coefficients																
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 Number of patent applications	0.49	5.47	0	851																		
2 Alliance experience with foreign suppliers	0.18	0.79	0	5	0.14																	
3 Alliance experience with foreign customers	0.14	0.7	0	5	0.06	0.37																
4 Alliance experience with foreign competitors	0.1	0.6	0	5	0.1	0.3	0.38															
5 Alliance experience with domestic suppliers	0.41	1.16	0	5	0.1	0.38	0.27	0.23														
6 Alliance experience with domestic customers	0.36	1.11	0	5	0.06	0.32	0.4	0.3	0.39													
7 Alliance experience with domestic competitors	0.2	0.81	0	5	0.04	0.18	0.24	0.37	0.27	0.37												
8 New internal practices	0.34	0.48	0	1	0.07	0.12	0.11	0.1	0.17	0.14	0.11											
9 New methods (with external relationships)	0.16	0.36	0	1	0.08	0.14	0.12	0.14	0.18	0.19	0.14	0.47										
10 Skills	25.32	28.33	0	100	0.03	0.03	0.05	0.1	0.02	0.14	0.15	0.09	0.13									
11 Firm age	23.9	20.18	0	547	0.02	0.05	0.02	0.01	0.1	-0.02	0.02	0.07	0.04	-0.17								
12 Firm size	326.18	1444.11	0	41509	0.04	0.11	0.02	0.08	0.14	0.02	0.07	0.06	0.06	-0.07	0.13							
13 Firm size squared	2.19E+06	3.87E+07	0	1.72E+09	0.01	0.05	0	0.02	0.07	0.01	0.03	0.03	0.03	-0.03	0.06	0.87						
14 Foreign owned	0.31	0.46	0	1	0.01	0.04	0.03	-0.02	-0.03	-0.01	-0.07	0.02	-0.01	-0.06	0.06	0.02	0					
15 Foreign markets	0.57	0.49	0	1	0.05	0.07	0.11	0.05	0.04	0.04	-0.01	0.14	0.07	-0.02	0.13	-0.04	-0.02	0.18				
16 R&D intensity	1.55	285.86	0	78216	0	0	0	0	0	0	0	0	0	0.02	0	0	0	-0.01	-0.01			
17 Training	40.24	434.97	0	52246.02	0.02	0.05	0.06	0.06	0.05	0.09	0.06	0.04	0.04	0.08	-0.03	-0.01	0	-0.02	0	0		
18 Process innovation	0.52	0.5	0	1	0.04	0.07	0.06	0.04	0.11	0.05	0.03	0.36	0.23	0.04	0.08	0.02	0.01	-0.01	0.19	0	0.04	
19 Concentration Ratio	14.2	8.56	6.36	70.08	-0.02	0	-0.05	0.02	0.05	-0.03	0.06	-0.05	-0.01	0.01	-0.03	0.08	0.03	-0.11	-0.26	0	-0.01	-0.08