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Production outsourcing, technological cooperation and E-business adoption by Spanish manufacturing firms☆

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ABSTRACT

This paper studies the adoption of e-business by manufacturing firms. We augment the Technology–Organization–Environment (TOE) framework to consider two organizational features, namely, production outsourcing and technological cooperation. We test the model on a longitudinal sample of Spanish firms covering the period 2002–2014. The results reveal that firms that outsource production are more likely to adopt Supplier-to-Business (S2B) and Business-to-Business (B2B). Technological cooperation with customers and suppliers also has a positive impact on S2B and B2B adoption.

1. Introduction

The ongoing digitalization of firms has implied a change in how they develop their activities, including how they communicate with other firms and the way in which they buy and sell goods and services. Understanding the reasons why firms adopt new technologies is critical for managers and policy makers. In a general context of productivity slowdown (Pilat and Criscuolo, 2018), the differences between firms at the productivity frontier and those lagging have increased (Andrews et al., 2016). One reason for this increasing divergence is that some firms have been first movers in the adoption of new technologies, whereas other firms have not kept pace.

This paper focuses on the adoption of e-business by manufacturing firms. E-business adoption has been related to differences in firm productivity (Falk, 2005; Quirós Romero and Rodríguez Rodríguez, 2010) and operational competence (Benítez et al., 2018). However, the evidence shows that, contrary to other technologies, its diffusion has been slow (Falk and Hagsten, 2015), creating differences in performance. Although this may seem surprising with e-business technologies, gradual and asymmetric technology diffusion are two frequent phenomena. This is not only true for older technologies, such as railways, the telegraph, or the telephone, but also for newer ones, like cell phones, personal computers, and the Internet (Comin and Hobijn, 2010). Gradual and asymmetric diffusion may happen even in those cases in which an innovation has important advantages over existing innovations (Greve, 2009). Understanding the

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drivers of e-business diffusion helps us to understand why firm heterogeneity occurs and it contributes to explain differences in performance through productivity and operational competence improvements (Falk, 2005; Quirós Romero and Rodríguez Rodríguez, 2010; Benítez et al., 2018). It also improves our understanding of the situations in which policy measures are needed.

We study the diffusion of e-business by focusing on firm boundaries. Extant research seems to assume a unique relationship between firm boundaries and investments in all technologies. This ignores the fact that the gap between information processing needs and capabilities may have different characteristics and may require different technologies in order to be closed. A particularly useful distinction is that which differentiates between those technologies that have an internal focus and those whose focus is external (see, for example, Clemons, 1986; Powell and Dent-Micallef, 1997;Dedrick and Kraemer, 2010). The first type includes those technologies utilized within a firm (in-firm technologies), whereas the second group consists of technologies employed in managing interorganizational relationships (beyond firm technologies). This paper focuses on one type of 'beyond firm technologies', e-business, and proposes that their use by firms is conditioned by firm boundaries. For our purposes, we define e-business technologies as those that allow 'conducting transactions along the value chain (including purchasing from upstream suppliers and selling products and services to downstream customers) by using the Internet platform in conjunction with existing IT infrastructure' (Zhu and Kraemer, 2005).

We propose that the vertical boundaries of the organization[4] are related to the use of e-business. The reason being that an increase in externalization implies that governing structures must be designed to manage external transactions and consequently, firms frequently invest in information technologies to cope with increased information processing needs. However, this increase in the interrelations between a firm and the market is not evident in the case of diversification or refocusing; and hence, it does not necessarily motivate the adoption of e-business. For similar reasons, we also propose that firms that are involved in technological cooperation are more likely to adopt e-business technologies.

To test our hypothesis, we chose a representative sample of manufacturing firms operating in Spain and followed through on the Survey of Business Strategies. The data collected provide us with information on the vertical boundaries and the technological cooperation activities of firms over the period 2002–2014. The sample includes information on the adoption of certain types of technologies that are mainly used for interorganizational communication. Specifically, we study the adoption of Internet-based technologies, such as Supplier-to Business (S2B), Business-to Business (B2B) and Business to Consumer (B2C).

We contribute to the understanding of the adoption of new technologies by focusing on the boundaries of the firm. More precisely, we widen the Technology–Organisation–Environment (TOE) framework to include production outsourcing and technological cooperation as two determinants of technology adoption. In doing so, we emphasize the importance of the type of technology analyzed, focusing on a technology that can be used for managing interorganizational relationships. Our results show that those firms that outsource production/cooperate technologically are more likely to use e-business technologies.

The rest of the paper is structured as follows. Section 2 describes the relevance of e-business for firm competitiveness and presents the technology–organization–environment framework used in this paper. Section 3 explains the logic relating outsourcing and cooperation and e-business adoption. Section 4 describes the sample, the variables, and the methodology. Finally, Section 5 presents the results and Section 6 the conclusions.

2. Background on e-business technologies and conceptual model

2.1. The importance of e-business technologies for firm competitiveness

E-business refers to developing transactions, offering customer services, sharing information and coordination processes with business partners by using the Internet platform in conjunction with the existing IT infrastructure (Zhu et al., 2003; Zhu and Kraemer, 2005). The links provided by these technologies are changing the ways in which firms acquire inputs, transform them into products or services and make them available to customers. Amit and Zott (2001) identify four drivers of value creation in e-business: efficiency, complementarity, lock-in and novelty. First, Internet-based technologies allow customers to obtain improved, up to date and comprehensive information that reduce search and bargaining costs and information asymmetries between customers and suppliers, generating efficiency gains. They also decrease the likelihood of mistakes in orders and enable a faster order fulfillment and management. Second, firms can also increase the value offered by offering bundles of complementary goods. Complementarities may be obtained not only by offering services that enhance the value of a firm's product, but also by combining online and offline assets, different technologies, or activities. Third, firms are also able to create value through customers and suppliers' lock-in, generating switching costs or network externalities. In this sense, they favor the repetition of transactions, as well as customer retention through the development of a dominant design of proprietary standard or through the establishment of trustful relationships. Finally, another important driver of value creation is the development of innovations. For example, e-business might facilitate the creation of new transaction structures, such as reverse markets where customers indicate their needs.

Research on the use of e-business technologies by firms has mainly focused on the consequences for productivity. The effect of e-business technologies on productivity has been documented in papers focusing on different countries and time windows. Criscuolo and Waldron's (Criscuolo and Waldron, 2003) research shows a 6% increase in productivity in UK manufacturing firms that use the Internet in the buying process, but not for firms that use it in the selling process. Quirós Romero and Rodríguez Rodríguez (2010) studied the efficiency consequences of the Internet as a channel of purchases and sales in a sample of Spanish manufacturing firms.

[4] The vertical boundaries of the firm determine which tasks in the vertical chain are performed inside the firm (make in house) and which are outsourced (buy in the market).

Their findings reveal that firms that use the Internet for activities related to the buying process improve their productivity by around 2.9%. However, the effect is not significant in the case of selling activities. Similarly, the adoption of B2B e-commerce has been identified as a driver of economic success (Tan and Ludwig, 2016). For example, Bertschek et al. (2006) find a 2% increase of B2B e-commerce on labor productivity for a sample of German firms.

Despite this evidence, the diffusion of e-business lags behind other technologies. Falk and Hagsten (2015) show that the adoption of e-commerce in Europe is lower and advances at a slower pace than other information and communication technologies. The average data for firms operating in 14 European countries shows that, in 2010, approximately one in four firms had adopted e-selling, whereas firms using e-selling or e-buying were around 60% of the total number of firms.

The analysis of more recent data shows that the diffusion of e-selling and e-buying among firms is still low compared to other technologies. The average percentage of firms with ten or more employees using e-selling was 23.72% in OECD countries in 2018 (OECD). However, this figure hides important differences between the countries considered. Looking at the extremes, Turkey was the country with a lower percentage of firms receiving orders over computer networks in 2018, with 9.76% of companies using e-selling. On the contrary, New Zealand was the country with the highest adoption of e-selling, with 60.17% of firms receiving orders through this technology. In Spain, 20.07% of firms with ten or more employees used e-selling in 2018.

Although the figures are higher in the case of e-buying, they can still be considered low. The average percentage of firms with ten or more employees using e-buying was 47.68% in OECD countries in 2018 (OECD). Greece is the country with a lower diffusion of e-buying, with 13.72% of firms placing orders over computer networks. Sweden is, in this case, at the other extreme, with 78.44% of firms using e-buying. The figure for Spain was 30.75% in 2018.

2.2. Augmenting the TOE framework: vertical boundaries of the firm and cooperation as determinants of e-business adoption

Different models have been used to study IT adoption by firms, with the theory of diffusion of innovations (Rogers, 1995) and the technology, organization, and environment framework (Tornatzky and Fleischer, 1990) being the most relevant in the case of firm-level studies (Hsu et al., 2006; Oliveira and Martins, 2011);). The TOE framework (Tornatzky and Fleischer, 1990) has proved a useful theoretical framework to analyze technology adoption and we use it in this paper to study e-business adoption. The TOE framework is structured around three elements: (1) the Technological context (T), which describes the technologies that a firm currently uses and its technical skills; (2) the Organizational context (O), which refers to the organizational characteristics and resources of firms, such as their size and scope, the quality of their human resources and the amount of slack resources available internally; and (3) the Environmental context (E), which refers to the arena in which a firm conducts its businesses (Tornatzky and Fleischer, 1990).

The TOE framework has previously been used in various information system domains. For example, this framework has been used to analyze the effect of mimetic, coercive and normative pressures on the intention to adopt software as a service (Kung et al., 2015); the factors that influence the use of big data analytics (Chen et al., 2015); cloud computing adoption, by integrating the TOE framework and diffusion of innovation theory (Oliveira et al., 2014); or the factors determining Internet use in different stages of the procurement process (Mishra et al., 2007).

Although researchers have proved that the technological, organizational, and environmental contexts affect adoption, they do not concur around a unique set of factors to measure each of the three dimensions (Zhu et al., 2003). In other words, researchers have used different factors for the technological, organizational, and environmental contexts, depending on the study. They have concurred with Tornatzky and Fleischer (1990) that the three TOE contexts influence adoption, but they have assumed that for each specific technology or context being studied, there is not a unique set of factors or measures.

In the case of e-business adoption, a great variety of organizational variables has been considered. Among them, we find a firm's technological competency, a skilled workforce, decentralization and visionary business leadership (Giotopoulos et al., 2017); firm size (Ilin et al., 2017; Chatzoglou and Chatzoudes, 2016; Shih, 2012; Ghobakhloo et al., 2011; Zhu and Kraemer, 2005; Zhu et al., 2003); CEO's support and characteristics (Ilin et al., 2017; Chatzoglou and Chatzoudes, 2016; Ghobakhloo et al., 2011); the attitude, subjective norm and perceived behavioral control of managers/owners (Nasco et al., 2008; Grandón et al., 2011); expected cost and benefits (Chatzoglou and Chatzoudes, 2016; Kurnia et al., 2015; Lin and Lin, 2008); organizational compatibility, organizational resource availability and governance systems (Lin and Lin, 2008; Kurnia et al., 2015); or the international and horizontal scope of a firm (Zhu et al., 2003; Zhu and Kraemer, 2005).

In this study, we propose that a firm's vertical boundaries and cooperation agreements are important variables of the organizational context that help us to understand e-business adoption. Considering production outsourcing and technological cooperation in the TOE model is important, as they affect transaction costs and therefore, information processing needs. To understand the positive relationship that we expect between these variables and e-business adoption, we focus our attention on the information processing model (Galbraith, 1973; Tushman and Nadler, 1978). This model states that the highest performing firms are those that match information processing needs and capabilities. When firms outsource production or collaborate with different agents, the resulting increase in information processing needs creates an imbalance between information processing needs and capabilities. In the following section, we propose that this imbalance may be corrected using e-business technologies.

The augmented TOE model proposes that both the vertical boundaries of the firm and cooperation activities are important in understanding e-business adoption. In the following section, we focus on production outsourcing and on technological cooperation and on their consequences for the use of e-business technologies.

3. Research model and hypotheses

3.1. The costs of Interorganizational collaboration and the role of e-business technologies

The information processing model maintains that firms are information processing systems facing different levels of uncertainty. A central element of this model is uncertainty. In fact, uncertainty determines the amount of information required so that 'the greater the uncertainty of the task, the greater the amount of information that has to be processed' (Galbraith, 1973). This theory proposes that to attain a greater performance, firms need to match information processing needs and information processing capabilities. In contexts where the information required to perform a task increases, firms may use technology to increase information processing capabilities and therefore, to fulfill information requirements (Bensaou and Venkatraman, 1995).

The increase in information requirements when a firm collaborates with other organizations stems from the increase in the information needed to face transaction costs. Transaction costs can be divided into two types: coordination costs and transaction risks (Clemons et al., 1993; Clemons and Row, 1992). Coordination costs are those arising from the efforts to integrate decisions taken in different economic activities. Transaction risks stem from the possibility that one party of an economic exchange engages in opportunistic behavior with the other economic agent(s) in the relationship. In fact, transaction risks increase with explicit coordination.

The information systems literature recognizes that explicit coordination increases the exposure to opportunist behavior and therefore, transaction risks (Clemons and Row, 1992). *Explicit coordination* refers 'to the extent to which activities are coordinated between economic activities through information or processes that are specific to the parties' (Clemons and Row, 1992). The three major sources of transaction risks are: transaction specific capital, information asymmetries and loss of resource control. First, by transaction specific capital we understand the investments that have a very low value in alternative uses. In the presence of asymmetric information and incomplete contracts, which are usual in economic exchanges, the party that has not made these investments can appropriate the benefits of the party that has invested. Second, information asymmetries may generate monitoring problems, making it difficult to measure the real contribution of each party to the relationship. This may result in shirking problems or reduced efforts of one party at the expense of the other. Finally, the loss of resource control occurs when resources are transferred in the relationship, and they are not returned or controlled at the time the relationship ends. The most important resources out of control tend to be information and know-how.

Investments in e-business technologies may be used to reduce transaction costs. Regarding coordination costs, investments in e-business technologies may be useful for a firm before, during and after interactions take place, improving communication and helping to coordinate interorganizational activities (Loebbecke et al., 2016; Wang and Benaroch, 2004; Chandrasekar Subramaniam, 2002; Lucking-Reiley and Spulber, 2001). E-business technologies may be used to coordinate all the activities related to searching, communicating, and establishing contracts between agents (Malone et al., 1987; Clemons et al., 1993). Additionally, they improve the ability of firms to perform other tasks that occur after establishing these contracts, and that have to do with ordering, billing, making transportation arrangements or confirming payments (Wang and Benaroch, 2004; Lucking-Reiley and Spulber, 2001).

The coordination advantages described above are not only obtained thanks to the establishment of links through which firms exchange information about different variables such as price, quality or delivery conditions (Malone et al., 1987; Clemons et al., 1993), but also because these technologies can improve organizational agility (Tallon et al., 2019) and reduce the complexities and thus, the costs associated with communication and coordination between firms.

Besides their effect on coordination costs, e-business technologies also reduce the transaction risks stemming from a closer integration of decisions (Amit and Zott, 2001; Clemons and Row, 1992). In particular, e-business technologies reduce the level of transaction specific capital needed to increase explicit coordination thanks to their ability to increase the frequency and transferability of applications that open standards based on the Internet facilitate (Amit and Zott, 2001; Clemons and Row, 1992). Furthermore, interactions can be standardized, and the cost spread over many interactions (Kumar and Van Dissel, 1996; Clemons and Row, 1992).

E-business technologies also allow reduction of the transaction risks of information asymmetry and loss of control. When agents share information about a transaction, the possibility of opportunistic behavior is reduced. By providing up to date and comprehensive information, e-business technologies help reduce information asymmetry between buyers and sellers (Amit and Zott, 2001), improve monitoring (Kim and Umanath, 2005; Amit and Zott, 2001) and therefore, reduce shirking by partners (Kim and Umanath, 2005). In this sense, transaction specific information provided by e-business technologies (Kim and Umanath, 2005; Amit and Zott, 2001) may be used for controlling agents' behavior, or for the establishment of incentives that make control less necessary (Clemons and Row, 1992).

3.2. Production outsourcing and e-business technology adoption

The outsourcing of production refers to a situation in which firms hire a third-party to perform manufacturing activities. Production outsourcing increases both coordination costs and transaction risk and is, therefore, and stimulus for the adoption of e-business technologies. In this context, the adoption of e-business technologies when firms engage in outsourcing activities provides managers with better information processing capabilities (Dedrick and Kraemer, 2010). These capabilities help firms to coordinate their activities with those of their national and international suppliers (Jean et al., 2021; Lal, 2002) improving the effectiveness and efficiency of these relationships. Regarding efficiency, e-business helps firms to obtain fast and adequate information before, during and after the transaction takes place, which allows to achieve the desired integration at an adequate cost (Garicano and Kaplan, 2001). The use of open standards, and the ability of e-business to codify and transfer know-how also decreases the overall costs (Clemons and Row, 1992). These technologies also improve the connectivity making relationships that arise when firm outsource production more

effective.

In a context of outsourced production, e-business technologies facilitate the specification of the characteristics of externalized production in a language that is understandable for all parties (Blois, 1986). This reduction of complexity is obtained by means of the codification of information and formalization (Argyres, 1999), which facilitates the transference of knowledge and of the details regarding the transactions between organizations. Another important advantage of codified information is that it facilitates the management of interfirm dependences and an adequate combination of externalized activities with those performed in house (Bardhan et al., 2006). Codification is important because it helps reduce coordination costs by limiting the independence of suppliers and by minimizing the number of errors (Atallah, 2002). This, in turn, makes quality controls technologically feasible (Blois, 1986) and allows incentive and cognitive conflicts to be addressed (Mani et al., 2010).[5] Therefore, e-business technologies reduce coordination costs related to searching suppliers, because they reduce the costs of searching products and facilitate price comparisons (Garicano and Kaplan, 2001). Furthermore, these technologies provide better information about product characteristics and about buyers and sellers (Garicano and Kaplan, 2001), which allows improving communication with other agents regarding transaction details, the costs of production and inventory management, among others (Garicano and Kaplan, 2001): Lucking Reiley and Spulberg, 2001).

Therefore, due to the improvement in information processing capabilities that the adoption of e-business technologies facilitates, we expect that firms engaged in production outsourcing are more likely to adopt e-business.

Hypothesis 1. *Firms that outsource production are more likely to adopt e-business technologies.*

3.3. Technological cooperation and e-business technology adoption

Technological cooperation refers to a situation in which firms collaborate with other agents to achieve technological innovation. In our case, we focus on technological collaborations with buyers, sellers and competing firms. That is, it includes the cases in which a company partners with suppliers, clients o competitors with the aim of achieving technological innovation. The technology collaboration agreements used may be of different types, including strategic alliances, joint ventures, technology licenses, outsourcing, and collective research organizations (Schilling and Shankar, 2019). Each of these forms of technological collaboration has its advantages and disadvantages, but they all contribute to increasing the costs of coordination and the risks of the transaction.

For example, technological collaboration tends to increase coordination costs due to the lack of a shared language or routines that allow the transfer of knowledge (Becker and Dietz, 2004). In fact, one important problem that may be present in technological collaborations is that knowledge tends to be sticky, or, in other words, it may be difficult to separate knowledge from its original source (Andersen, 1999). Technological collaborations also increase the coordination costs associated with the integration of diverse resources and knowledge (Moaniba et al., 2019; Becker and Dietz, 2004), which may be very relevant in the case of technological collaborations. In the same way, they require the existence of procedures that allow internalizing what has been learned (Hamel and Prahalad, 1990; Hamel et al., 1989). Technological collaborations are also subject to transactional risk (Clemons and Row, 1992; Clemons et al., 1993). In particular, to opportunism derived from the existence of low levels of commitment in the relationship. Technological collaborations tend to fail because of free riding, opportunistic behavior and value misappropriation caused by the existence of a divergence of interests and the lack of a mutual understanding between partners (Moaniba et al., 2019).

Therefore, although the nature of technological collaboration is different from the one of production outsourcing, it also increases both coordination costs and transaction risks (Sanders, 2007). To cope with the increased uncertainty of the tasks, managers can increase information processing capabilities through the adoption of e-business technologies.

Technological collaboration requires many interactions between partners. These interactions involve not only knowing the technical specifications of technology but also sharing the frequently embodied knowledge in the technology (Lal, 2002). In this context, e-business technologies may facilitate knowledge exchange, allowing partners to access historical and current information. In fact, e-business technologies improve the flow of information by providing access to information more accurately, timely and easily and relatively low transaction cost (Sanders, 2007). For example, they may be very useful at the time of exchanging product designs between parties (Lal, 2002).

Additionally, these technologies also improve connectivity between different partners through their ability to codify knowledge and to engender specialized routines and/or standard operating procedures (Rosenzweig, 2009). This improvement not only facilitates the exchange of knowledge, but also the recombination and creation of knowledge, which helps partners to develop better products and services (Jean et al., 2021; Rosenzweig, 2009; Lal, 2002).

Therefore, due to the improvement in information processing capabilities that the adoption of e-business technologies facilitates, we expect that firms engaged in technological collaboration are more likely to adopt e-business.

Hypothesis 2. *Firms that engage in technological cooperation with competitors, buyers or sellers are more likely to adopt e-business technologies than firms that do not cooperate.*

[5] Incentive conflict assumes the existence of possible opportunistic behavior. This conflict affects firms' motivation to process information accurately. Cognitive conflict assumes the lack of a common communication language and therefore, the lack of a shared understanding.

4. Empirical analysis

4.1. Sample description

The data set used in the empirical analysis comes entirely from the Survey of Business Strategies (ESEE),[6] a survey of manufacturing firms operating in Spain. The information we use belongs to the period 2002–2014. Although the survey is not specifically designed for studying investments in e-business technologies, the questionnaire includes a set of questions regarding the use of several technologies that facilitate interorganizational transactions (beyond firm technologies). More precisely, the questionnaire includes information about the use of Supplier-to-Business (S2B), Business-to-Business (B2B) and Business to Consumer (B2C) technologies that we use for the empirical analyses, with some caveats that we explain below. A first advantage of the sample is that it is representative of the population of Spanish manufacturing firms. In 1990, the first year in which the survey was conducted, firms between 10 and 200 employees were selected randomly, while firms with more than 200 employees were surveyed on a census basis. In the following years, those firms that dropped out of the original sample were replaced each year by firms with similar characteristics. Another, advantage is that the survey follows many firms, which offers a more complete picture of technology adoption at the firm level than previous papers. This data set has been used in previous research, such as in productivity studies (Añón et al., 2017; Guadalupe et al., 2012) and in adoption of process technologies Gómez and Vargas (2009) and Gómez and Vargas (2012), for example.

From this dataset we built an unbalanced panel that consists of 22902 observations and 3539 firms. Table 1 shows the composition of this panel according to the number of years a given firm is observed.[7]

4.2. Variable description and measurements

4.2.1. Dependent variables

4.2.1.1. E-business technologies. To test our two hypotheses, we considered three technologies. Two of them may be used to perform supplier and interfirm transactions over the Internet, i.e., S2B and B2B. Along with these technologies, we also studied an e-business technology, B2C, that is not clearly related to the outsourcing of production, but that could be related to cooperation with a firm's customers. We used three dummy variables that take a value of one if a firm used the technology, and zero otherwise, to represent the adoption of these three different e-business technologies.

4.2.2. Independent variables

To measure the two hypotheses proposed above, we defined two sets of variables. The first set consists of one variable labeled *Production outsourcing* and captures the vertical boundaries of a firm (Hypothesis 1). This is not a full measure of the externalization of a firm's activities all along the vertical chain, but only of production activities. The second set, *Cooperation in technological activities*, consists of three variables that focus on the activities that a firm performs to acquire knowledge from external partners through cooperation agreements with three types of agents: suppliers, competitors, and customers (Hypothesis 2).

4.2.2.1. Production outsourcing. To measure production externalization, we utilized the ratio of purchases of final products and tailored components from other firms divided by the total value of purchases. We calculated this measure to be consistent with previous papers in the information systems literature (Bardhan et al., 2006; Dedrick and Kraemer, 2010), which have used it. The resulting ratio varies from zero (when all production is performed internally) to 100 (when a firm outsources all its production). According to Hypothesis 1 and given that achieving the benefits of production outsourcing requires a high degree of integration (Lahiri, 2016; Bardhan et al., 2006), we expect that this variable to be positively related with the adoption of S2B and B2B. However, the fact that the measure focuses on production activities makes the link with B2C less clear, given the presence of intermediate activities between transformation of raw materials and selling in the value chain.

4.2.2.2. Cooperation in technological activities. The survey includes information on a firm's cooperation in technological activities with the three types of partners mentioned above. Their main purpose is to acquire knowledge for use as an input in the innovation activities performed by a firm. As in previous studies (Un et al., 2010; Un and Asakawa, 2015), each type of research and development (R&D) collaboration is measured with a dummy variable that takes the value of one if a firm indicates that it had R&D collaboration agreements with each R&D partner (customers, suppliers, and competitors) in a given year, and zero otherwise. We expect the variable cooperation in technological activities to be positively related with the adoption of e-business technologies. Technological collaborating firms are more likely to adopt e-business because they need more interactions through which exchange specifications and share intangible and embodied knowledge in the technology than other firms (Lal, 2002). The type of cooperation agent is expected to

[6] The questionnaires and the data set are available at https://www.fundacionsepi.es/investigacion/esee/en/svariables/disponibles.asp. The survey is produced by the Fundación Empresa Pública, an organization depending on the Spanish Ministry of the Treasury. To access the data set, researchers must submit a scientific research project, they agree to use the data exclusively '…for the submitted research project, not to transfer the data to any third party, and …' to maintain '…the confidentiality of the database when the results of the research are disclosed'. Information on the use of the database for replication studies can be obtained from the web page above.

[7] See Appendix A for the exact wording of the questionnaire.

Table 1
Distribution of firms and observations.

Number of firms	Number of annual observations per firm	Number of observations
489	13	6357
79	12	948
63	11	693
325	10	3250
215	9	1935
211	8	1688
248	7	1736
300	6	1800
285	5	1425
237	4	948
422	3	1266
191	2	382
474	1	474
3539		22902

condition the type of e-business technology adopted by a firm. Thus, we expect *Cooperation with Suppliers* and *Cooperation with Competitors* to be positively related to the adoption of S2B and B2B, but not to B2C. *Cooperation with Customers*, however, could be related with the adoption of B2C.

4.3. Control variables

The models that we estimated also include a set of control variables influencing the decision to adopt a given technology and the total investment that a firm makes. To organize them, we use the three elements of the TOE framework that refer to the Technological, Organizational and Environmental contexts that surround the adoption of e-business technologies. The control variables used have been selected from the literature concerning information systems and diffusion theories.

4.3.1. Technological context variables (T)

This element takes into consideration the technology readiness of a firm defined as the 'level of sophistication of IT usage and IT management in an organization' (Iacovu et al., 1995, p. 469). Using this definition implies that technology readiness is built not only by physical resources but also human resources that are complementary to physical assets (Mata et al., 1995). In this regard, several authors have suggested that technological readiness consists of technological infrastructure and IT human resources (Zhu et al., 2006; Oliveira and Martins, 2010). Technological infrastructure creates a platform that enables Internet-related business (Zhu et al., 2003), while IT human resources provide the knowledge and skills that facilitate the use of Internet-related applications (Zhu and Kraemer, 2005).

4.3.1.1. Technological infrastructure. The survey offers information on the use of several manufacturing technologies that are currently being implemented by a firm. More precisely, the questionnaire gives us information on whether a firm uses numerically controlled machines, robotics, CAD, flexible manufacturing systems and LAN. We included the variable *Technological infrastructure* that ranges between zero and five depending on the number of technologies a firm declares to use. The information to construct this variable is available every four years and will be used in the *Robustness checks* section.

4.3.1.2. IT human resources. We approximate the knowledge that a firm has accumulated in the use of information technologies through the capitalized value of information technology training. Following previous papers (see, for example, Dewan and Kraemer, 2000 or, more recently, Gómez et al., 2017), we calculated a capitalization of training in information technologies with information from every three years and assuming a depreciation rate of 33%.

4.3.2. Organizational context variables (O)

4.3.2.1. Firm size. Previous studies analyzing the diffusion of innovations relate the size of a firm to the adoption of new technologies. More precisely, they argue that larger firms are more likely to adopt them (Astebro, 2002; Karshenas and Stoneman, 1993; Zhu et al., 2003; Hollenstein, 2004; Hollenstein and Woerter, 2008; Shih, 2012; Ilin et al., 2017). The reasons behind this positive relationship are that larger firms: (1) tend to have more slack resources; (2) are more likely to achieve economies of scale; (3) are more capable of assuming risks associated with e-business adoption; and (4) have more power to urge their partners to adopt e-business technologies. Size is measured by the number of employees working for a given firm (in thousands), we expect a positive sign for the accompanying coefficient.

Export intensity. The literature on the diffusion of new technologies suggests the importance of considering a firm's presence in international markets when analyzing the adoption of technologies (Hollenstein, 2004). Export-oriented firms may utilize e-business technologies to reduce search costs and inventory holding costs (Chopra and Meindl, 2001; Zhu et al., 2003; Zhu et al., 2006). They may also invest in e-business technologies to tackle the higher levels of competition present in international markets. Therefore, we

expected a positive relationship between a firm's export orientation and the adoption of information technologies. Export intensity is measured by the ratio of total exports to sales (Lal, 2002).

4.3.2.2. Diversification. Although we do not have reasons to expect a specific relationship between diversification and beyond firm technologies, we also control for the degree of firm diversification, as previous papers on technology adoption have done. To that aim, we used a diversification measure provided by the Fundación Empresa Pública. The original variable provided distinguishes between non-diversified firms, firms with related diversification and firms with unrelated diversification. We have recoded this variable into a dummy variable that takes a value of zero when the firm is not diversified and one when the firm is diversified. Non-diversified firms are those who participate in a single industry (at the 3-digit level of the National Classification of Economic Activities). Diversified firms are those involved in several industries (at the 3-digit level). This categorical variable has been used in previous studies (see for example (García-Quevedo et al., 2014; Gomes and Livdan, 2004).

4.3.2.3. R&D intensity. This variable is included to recognize the influence of absorptive capacity in increasing the likelihood of adopting new technologies. The inclusion of this variable accounts for the fact that investments in new technologies not only depend on the amount of available information, but also on a firm's ability to assimilate and apply it to commercial ends (Cohen and Levinthal, 1990). Therefore, we expect that those firms presenting a higher ratio of R&D spending to sales would have a higher capacity to take advantage of information on new technologies and they would be more likely to invest in them (Hollenstein, 2004; Hollenstein and Woerter, 2008; Gómez et al., 2012a, 2012b).

4.3.2.4. Foreign capital. This variable measure whether foreign investors possess a portion of a firm's capital. The inclusion of this variable is justified by the fact that foreign parent companies often transfer new technology to domestic affiliates (Hollenstein and Woerter, 2008; Haller and Siedschlag, 2011). We include a dummy variable taking a value of one if the presence of foreign capital in a focal firm is higher than 30%, and zero otherwise. This threshold has been employed by other empirical studies that focus on manufacturing firms (see, Merino and Salas, 1995; Salas and Merino, 1996).

4.3.2.5. Cooperation with wholesalers/retailers. We define a variable that takes a value of one if a firm has cooperated with wholesalers or retailers in a given year, and zero otherwise. The information to construct this variable is available every four years and will be used in the *Robustness checks* section. Wholesalers and retailers are intermediaries located down in the value chain and to whom the firm sells its products. Collaboration with wholesalers and retailers involves the exchange of information that facilitates matching customer needs with production. The ability to transfer this information quickly allows firms to adequately analyse the market and predict the demand (Rawwas et al., 2008).

4.3.3. Environmental context variables (E)

4.3.3.1. Market stability. When market stability is low (i.e., uncertainty is high), firms tend to collect more information from the market in order to better forecast trends and to coordinate the actions needed to anticipate those tendencies. In such environments, e-business technologies will help firms to react quickly and efficiently to market changes and consequently, investments in these technologies increase. To control for this effect, we included a dummy variable taking the value of one when all the markets served by a firm are characterized as stable by the firm, and zero otherwise. Therefore, we expect the sign of this variable to be negative in all the analyses (Gómez et al., 2017).

4.3.3.2. Market Concentration. Market structure has traditionally been linked to the degree of innovation and to the incentives for firms to invest in technology. However, the direction of the influence of the market structure is ambiguous in most of cases (Reinganum, 1981). We measured concentration by adding the market shares of the four largest firms in every industry (CR_4) (Ray et al., 2009; Shih, 2012). This variable has been previously used in different papers that have utilized the information provided by the Survey of Business Strategies (ESEE) (see, for example, Manez et al., 2015 and (Gómez and Vargas, 2012).

4.3.3.3. Industry variables. Other industry features, besides market concentration and market stability, could also affect the likelihood of adopting a given technology. To control for unobserved heterogeneity and omitted variables bias, we used 19 dummy variables to control for differences between the 20 industries identified in the survey.

4.3.3.4. Time variables. In order to control for the higher likelihood of adoption that may be induced by the learning-by-contact process, i.e. the epidemic effect or any other temporal specific effect, we also include year dummy variables Gómez and Vargas (2009) and Gómez and Vargas (2012).

Table 2 offers some descriptive statistics and the correlation matrix between the variables of interest used in the analysis. About a quarter of firms (29.4%) are using S2B technologies (remember that e-buying was used by 30.75% of Spanish firms in 2018). This figure is smaller when B2B or B2C technologies are considered, being 8.7% and 6.7%, respectively. Firms outsource 7.59% of the total value of purchases, on average. About one fifth of the firms engage in technological cooperation with suppliers (20.1%), 16.9% with customers and only 2.5% with competitors. Finally, the correlations between the independent variables are generally low, except for cooperation with customers and cooperation with suppliers, which present a high positive correlation (0.675). Due to their high

Table 2
Descriptive statistics of the variables (22,902 observations).

	Mean	Std.Dev.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) S2B	0.294	0.456	1.000													
(2) B2B	0.087	0.282	0.252***	1.000												
(3) B2C	0.067	0.249	0.198***	0.515***	1.000											
(4) Production outsourcing	7.592	16.609	0.089***	0.029***	0.021***	1.000										
(5) Cooperation with customers	0.169	0.374	0.149***	0.088***	0.014**	0.073***	1.000									
(6) Cooperation with competitors	0.025	0.157	0.065***	0.035***	0.018***	0.061***	0.263***	1.000								
(7) Cooperation with suppliers	0.201	0.400	0.165***	0.122***	0.036***	0.099***	0.675***	0.264***	1.000							
(8) IT human resources	1.688	3.408	0.144***	0.107***	0.050***	0.072***	0.288***	0.146***	0.311***	1.000						
(9) Firm size	0.214	0.684	0.078***	0.115***	0.062***	0.033***	0.168***	0.212***	0.245***	0.298***	1.000					
(10) Export intensity	0.214	0.281	0.139***	0.068***	0.026***	0.084***	0.296***	0.087***	0.291***	0.208***	0.179***	1.000				
(11) Diversification	0.135	0.342	0.054***	0.026***	0.029***	0.027***	0.050***	0.019***	0.055***	0.044***	0.069***	0.030***	1.000			
(12) R&D intensity	0.008	0.026	0.120***	0.024***	0.019***	0.108***	0.305***	0.187***	0.306***	0.153***	0.116***	0.161***	0.017**	1.000		
(13) Foreign capital	0.158	0.365	0.056***	0.106***	0.019***	0.014**	0.213***	0.099***	0.200***	0.247***	0.273***	0.300***	-0.001	0.052***	1.000	
(14) Market stability	0.373	0.484	-0.072***	-0.047***	-0.031***	-0.047***	-0.080***	-0.042***	-0.090***	-0.061***	-0.018***	-0.079***	-0.040***	-0.043***	-0.007	1.000
(15) Market concentration	42.943	14.156	0.077***	0.022***	0.022***	-0.005	0.047***	0.072***	0.051***	0.058***	0.112***	0.051***	-0.043***	0.099***	0.052***	-0.016**

* ** $p < 0.01$, * * $p < 0.05$, * $p < 0.1$

correlation and the fact that these two variables are used to measure Hypothesis 2, they have not been considered simultaneously in any of the estimations.

4.4. Methodology

Given the binary character of the dependent variables, we analyse the impact of firm boundaries on the adoption of beyond firm technologies using a probit[8] model. In these cases, other regression methods are largely inappropriate (Greene, 2012). To address the potential problems created by the existence of unobserved heterogeneity, we used a random-effects panel probit model. More precisely, the empirical model takes the following econometric specification[9]:

$$\begin{aligned} E-business\ \ use_{i,t} = {} & \beta_0 + \beta_1 x\ \ Production\ \ outsourcing_{i,t} + \beta_2 x\ \ Cooperation\ \ in\ \ technological\ \ activities\ \ _{i,t} \\ & + \beta_3 x\ \ IT\ \ human\ \ Resources\ \ _{i,t} + \beta_4 x\ \ Firm\ \ size\ \ _{i,t} + \beta_5 x\ \ Export\ \ intensity\ \ _{i,t} \\ & + \beta_6 x\ \ Diversification\ \ _{i,t} + \beta_7 x\ \ R\&D\ \ intensity_{i,t} + \beta_8 x\ \ Foreign\ \ capital_{i,t} + \beta_9 x\ \ Market\ \ stability_{i,t} \\ & + \beta_{10} x\ \ Market\ \ concentration_{i,t} + \beta_m x\ \ industry_i + \beta_j x\ \ year_t + \varepsilon_{i,t} \end{aligned}$$

where ε is the error term, i = 1,…, N denotes the firm, and t = 1…T stands for the year.

5. Results

Table 3 presents the results of estimating a random effects probit model and testing our hypotheses. We have estimated three sets of models, one for each of the e-business technologies analyzed, i.e S2B B2B and B2C. Estimating several models for each e-business technology allows us to compare their global adjustment and to choose the preferred model (the tests comparing the models are presented at the bottom of the Table). Therefore, Table 3 attempts to verify if firms using outsourcing are more likely to utilize e-business technologies (Hypothesis 1). Similarly, we also investigate whether firms that cooperate in technological activities are more likely to adopt e-business technologies (Hypothesis 2).

Models 1a, 2a and 3a, present results of the analysis with only the control variables. These three models serve as benchmarks for the augmented models. Columns 1b, 2b and 3b incorporate the analysis of the vertical boundaries of a firm through the variable *Production outsourcing*. Finally, columns 1c, 2c, 3c and 1d, 2d, 3d examine the impact of the different types of collaboration considered: collaboration in technological activities with customers, suppliers and competitors. The reason for not presenting a full model is that the variables *cooperation with customers* and *cooperation with suppliers* are highly correlated. It is well known that high correlations make it difficult to obtain coefficients with small standard errors (Gujarati, 2004).

The tests presented at the bottom of Table 3 compare the fully specified models and their nested counterparts. Together with the Wald test, they not only show that the models are globally significant, but also that the augmented models (1c, 2c, 3c and 1d, 2d, 3d), are preferred in the case of S2B and B2B, but not in the case of B2C. We will focus our comments on the more complete models and use the two previous sets of estimations (1a, 2a, 3a and 1b, 2b, 3b) to evaluate the stability of the results and for comparison purposes.

First, the results obtained confirm that outsourcing production is positively related to the adoption of S2B and B2B, but not for B2C.

Second, the involvement in cooperation activities with external partners is partially related with the adoption of certain e-business technologies, but this is not an effect affecting all of them equally. Firms that cooperate with *customers* in technological activities have a higher likelihood of using S2B and B2B, but not B2C. Similarly, *Cooperation with suppliers* in technological activities increases the probability of using S2B and B2B, but not of using B2C. Although the results show that it has a negative influence on the adoption of B2C in model 3d, this model does not have a higher explanatory power than their nested counterparts (models 3a, 3b and 3c). Finally, the variable *Cooperation with competitors* is not significantly related to the adoption of S2B, B2B and B2C.

The control variables are distributed in three groups, according to the TOE model: technological, organizational and environmental context variables. Regarding the technological context, the results presented in Table 3 show that the variable *IT human resources* has a positive and significant effect on the use of all three technologies.

Among the organizational context variables, we do not find a clear pattern of influences. *Firm size* has a positive influence on S2B, B2B and B2C. *Export intensity* and *diversification* show a positive effect on S2B and on B2B. Finally, *R&D intensity* only has a positive impact on the adoption of S2B and *foreign capital* on S2B and B2B.

Finally, among the variables characterizing the environmental context, *market stability*[10] has a negative effect on the use of S2B and B2B technologies. In other words, firms operating in stable environments have less incentives to use them. Market concentration also reduces the probability of using B2B and B2C technologies, but it shows no significant influence on the adoption of S2B.

[8] The main difference between logit and probit models is their distribution. Logit uses logistic distribution, and probit uses the standard normal distribution. Estimates from both models produce similar results (Greene, 2012).

[9] The regression results presented in the next section (Results) are stable when we use an alternative model with lagged independent variables.

[10] In order to control for omitted factors that do not change over time, and following the recommendation from one of the reviewers, we reestimated the model including an interaction term between industry and year dummies. We obtained similar results.

Table 3
Results of the random effect probit analysis of e-business adoption in manufacturing firms.

	Model 1 S2B use				Model 2 B2B use				Model 3 B2C use			
	[1a]	[1b]	[1c]	[1d]	[2a]	[2b]	[2c]	[2d]	[3a]	[3b]	[3c]	[3d]
Production outsourcing		0.00282***	0.00269**	0.00252**		0.00350**	0.00321**	0.00310**		0.00249	0.00240	0.00267
		(2.61)	(2.49)	(2.33)		(2.25)	(2.06)	(1.99)		(1.43)	(1.38)	(1.54)
Cooperation with customers			0.225***				0.316***				0.0768	
			(4.31)				(4.33)				(0.90)	
Cooperation with suppliers				0.315***				0.288***				-0.141*
				(6.65)				(4.31)				(−1.79)
Cooperation with competitors			0.0597	0.0230			-0.0893	-0.0971			0.0887	0.163
			(0.61)	(0.23)			(−0.63)	(−0.69)			(0.53)	(0.97)
IT human resources	0.0243***	0.0239***	0.0228***	0.0217***	0.0162**	0.0158**	0.0134*	0.0136*	0.0253***	0.0251***	0.0246***	0.0265***
	(5.01)	(4.94)	(4.71)	(4.47)	(2.31)	(2.26)	(1.91)	(1.93)	(3.16)	(3.14)	(3.07)	(3.29)
Firm size	0.240***	0.242***	0.229***	0.210***	0.302***	0.304***	0.293***	0.282***	0.338***	0.338***	0.333***	0.344***
	(4.28)	(4.31)	(4.09)	(3.75)	(4.61)	(4.65)	(4.50)	(4.34)	(5.06)	(5.07)	(4.98)	(5.12)
Export intensity	0.422***	0.412***	0.391***	0.378***	0.586***	0.579***	0.547***	0.540***	0.0748	0.0682	0.0546	0.0867
	(4.30)	(4.20)	(3.99)	(3.85)	(4.20)	(4.14)	(3.91)	(3.86)	(0.50)	(0.45)	(0.36)	(0.57)
Diversification	0.143***	0.139**	0.135**	0.139**	0.198**	0.195**	0.195**	0.191**	0.0520	0.0501	0.0474	0.0530
	(2.58)	(2.51)	(2.44)	(2.50)	(2.44)	(2.39)	(2.40)	(2.35)	(0.60)	(0.58)	(0.55)	(0.61)
R&D intensity	2.720***	2.647***	2.239***	1.880***	0.810	0.726	-0.0163	0.0928	0.688	0.617	0.414	0.843
	(3.80)	(3.70)	(3.12)	(2.63)	(0.71)	(0.64)	(−0.01)	(0.08)	(0.57)	(0.51)	(0.34)	(0.69)
Foreign capital	0.205***	0.202***	0.193***	0.197***	0.453***	0.452***	0.433***	0.446***	0.0871	0.0839	0.0789	0.0873
	(2.74)	(2.70)	(2.58)	(2.64)	(4.63)	(4.62)	(4.43)	(4.58)	(0.77)	(0.74)	(0.69)	(0.77)
Market stability	-0.100***	-0.100***	-0.095***	-0.092***	-0.128**	-0.124**	-0.120**	-0.118**	-0.0888	-0.0877	-0.0848	-0.0914*
	(−3.04)	(−3.03)	(−2.88)	(−2.78)	(−2.54)	(−2.47)	(−2.38)	(−2.35)	(−1.62)	(−1.59)	(−1.54)	(−1.66)
Market concentration	0.0002	0.0002	0.00008	-0.00003	-0.0097**	-0.0097**	-0.00996**	-0.00968**	-0.018***	-0.018***	-0.018***	-0.018***
	(0.08)	(0.06)	(0.03)	(−0.01)	(−2.23)	(−2.23)	(−2.28)	(−2.22)	(−3.77)	(−3.78)	(−3.78)	(−3.79)
Industry variables	Included				Included				Included			
Time variables	Included				Included				Included			
Constant	-1.387***	-1.379***	-1.365***	-1.370***	-2.820***	-2.814***	-2.794***	-2.805***	-1.981***	-1.978***	-1.978***	-1.979***
	(−5.46)	(−5.44)	(−5.40)	(−5.42)	(−7.86)	(−7.83)	(−7.79)	(−7.83)	(−5.46)	(−5.46)	(−5.45)	(−5.45)
No. observations	22,902	22,902	22,902	22,902	22,902	22,902	22,902	22,902	22,902	22,902	22,902	22,902
Wald Test	807.5***	814.4***	832.4***	856.2***	246.3***	250.4***	273.1***	269.1***	304.1***	305.7***	306.5***	308.8***
Test comparison (vs 1)		6.84***	27.26***	52.91***		5.08**	23.73***	23.57***		2.06	3.32	5.71
Test comparison (vs 2)			20.43***	46.09***			18.74***	18.54***			1.26	3.65

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; t-ratios in parentheses

Table 4
Results of the random effect probit analysis of e-business adoption in manufacturing firms.

	Model 1 S2B use				Model 1 B2B use				Model 1 B2C use			
	[1a]	[1b]	[1c]	[1d]	[2a]	[2b]	[2c]	[2d]	[3a]	[3b]	[3c]	[4d]
Production outsourcing		0.004***	0.004***	0.004***		0.006**	0.006**	0.005**		0.007***	0.007***	0.007***
		(2.81)	(2.80)	(2.58)		(2.48)	(2.53)	(2.36)		(2.78)	(2.78)	(2.81)
Cooperation with customers			0.258***				0.351***				-0.0441	
			(3.49)				(3.23)				(−0.34)	
Cooperation with suppliers				0.330***				0.352***				-0.0994
				(4.73)				(3.47)				(−0.83)
Cooperation with competitors			0.167	0.142			-0.00517	-0.00713			0.160	0.179
			(1.04)	(0.89)			(−0.02)	(−0.03)			(0.60)	(0.67)
Technological infrastructure	0.150***	0.149***	0.143***	0.138***	0.119***	0.117***	0.108***	0.105***	0.0443	0.0415	0.0426	0.0445
	(8.44)	(8.37)	(8.00)	(7.73)	(4.61)	(4.53)	(4.14)	(4.01)	(1.55)	(1.45)	(1.48)	(1.54)
IT human resources	0.0439***	0.0432***	0.0404***	0.0389***	0.0274**	0.0268**	0.0235**	0.0225**	0.0348***	0.0340***	0.0343***	0.0355***
	(5.82)	(5.73)	(5.33)	(5.12)	(2.53)	(2.46)	(2.15)	(2.05)	(2.76)	(2.69)	(2.69)	(2.77)
Firm size	0.0341	0.0349	0.0262	0.00628	0.177***	0.179***	0.179***	0.160**	0.119 *	0.118 *	0.113	0.118 *
	(0.67)	(0.68)	(0.51)	(0.12)	(2.90)	(2.93)	(2.88)	(2.57)	(1.69)	(1.68)	(1.58)	(1.65)
Export intensity	0.430***	0.420***	0.380***	0.365***	0.241	0.237	0.184	0.180	0.136	0.130	0.139	0.149
	(3.82)	(3.75)	(3.37)	(3.23)	(1.42)	(1.39)	(1.07)	(1.05)	(0.73)	(0.70)	(0.74)	(0.79)
Diversification	0.173**	0.169**	0.165**	0.168**	0.165	0.162	0.157	0.160	0.238**	0.235*	0.237*	0.239**
	(2.27)	(2.23)	(2.16)	(2.20)	(1.43)	(1.40)	(1.35)	(1.37)	(1.97)	(1.94)	(1.96)	(1.97)
R&D intensity	3.030***	2.849***	2.094**	1.868*	-1.661	-2.040	-3.407*	-3.583*	0.161	-0.304	-0.329	-0.163
	(3.02)	(2.84)	(2.05)	(1.82)	(−0.91)	(−1.09)	(−1.67)	(−1.74)	(0.09)	(−0.17)	(−0.18)	(−0.09)
Foreign capital	-0.0345	-0.0359	-0.0562	-0.0478	0.406***	0.409***	0.384***	0.401***	0.136	0.132	0.133	0.132
	(−0.41)	(−0.43)	(−0.66)	(−0.56)	(3.40)	(3.41)	(3.18)	(3.32)	(0.97)	(0.93)	(0.94)	(0.93)
Cooperation with wholesalers/retailers	0.279***	0.274***	0.271***	0.257***	0.474***	0.473***	0.471***	0.458***	0.377***	0.373***	0.374***	0.378***
	(4.54)	(4.47)	(4.42)	(4.17)	(5.57)	(5.55)	(5.49)	(5.34)	(4.03)	(3.98)	(3.98)	(4.02)
Market stability	-0.128**	-0.124**	-0.115**	-0.110**	-0.189**	-0.181**	-0.172**	-0.168**	-0.141 *	-0.135	-0.135	-0.138
	(−2.52)	(−2.44)	(−2.26)	(−2.16)	(−2.43)	(−2.33)	(−2.19)	(−2.15)	(−1.66)	(−1.58)	(−1.58)	(−1.61)
Market concentration	0.000911	0.000768	0.000791	0.000756	-0.0130**	-0.0128**	-0.0132**	-0.0127**	-0.0247***	-0.0249***	-0.0248***	-0.0248***
	(0.23)	(0.19)	(0.20)	(0.19)	(−2.23)	(−2.20)	(−2.25)	(−2.17)	(−3.85)	(−3.87)	(−3.85)	(−3.86)
Industry variables	Included				Included				Included			
Time variables	Included				Included				Included			
Constant	-1.386***	-1.374***	-1.369***	-1.374***	-2.168***	-2.190***	-2.175***	-2.201***	-0.899**	-0.897**	-0.908**	-0.904**
	(−4.88)	(−4.85)	(−4.83)	(−4.83)	(−5.05)	(−5.08)	(−5.02)	(−5.08)	(−2.08)	(−2.06)	(−2.09)	(−2.08)
No. observations	7100	7100	7100	7100	7100	7100	7100	7100	7100	7100	7100	7100
Wald Test	538.6***	545.2***	551.1***	556.1***	179.5***	181.4***	186.3***	186.5***	146.7***	149.5***	149.4***	149.8***
Test comparison (vs 1)		7.88***	22.94***	33.07***		6.15**	16.48***	18.05***		7.75***	8.15**	8.70**
Test comparison (vs 2)			15.11***	25.29***			10.59***	12.22***			0.42	0.99

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$; t-ratios in parentheses

Table 5
Results of the multivariate probit analysis of e-business adoption in manufacturing firms.

	S2B use [1a]	B2B use [1b]	B2C use[1c]	S2B use[2a]	B2B use[2b]	B2C use [2c]	S2B use [3a]	B2B use [3b]	B2C use [3c]
Production outsourcing	0.004***	0.003**	0.003**	0.004***	0.003**	0.003**	0.004***	0.003*	0.003**
	(3.37)	(2.01)	(2.16)	(3.42)	(2.08)	(2.13)	(3.20)	(1.90)	(2.16)
Cooperation with customers				0.200***	0.183***	-0.021			
				(3.51)	(2.59)	(0.28)			
Cooperation with suppliers							0.215***	0.225***	-0.042
							(4.00)	(3.50)	(0.57)
Cooperation with competitors				0.085	-0.094	0.002	0.084	-0.107	0.014
				(0.71)	(0.60)	(0.01)	(0.70)	(0.69)	(0.10)
Technological infrastructure	0.117***	0.089***	0.034*	0.112***	0.084***	0.034*	0.110***	0.081***	0.036*
	(9.08)	(5.43)	(1.82)	(8.68)	(5.12)	(1.83)	(8.48)	(4.93)	(1.87)
IT human resources	0.033***	0.021***	0.022***	0.030***	0.019***	0.023***	0.029***	0.018**	0.023***
	(5.77)	(3.03)	(2.93)	(5.18)	(2.66)	(3.02)	(5.03)	(2.48)	(3.07)
Firm size	-0.005	0.105**	0.063	-0.011	0.108***	0.063	-0.022	0.098**	0.065
	(0.17)	(2.51)	(1.51)	(0.32)	(2.58)	(1.50)	(0.65)	(2.34)	(1.54)
Export intensity	0.292***	0.090	0.068	0.259***	0.055	0.073	0.254***	0.049	0.075
	(3.66)	(0.89)	(0.63)	(3.22)	(0.54)	(0.68)	(3.16)	(0.48)	(0.69)
Diversification	0.114**	0.077	0.171**	0.112**	0.074	0.173**	0.112**	0.072	0.175**
	(2.00)	(1.02)	(2.18)	(1.98)	(0.98)	(2.21)	(1.96)	(0.95)	(2.24)
R&D intensity	1.940**	-1.241	0.722	1.261	-1.857	0.764	1.183	-2.111*	0.839
	(2.21)	(1.17)	(0.69)	(1.47)	(1.60)	(0.75)	(1.40)	(1.79)	(0.83)
Foreign capital	-0.073	0.213***	0.036	-0.087	0.203***	0.035	-0.080	0.206***	0.033
	(1.17)	(2.81)	(0.43)	(1.39)	(2.67)	(0.42)	(1.28)	(2.73)	(0.40)
Cooperation with wholesalers/retailers	0.250***	0.413***	0.301***	0.249***	0.414***	0.300***	0.234***	0.399***	0.302***
	(5.46)	(7.40)	(5.01)	(5.44)	(7.39)	(4.98)	(5.13)	(7.13)	(4.99)
Market stability	-0.100***	-0.130***	-0.088*	-0.093**	-0.125**	-0.089*	-0.090**	-0.119**	-0.090*
	(2.76)	(2.61)	(1.71)	(2.56)	(2.52)	(1.72)	(2.49)	(2.41)	(1.74)
Market concentration	0.002	-0.009**	-0.016***	0.002	-0.009**	-0.016***	0.002	-0.009**	-0.016***
	(0.63)	(2.36)	(4.27)	(0.66)	(2.37)	(4.25)	(0.62)	(2.37)	(4.28)
Industry variables	Included			Included			Included		
Time variables	Included			Included			Included		
Constant	-1.015***	-1.289***	-0.495**	-1.016	-1.281	-0.499	-1.014***	-1.286***	-0.491**
	(5.07)	(5.10)	(2.01)	(5.07)***	(5.04)***	(2.02)**	(5.10)	(5.04)	(1.98)
	rho21		0.372***	rho21		0.371***	rho21		0.370***
	rho31		0.343***	rho31		0.344***	rho31		0.343***
	rho32		0.732***	rho32		0.733***	rho32		0.735***
No. observations	7100			7100			7100		
Wald Test	1020.95***			1041.86***			1042.53***		
LR Test of rho21 =rho31 =rho32 = 0	1029.13***			1029.93***			1033.00***		

*$p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; t-ratios in parentheses.

5.1. Robustness checks and additional results

To test the robustness of the results, we conducted additional analyses. First, we conducted a random effects probit model including information on variables for which available information is quadrennial (*Collaboration with wholesalers/ retailers* and the use of *Technological infrastructure*). The disadvantage of this approach is that we have less observations, given that we can only build a panel with years 2002, 2006, 2010 and 2014. Thus, the number of observations available decreases from 22,902 to 7100. The results of these analyses, which are shown in Table 4, lead to similar conclusions in terms of the main variables in the case of S2B and B2B. In the case of B2C the comparison of the models indicate that the preferred model is model 3b. In this model, the variable *Production outsourcing* is positive and significant, supporting Hypothesis 1. The effect of *Technological infrastructure* is positive and significant in the case of S2B and B2B, and non-significant in the case of B2C. The variable *Cooperation with wholesalers/retailers* presents a positive and significant impact on the three technologies analysed in this paper.

Second, to reduce concerns on the effects of unobserved heterogeneity we estimated a multivariate probit model. This model assesses the correlation among the decisions to adopt the three e-business technologies considered, once we have considered the influence of the variables included in the model. If there are unobserved factors influencing the adoption of e-business, the correlations should be significant. Table 5 presents the results of the three multivariate models estimated over the 7100 observations. The conclusions are, again, consistent with those reached from the main estimations. The rho coefficients, which are presented at the bottom of the table are all positive and significant, suggesting that the adoption of the three technologies is interrelated. As mentioned, this can be interpreted as a result of the influence of unobserved heterogeneity. However, as these technologies are similar, the significant rho coefficients could also be indicating that they tend to be adopted together.

6. Discussion

In this paper, we have argued that the organization of a firm's activities along the vertical chain and its engagement in cooperation activities are important to understand the decisions of firms to adopt e-business technologies. Accordingly, we have augmented the TOE model to accommodate these two dimensions of a firm's strategy into the Organization dimension. To achieve this integration, we have used the information processing model (Galbraith, 1973; Tushman and Nadler, 1978). In this way, we extend the TOE model with two new elements that have not been considered before. Our main argument is that firms that outsource a higher proportion of their activities and those that cooperate with other agents in technological activities, let it be competitors, buyers or sellers, suffer from higher transaction costs and increase their information processing needs. To reduce transaction costs, these firms increase information processing capabilities through the adoption of e-business technologies. As a result, our hypotheses have proposed a positive relationship between the externalization of production and technological cooperation, on the one hand, and the use of e-business technologies, on the other.

To test the hypotheses, we focused on a representative sample of Spanish manufacturing firms, from which we obtained information on the adoption of three e-business technologies: those that serve to organize transactions between suppliers and firms (S2B), between businesses (B2B) and between businesses and consumers (B2C). The estimation of panel data probit models reveals that firms that outsource a higher proportion of their production are more likely to use S2B and B2B technologies. They also show that cooperation with customers and suppliers induces firms to adopt S2B and B2B technologies. However, customer cooperation is not related to B2C. This reveals that cooperation with customers and suppliers have stronger relationships with B2B and S2B adoptions than with B2C adoption.[11] Finally, cooperation with competitors is not related with any of the three e-business technologies analysed in this paper. This result could be explained because cooperation with competitors usually has as result complex relationships and difficulties in resource sharing and managing interactions. These difficulties, which are hard to avoid, might explain firms not willing to invest on e-business technologies to communicate with their competitors.

7. Conclusions

7.1. Implications for theory

This paper contributes to the literature in two ways. First, it contributes to the explanation of the adoption of e-business technologies. This is important, as the diffusion of e-business technologies has been slow compared with other technologies. The analyses of the most recent data from OECD countries shows that e-selling was only used by around one out of five firms, while e-buying is used by approximately half of the firms sampled. The figures for Spain are very close to the average in the case of e-selling and lower in the case of e-buying, given that only one third of firms had adopted the corresponding technologies in 2018. Our results offer general support to the idea that both production outsourcing and technological cooperation assist in the explanation of these figures and, in particular, in the case of S2B and B2B. In this sense, we must bear in mind that less than a half of the firms included in our sample cooperate with any of the other agents. Similarly, the percentage of firms that outsource their production is 55%. Although, by no means can this be used as a complete explanation of the low adoption figures, these elements can certainly contribute to it. In particular, they suggest that firms adapt their investments in information technologies to their needs in terms of information processing: those firms that suffer more from

[11] As one of the reviewers suggests, the non-significant sign of cooperation with customers in the case of B2C might also be due to the introduction in the model of the variable "Cooperation with Wholesalers/Retailers", which has a positive and significant impact on B2C in Tables 4 and 5.

coordination costs and transaction risks, as a result of cooperation and outsourcing, are more likely to adopt e-business. This suggestion is important for understanding differences in technology adoption between firms in a context in which firm cooperation is relatively frequent and value chains are globally distributed.

Apart from this, there are other perhaps more classical variables that also distinguish adopters from non-adopters. Making use of TOE framework these variables are structured around three elements: technological context (T), organizational context, (O) and environmental context (E). Out of the three elements, the variables included in the technological context are always positive and significant in explaining the use of e-business technologies. This finding means that firms with a deeper IT knowledge are more likely to use e-business technologies. Therefore, firms in which employees have been trained in the use of information technologies are more likely to use e-business technologies.

Regarding variables included in the dimension organizational context, larger, more diversified, more internationalized or that are at least partially owned by foreign investors are more likely to adopt some but not all the e-business technologies analysed. This means that the advantages of size or the knowledge transfer for the participation in international markets or the presence of foreign investors do not prevail. This result reveals that e-business use is not a phenomenon associated exclusively to large, diversified, or internationalized firms. Therefore, our results indicate that such variables have different impact on the likelihood of using the three e-business technologies considered.

In relation to environmental context, market stability and market concentration also clarify why manufacturing firms are less likely to adopt e-business. This result is consistent with previous studies that have identified competitive pressure as an important determinant of e-business adoption (see for example, (Zhu et al., 2003).

Second, and more generally, the paper contributes to modeling the factors explaining the adoption of information technologies. The TOE framework of Tornatzky and Fleischer (Tornatzky and Fleischer, 1990) is a classical approach to the study of technology adoption. In the past, this model has included a variety of organizational variables, such as firm size or the international and horizontal scopes of a firm. Our proposal expands the TOE framework by considering the vertical and horizontal boundaries of a firm, a valuable addition that, to our knowledge, has not been previously considered. The reason to augment the TOE framework through these two dimensions is based on the information processing model (Galbraith, 1973; Tushman and Nadler, 1978) and leads us to contend that the increase in uncertainty motivated by cooperation and outsourcing is key to understanding why firms adopt new technologies. In particular, as argued, the uncertainty induced by cooperation and outsourcing increases information costs and elevates coordination costs and transaction risks. As we have shown, the consideration of these two variables has proved useful to explain why some firms are more likely to use e-business technologies than others. Although one might think that the addition of these two variables is specific to e-business, there are other technologies that could also be affected by them and in particular, those technologies whose focus is external (beyond firm technologies). More generally, the integration of the information processing model of Galbraith (1973) and Tushman and Nadler (1978) and the TOE framework (Tornatzky and Fleischer, 1990) may be used in the future for theoretical developments that improve our understanding of the organizational variables that explain technology adoption.

7.2. Implications for practice

This paper has implications for (1) managers, (2) vendors, and (3) governments. First, if the technologies analyzed in this work are related to productivity (Falk, 2005; Quirós Romero and Rodríguez Rodríguez, 2010), the results suggest that only a small group of companies is benefiting from better performance. Even if the differences in productivity were only achieved in the technologies used for purchase and not in those used for sale (Criscuolo and Waldron, 2003; Quirós Romero and Rodríguez Rodríguez, 2010), the data from our sample suggest that somewhat more than 70% of Spanish companies had not adopted S2B in 2014 and those corresponding to 2018 indicated that only 30.75% of companies had adopted e-buying technologies. As we mentioned at the beginning, it is important to bear in mind that there are significant differences in the adoption of these technologies between different countries, which would have clear repercussions on their productivity. In any case, our results suggest that there are common drivers of this adoption, mainly in the case of S2B and B2B, such as the outsourcing of production, cooperation with customers and suppliers, the training of human resources, or the existence of previous technologies in the company, among other factors. As can be seen, managers can act on some these variables and, therefore, facilitate the adoption of e-business technologies. Second, and following this line of reasoning, to the extent that our paper characterizes the firms more prone to the adoption of e-business technologies, it offers key information to vendors to identify the firms more likely to use them. Following the proposal of this paper, firms outsourcing production and collaborating with other agents are more likely to invest in S2B and B2B technologies.

Finally, governments could incentivize the adoption of e-business technologies through policy measures. For example, by providing firms with incentives to train their human resources in information technologies. Regarding firm size, although our main results show a lower likelihood of small firms to adopt e-business technologies, the additional results presented in Tables 4 and 5 are not fully consistent with this result. This is, however, consistent with previous papers analyzing the adoption of e-business technologies and related technologies. For example, the finding is consistent with the empirical results of Oliveira and Martins (2010)) and Wang and Cheung (2004). Similarly, they are also consistent with the analysis of e-market adoption (Duan et al., 2012), e-SCM adoption (Lin, 2014) and ERP adoption (Ilin et al., 2017). Given the focus on firm size of European policies directed at digitization, this results should be taken into account in policy design.

7.3. Limitations and future research

It is also important to highlight the limitations of this paper. First, the information provided belongs to a sample of Spanish

manufacturing firms. It is well documented that firms in Spain tend to be smaller than their European counterparts (European Commission, 2003; Galan et al., 2005) and this could partially explain the lag in adoption of e-business technologies in comparison with firms operating in countries with higher adoption intensities. Second, the information provided only allows us to know whether a firm has adopted the technology or not, but we do not have information on the intensity of the investments performed. Thirdly, our measures of outsourcing and cooperation are limited to given steps in the value chain, in the first case, and to some types of cooperation agreements. Future research could offer a more comprehensive study of how firms organize their vertical and horizontal boundaries and re-evaluate their consequences on technology adoption.

In particular, it would be interesting to have information on the type of supplier providing inputs and, more precisely, whether the supplier is domestic or foreign. The reason is that some of the problems described in the theory, such as the one that refers to coordination costs, will become much more evident in an international context, in which companies are not only geographically distant, but they also are culturally different. Similarly, we also do not have information on whether the cooperation is carried out with domestic companies or foreign companies. As one of the referees suggests, if the companies are domestic and consequently, geographically closer to the target company, it would be expected that there would be less needed to use e-business technologies than if they were geographically distant companies. Finally, technological cooperation can take many different forms. For example, it can be a cooperation through alliances, or it can materialize using licenses or with the creation of a joint venture (Schilling and Shankar, 2019). These formulas generate differences in terms of the costs of coordination and the risks associated with the transaction and, therefore, could explain differences in the incentives to adopt e-business technologies.

Appendix 1

The following lines present the questions that have been used to construct each of the variables. We start by the dependent variables appear and then we present the independent and control variables.

Dependent variables.

S2B, B2C and B2B adoption.

State the use of new internet-based technologies by your company in 20XX.

	No	Yes
You buy goods or services (suppliers) through internet (S2B)		
You have a sale system for final consumers through internet (B2C)		
You have a sale system for other companies through internet (B2B)		

Independent variables.

Production outsourcing.

State whether in 20XX you contracted with third parties the manufacture of custom-made finished products or parts. If so, state its value.

	No	Yes	Value in euros
Your company provides the materials			
Your company does not provide the materials			

Technological cooperation.

State whether in the year 20XX the company had carried out the following actions.

	No	Yes
There was technological collaboration with customers		
There was technological collaboration with suppliers		
There was technological collaboration with competitors		

Control variables.

Technological context variables (T).

Technological infrastructure.

State whether the production process uses any of the following systems:

	No	Yes
Computer-digital machine tools		
Robotics		
Computer assisted design		
Combination of some of the above systems through a central computer (CAM, flexible manufacturing systems, etc.)		
Local Area Network (LAN) in manufacturing activity		

IT human resources.

State the external expenses in training incurred by your company in xxxx, according to the following items.

	No	Yes	Value
Computing and information technologies			
Foreign languages			
Sales and marketing			
Engineering and technical training			
Other issues			

Organizational context variables (O).

Firm size.

	Number of employees
Total staff in the company at 31–12–20XX	

Export intensity.

State whether the company, either directly or through other companies belonging to the same group, exported goods or services in 20XX (even in the European Union) and their value.

No
Yes
Value

Summary of some items of the Operating account.

Total Sales (general chart of accounts)	Value

Diversification.

State in order of importance the main products manufactured by this company in 20XX, indicating the percentage which one represents over the total of sales in the year, until reaching at least 50% of the turnover.

	% of sales
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

From this information, a categorical variable is built (by the data provider) that indicates whether the company is diversified and, in the latter case, if diversification is related or unrelated. Therefore, the variable takes three states, based on the National Classification of Economic Activities (CNAE-09) at 2 and 3 digits:

0 = The company is not diversified (it only defines a 3-digit product).

1 = The company has related diversification (defines more than one 3-digit product and these are in the same 2-digit sector).
2 = The company has unrelated diversification (defines more than one 3-digit product and some of these are in a different 2-digit sector).

R&D intensity.

State the R&D expenses made by the company in 20XX, according to.

	It does not have	It has	Value (euros)
External expenses			
Internal expenses			
Total expenses			

Summary of some items of the Operating account.

Total Sales (general chart of accounts)	Value

Foreign capital.

State whether into the company's capital there was some foreign participation directly or indirectly and its percentage in 20XX.

No	Yes	Percentage

Cooperation with wholesalers/retailers.

State whether the company subscribed in 20XX commercialization agreements with wholesalers or retailers.

No
Yes

Environmental context variables (E).

Market stability.

Define the main market or markets which the company serves, so that:

- They represent, at least, 50% of total sales.
- They can be identified by the product line, customer kind to which they are sold, or any other characteristic which you might consider necessary

M1	1st market	% total sales	In expansion Stable In decline
M2	2nd market	% total sales	In expansion Stable In decline
M3	3rd market	% total sales	In expansion Stable In decline
M4	4rd market	% total sales	In expansion Stable In decline
M5	5rd market	% total sales	In expansion Stable In decline

Industry variables.

Activity.

Describe in detail the company's main activity

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