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Are in-house and outsourcing innovation strategies interlinked? Evidence from the European agri-food sector

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The paper investigates the determinants of innovation strategies in the agri-food sector and the potential complementarity of these strategies. Innovation strategies are distinguished as in-house and outsourcing. The choice between strategies is motivated by transaction cost minimization, property rights appropriation and optimization of firms' resources and competences. A bivariate probit model is implemented using cross-section data on 1,393 agri-food firms in seven EU countries. Results show that: decisions to innovate in-house or to outsource are not interlinked; high quality human resources and the use of ICT influence both the decision to innovate in-house and outsourcing, while organizational aspects, especially those related to decision-making within the firm, are relevant only for in-house innovation. Finally, we also find that large and internationalized firms are more likely to innovate in-house.

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1. Introduction[1]

It is widely recognized that innovation strategies are a key determinant of firm performance and competitiveness (Cruz-Cázares et al., 2013; Han and Bae, 2014; Huang et al., 2009). Firms are increasingly forced to actively decide on their organisational boundaries to innovate, either through in-house innovation activities or by outsourcing at least part of the innovation process. In recent years, outsourcing has gained in importance as an innovation strategy (Han and Bae, 2014; Narula, 2004). The increase in knowledge content of products has driven firms to utilise external means to innovate. A large number of studies have investigated and tried to explain this phenomenon (see (Huang et al., 2009) for an overview). There is no question that outsourcing, commonly defined as the transfer of activities and processes previously conducted internally to an external party is one of the most sustained trends of concurrent business (Hätönen and Eriksson, 2009). Different strands of the literature offer different visions of how to define the outsourcing concept and some of them are antagonistic (Hätönen and Eriksson, 2009; Rama and Holl, 2013). While innovation strategies are sector-specific (Alfranca et al., 2004), most of these studies have focused on manufacturing and there is little empirical evidence on innovation strategies in agri-food firms (Hernández-Espallardo et al., 2011; Pascucci et al., 2011, 2012; Triguero et al., 2013). An explanation of the limited research interest in innovation studies on the agri-food sector can be that the sector is generally believed to be a low-tech industry displaying low innovation intensity (Mark-Herbert, 2004; Triguero et al., 2013). However, several authors claim that innovation processes in the agri-food industry are becoming more complex, maybe even more than in other sectors (Enzing et al., 2011; Rama, 2008). Reasons for this development include the biotechnology revolution and the increased pressure to maintain better process controls to guarantee food safety, variety and quality. These developments are, for instance, especially relevant for the rise in functional foods, a novel food category that combines technological know-how from both the medical and the food domain (Mark-Herbert, 2004; Triguero et al., 2013).

The contribution of this article to the existing literature investigating firms' innovation strategies is threefold. First, the focus of this study will be on the agri-food sector. While some authors claim that innovation activities in the agri-food sector are dominated by

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multinational food companies (Alfranca et al., 2004), the sector itself is dominated by small and medium sized companies (SMEs). In light of increased innovation pressure, it will be especially relevant to see how these SMEs are affected. Second, the literature on firms' decisions to use external or internal resources to innovate has generally ignored the potential complementarity between these strategies. The various strands of extant empirical research are in fact inconclusive about the complementarity or substitutability between different innovation mechanisms, such as internal and external R&D (Cassiman and Veugelers, 2006; Cruz-Cázares et al., 2013; Hagedoorn and Wang, 2012). The current study will explicitly allow to assess complementarity or substitutability between in-house production and outsourcing of innovation processes in the agri-food sector. Finally, most of the previous research on innovation strategies in the agri-food sector is based on case-studies or on small samples of firms (Triguero et al., 2013). This study will use the EU-EFIGE Bruegel-UniCredit dataset (in short, EFIGE), a database collected within the EFIGE project[2]. The dataset consists of a representative sample (at country level) of around 15,000 surveyed firms in seven European countries (Austria, France, Germany, Hungary, Italy, Spain, United Kingdom). The sub-sample that we will employ in the current study contains around 1,400 agri-food firms. Data were collected in 2010, covering the years 2007 to 2009.

The next section will present the basis for the conceptual framework and focuses on the central contributions of transaction cost economics and the resource-based view of the firm. Section 3 derives specific hypotheses about the determinants of agri-food firms' strategies to innovate in-house or to source innovations externally. The framework also presents arguments about the conditions under which in-house production and outsourcing are expected to be complementary strategies. Section 4 presents the data and research methodology. Section 5 discusses the results. Finally, we present the discussion and conclusions.

2. Literature review on antecedents of innovation strategies

Transaction Cost Economics (TCE) has been the dominant paradigm in the study of the "make or buy" decision across different contexts, including innovation governance (Arvanitis and Loukis, 2013; Gooroochurn and Hanley, 2007; Pascucci et al., 2011, 2012; Stanko and Calantone, 2011; Williamson et al., 1989). According to TCE, internalisation (the "make" or "in-house" decision) minimizes transaction costs when uncertainty, asset specificity, and

[2] "European Firms in a Global Economy": internal policies for external competitiveness. The project has been supported by the Directorate General Research of the European Commission through its 7th Framework Programme and is coordinated by Bruegel.

appropriability are relatively high (Teece, 1986; Williamson et al., 1989); conversely the market (the "buy" or "outsourcing" decision) is preferred (Williamson, 1985). Transaction costs include: adaptation costs, namely efforts to adjust contracts to changing conditions resulting from environmental uncertainty; safeguarding costs, i.e. the costs of preventing opportunistic behaviour by a contracting partner after the contract is signed; measurement costs, the costs to verify contract compliance (Stanko and Calantone, 2011). High asset specificity and uncertainty can lead to high adaptation, safeguarding and measurement costs. Under these conditions firms may decide to internally control resources and outputs. Empirical studies find an unambiguous relation between higher asset specificity and internal innovation efforts and governance. The measures used to proxy asset specificity include sunk costs such as R&D (Gooroochurn and Hanley, 2007; Pascucci et al., 2011, 2012), the use of proprietary technologies and of skilled labour (Cruz-Cázares et al., 2013), and measures for firm diversification (Nakamura and Odagiri, 2005). Uncertainty is often analysed through two main dimensions. On the one hand, scholars have investigated market uncertainty as uncertainty related to the unpredictable fluctuation of demand. However, no significant empirical findings have been found for its impact on innovation governance decisions (Gooroochurn and Hanley, 2007; Love and Roper, 2005). On the other hand, scholars have used technological uncertainty as a dimension of uncertainty related to the firm's inability to forecast technical requirements. Commonly used proxies of technological uncertainty are R&D projects at the early/advanced stage, project duration and number of technologies used. Empirical findings about the impact of this type of uncertainty have been ambiguous (Calantone and Stanko, 2007; Stanko and Calantone, 2011).

The Resource-Based View of the firm (RBV) has been the second main paradigm to explain firms' outsourcing decisions. Resources include all assets, capabilities, organisational processes and knowledge controlled by a firm. In this sense, RBV overcomes some criticisms of TCE, namely that it fails to incorporate innovation, learning and the nature of knowledge (Nooteboom, 2004; Pascucci et al., 2012; Teece, 2007). RBV adds a dynamic ability in the development of new competences and resources instead of focusing only on the static dimension of efficiency as in TCE (Nooteboom, 2004). Several antecedents have been found in the literature for the decision to outsource. First, following the RBV perspective, external R&D is selected for those activities in which the firm is not specialised or that are non-core activities (Cruz-Cázares et al., 2013). Second, with regard to appropriability, namely the extent to which results from innovative activities can be protected and are not easily diffused

within an industry (Stanko and Calantone, 2011), studies confirmed that the threat of losing intellectual property makes internalisation more likely. Third, the path to competitive advantage matters: when technological competence is not viewed as a viable path to competitive advantages, firms favour outsourcing. Finally, low cost goals, profit margins, and firm size matter. Empirical evidence suggests that low cost goals are negatively associated with outsourcing, while high profit margins are conducive to external sourcing. However, findings differ according to the technology level of the industry. In terms of the dimension of the firm, small firms tend to either exclusively develop technology in-house or contract development externally, while larger firms tend to adopt both strategies simultaneously (Veugelers and Cassiman, 1999).

3. Factors affecting innovation strategies in agri-food firms

Starting from the TCE and RBV frameworks presented in section 2, this section adds insights from the strategic management literature and the specific features that characterize the agri-food sector to derive hypotheses about the innovation outsourcing decisions of food firms.

The relationship between the level of technological resources and strategy selection has not been extensively studied in the literature. ICT can be seen as an asset of a firm, justifying the choice to innovate in-house to benefit from the derivative advantages. However, some scholars have argued that the more technological resources available to the firm, the greater the probability of outsourcing innovation (Zhao et al., 2005). Extensive internal and external communication networks can be seen as a precondition for firms that outsource innovation activities since they increase the firm's absorptive capacity to facilitate the necessary scanning and integrating activities when firms acquire knowledge and technologies from outside their boundaries (Cruz-Cázares et al., 2013). Hence, openness to other firms could also help to manage complex ICT systems. Moreover, a low level of technological resources indicates that R&D is not a core activity of the firm. Furthermore, ICT reduces the external transaction and coordination costs making it feasible for firms to outsource activities (Arvanitis and Loukis, 2013).

Hypothesis 1. **(1a)** A sophisticated ICT system leads to in-house innovation to internalize benefits. **(1b)** On the other hand, complex ICT systems can also lead to outsourcing to share the management of complex systems.

Human capital endowment, a factor complementary to the intensive use of ICT and of flexible forms of workplace organization, is also expected to influence the decision to innovate in-house or to outsource (Arvanitis and Loukis, 2013). In particular, human capital endowments determine the firm's capacity to develop and implement R&D projects and represents a decisive factor with regard to the type of innovation achievement (Cruz-Cázares et al., 2013). The presence of highly qualified employees and employees dedicated to R&D activities represents an asset specificity leading to innovating in-house. On the other hand, if it is considered as a dynamic capability, specific human capital endowments can also lead to the innovation outsourcing strategy.

Hypothesis 2. (2a) Companies with a high share of employees dedicated to R&D activities and with a high share of highly-skilled employees are more likely to innovate in-house to protect these specific assets. **(2b)** On the other hand, highly skilled or highly specialised employees can also lead to outsourcing of innovation for companies that want to exploit dynamic capabilities.

The impact of product and process innovation in the strategy decision of the firm is another interesting aspect we consider. For example, according to (Veugelers and Cassiman, 1999), process innovation is more likely to be outsourced than product innovations. Product innovation is considered as a firm-specific input, therefore leakage through outsourcing has more important strategic implications than for generic process innovations. Leakage over generic R&D innovations cannot be used opportunistically by the supplier firm since most firms are contracting these innovations.

Hypothesis 3. Process innovation is more likely to be outsourced than product innovation.

Previous studies have identified chain and network relations as a factor that can influence the decision of a firm to outsource innovation (Pascucci et al., 2011). These relations include the linkages between the agri-food firm and other actors in the food chain and may reflect the attitude to enter into formal and/or relational networks (consortia, production-based associations, manufacturing joint-ventures, informal contracts). The positive influence of such "networking" attitudes on innovation capacities is derived from the possibility to share information and "know-how", the reduction of uncertainty and increasing economies of scale for the involved firms (Teece, 1996). Furthermore, the expertise gained in managing intra-

group relationships may be a capability of the firm that can be further exploited by engaging in extra-group activities (Love and Roper, 2001). Being part of a business group in fact eases outsourcing agreements by reducing transaction costs within the group and improving appropriability conditions over R&D results. Accordingly, firms belonging to business groups may be less reluctant to buy R&D from external sources that belong to the same group.

Hypothesis 4. Firms that are part of a larger group of companies are more likely to outsource innovation activities and to access group resources.

There are some particular organizational characteristics of a firm that favour the outsourcing of innovation because of the reduction of transaction and coordination costs inside the firms. One such organizational characteristic is the level of decentralization of decision-making inside the firm (Arvanitis and Loukis, 2013), the other is the functional flexibility of labour (Storey et al., 2002). The decentralization of decision-making in firms in advanced industrialized countries is driven by a variety of inter-related forces such as the introduction of computerized information and communication systems (Lindbeck and Snower, 2000). As a result, occupational barriers are dissolving, more attention is given to the capacity of people to acquire and use multiple skills, greater emphasis is placed on continuous learning and skills development, the ability to exploit complementarities, the sharing of tasks and the opening up of the boundaries of the firm.

Hypothesis 5. Firms with a relatively high degree of decentralization of decision-making inside the firm are more inclined to outsource innovation activities.

In the face of the increased use of fixed-term and of part-time contracts to reduce operating costs, questions arise about the influence these flexible employment forms may have on the capacity and probability to innovate and on innovation performances (Martínez-Sánchez et al., 2009; Michie and Sheehan, 2003; Storey et al., 2002). To our knowledge, however, very little attention has been devoted in the literature to the impact of flexibility specifically on innovation strategies, even less with reference to the agri-food sector. On the one hand, flexibility of employment could be part of an in-house innovation strategy as highly skilled employees are hired specifically to develop a certain innovation within the firm. On the other hand, in-house innovation may also require permanent employees that know best how to use the firms' resources and capabilities to develop innovations. Similar reasoning could also hold

for the opposite situation: being able to benefit from open innovation processes, the implementation of outsourced innovations could also require more permanently employed employees that are familiar with the internal workings of the firm and that know best which external technologies are most appropriate for the firm. This suggests the need for caution in interpreting the estimates.

Hypothesis 6. The impact of flexibility in employment contracting on the decision to outsource or internalize innovation is uncertain.

The firm's level of internationalisation represents an important commercial resource, namely the reputation and relationship with foreign clients. By internationalizing, firms create new networks and gain access to foreign knowledge and technologies, which could reduce the transaction costs with potential suppliers. This may facilitate the decision to outsource innovation. (Görg et al., 2008) argue that exporters have a potential advantage vis-à-vis non exporters in accessing extensive knowledge about where to procure low-cost inputs in the world market, which is an important precondition for outsourcing (Arvanitis and Loukis, 2013).

Hypothesis 7. The higher the firm's degree of internationalization, the higher the probability of selecting the outsourcing strategy.

The proprietary and ownership features of a firm and its dimension (size) are important strategic variables. (Carrasco-Hernández, 2013) suggests that the relationships among the members of family firms can foster the development of innovations, although this relationship could be conditioned by the family that owns the firm. Small and medium-sized enterprises are mostly family owned in many economies (Dunn, 1996), and this is particularly true for agri-food firms. Like other firms, in order to be competitive, family businesses have to be innovative. They can be more innovative and "aggressive" in their markets due to their relatively smaller size, greater (local) market knowledge and relative financial independence compared to large companies (McCann et al., 2001). However, family firms may be ill-equipped to build innovation capabilities, their financial resources are more limited, and/or their family members are overly concerned with wealth preservation, and thus limit their investments (Carney, 2005). Creating innovative capabilities requires extensive investment in R&D and technological diversification, and it usually forces the family to establish business

associations, or cede some ownership to parties outside the firm, such as venture capitalists or institutional investors (Carrasco-Hernández, 2013).

Hypothesis 8. Family owned firms are more likely to outsource innovation activities.

Although the food industry initially lagged behind in terms of quality certification (e.g. ISO9000), increased competition and the growing power of retailers have forced food firms along the entire chain to reorganise quality systems and implement standards (Avermaete et al., 2003). Some studies show that the implementation of these standards in food firms may potentially result in innovation in products and processes and lead to competitive advantages. Implementation of ISO 9000 in small food firms in particular implies a radical change in the organisation and puts conditions on the technologies and materials used in processing (Avermaete et al., 2003). To our knowledge, the impact of quality certification on the decision whether to innovate in-house or to outsource has not received attention in the literature yet. Our hypothesis is that quality certification represents part of an in-house innovation strategy since it helps to save on transaction costs associated with the search of appropriate suppliers and customers, the negotiation of contracts and their control (López-Mielgo et al., 2009).

Hypothesis 9. Quality certification has a positive impact on in-house innovation activities.

The theoretical literature drawing on TCE and property rights considers the choice between external sourcing and internal development as substitutes (the classic dichotomy "make *or* buy"). Unless outsourcing stresses the advantage of tapping existing, specialized knowledge, it may create considerable transaction costs, ex-ante in terms of search and negotiation costs, and ex-post to execute and enforce the contract (Veugelers and Cassiman, 1999). At the same time, however, it is often the complexity of transactions that pushes towards the adoption of *plural* forms of organization and governance of innovation (Ménard, 2013). Absorptive capacity and open innovation, on the contrary, stress that in-house and outsourcing can be regarded as complementary strategies rather than alternatives (Cassiman and Veugelers, 2006; Cruz-Cázares et al., 2013). Own in-house R&D activities are in fact often found to reduce some of the inefficiencies and problems associated with external acquisitions, if only because they allow to modify and improve external acquisition (Veugelers and Cassiman, 1999) and to facilitate a smooth assimilation of any externally acquired technology, through the notion of *absorptive* capacity (Arora and Gambardella, 1990); (Cohen and Levinthal, 1989). On the

one hand, then, a stream of empirical research identifying the relationship between internal and external sources of innovation have found substitutability (or no complementarity) between these activities (Hagedoorn and Wang, 2012; Hess and Rothaermel, 2011). On the other hand, a number of studies have demonstrated that internal R&D and external technology sourcing are complementary innovation activities, suggesting their interrelatedness in improving a firm's innovation performance(Cassiman and Veugelers, 2006; Hagedoorn and Wang, 2012) Existing studies indicate that the complementarity or substitutability of innovation strategies is conditional upon the sector. (Arora and Gambardella, 1990) for example find complementarities in the internal and external linkages of large chemical and pharmaceutical producers in the new biotechnology business. (Cruz-Cázares et al., 2013) support this finding for high tech industries; (Veugelers and Cassiman, 1999) find that most of the Belgian agri-food firms use a combination of strategies, although small firms have a higher probability of using an exclusive make or buy strategy and are less likely to combine these strategies as compared to the larger firms.

Hypothesis 10. In the agri-food sector, in-house and outsourcing innovation strategies are more likely to be substitutes than complements.

4. Data, empirical methodology and variable definitions

4.1. Sample

The analysis in the paper exploits EFIGE, a database collected within the EFIGE project supported by the Directorate General Research of the European Commission through its 7th Framework Programme and coordinated by Bruegel[3]. The dataset has several unique features. First, in order to be representative of the manufacturing structure of the seven countries covered (Austria, France, Germany, Hungary, Italy, Spain, United Kingdom), it is stratified by industry, region and firm size structure. Second, data are fully comparable across countries, since EFIGE derives from responses to the same questionnaire administered over the same time span (January to May 2010). Finally, for the first time in Europe, it combines quantitative and qualitative information on firms' characteristics and activities, for numerous items split into six sections (proprietary structure of the firm; structure of the workforce; investment, technological innovation and R&D; internationalisation; finance; market and pricing). Most of the questions refer to 2008, some ask for information related to 2009 and

[3] Bruegel is a European think tank based in Brussels specialising in Economics (http://www.bruegel.org/about/).

years prior to 2008 in order to obtain a picture of the effects of the crisis as well as the dynamic evolution of firm activities (Altomonte et al., 2013). Data are cross-sectional and have the advantage of being neither focused on nor limited to innovative firms, which could have led to selection bias.

For the analysis in this paper, 1,393 firms have been selected as representative of the European agri-food manufacturing sector according to the Statistical classification of economic activities in the European Community (NACE 2). Almost 33% (459) of the sampled firms is based in Spain, 24% (330) in Germany, 17% (238) in Italy and 15% (212) in France. The majority of firms in the sample (86%, 1199 firms) is active in the manufacturing of food products, with 339 firms (24%) involved in the manufacturing of bakery and farinaceous products, 327 firms (24%) involved in the processing and preserving of meat and in the production of meat products, and 320 firms (9%) in the processing and preserving of fruit and vegetables. The remaining 14% of the sample (194 firms) are manufacturers of beverages. Table 1 shows that the food sector in Europe is dominated by firms with less than 50 employees, with only 8% of the sample reporting more than 250 employees[4].

INSERT HERE TABLE 1

In terms of turnover (table 2), 38% of the sample (524 firms) declares a turnover between 2 and 10 millions of euro, while 15% (215) declares a turnover of less than 1 million and only 2% (29) reports a turnover in 2008 greater than 250 million euro. In terms of the legal form, 64% (892) of the sampled firms are limited liability corporations (table 3).

INSERT HERE TABLE 2 AND TABLE 3

Considering the innovation features of the surveyed food firms, confirms the low innovation intensity of the agri-food sector observed by other authors. Almost 28% of the sample (389 firms) declares that they did not introduce any process or product innovation and they did not carry out any R&D activity in the period 2007-2009. These firms are small and medium firms (less than 250 employees), almost 76% (294) is family owned, 69% (253) are limited liability corporations and more than 11% of the 389 firms belongs to a larger group of firms. Hungary presents the highest percentage of non-innovative firms (37%), followed by Germany (33%) France (29%) and Italy (28%). None of these firms declared any investments in R&D and

[4] The survey excludes firms smaller than 10 employees.

almost 14% of them (54) did not invest any percentage of their turnover in plants, machines, equipment and ICT in the period 2007-2009.
In terms of efforts for R&D activities, almost 40% of all firms in the sample (556) declared to have invested a percentage of their turnover in R&D in the period 2007-2009. The remaining firms (814) declared they did not undertake any R&D activity, however, almost 89% of them (724) invested in the same period a percentage of their turnover in plants, machines, equipment and ICT; 38% (275) of them declared they had carried out some product innovations, 32% (234) carried out process innovations.

4.2 Variables for the empirical model

Dependent variables

The set of data considered allows us to define two dependent variables for our analysis. The first is INHOUSE and refers to firms that declared to have undertaken *internal* activities of research and development, meaning that they realized research activities in their laboratories and they appropriated the results of their research. In other words, these firms possess property rights on patents, copyrights and trademarks created using internal resources. INHOUSE was constructed as a combination of five different indicators: whether the firms claimed to have performed R&D activities only internally in 2007-2009; whether they applied for a patent, registered an industrial design, registered a trademark, or claimed a copyright in the same period. INHOUSE then takes the value 1 when firms declared at least one of these activities, 0 otherwise.

The second dependent variable is OUTSOURCING and aims at representing all the research resources acquired from outside the firm and the investments in external activities, such us technologies, machines, innovations developed by other firms. The variable was indeed constructed based on three variables: ICT_INVEST, R&D_OUTSOURCED, EXT_R&D. In the former, firms declared to have invested in plants, machines, equipment and ICT in the period 2007-2009, in the second that they have acquired R&D from another firm in the group, in the third to have acquired R&D from external (to the group) sources. OUTSOURCING than takes the value 1 if firms declared investments in plants, machines, equipment and ICT greater than 0% and/or declared to have acquired R&D externally to the firm (in the group) or to the group (externally). Therefore, it indicates efforts to buy and outsource technology and

activities for which internal resources are not sufficient. Table 4a presents the descriptive statistics of these variables.

INSERT HERE TABLE 4a

Almost 92% of the European food-firms (1,277) outsource innovation (see table 4b), while 45% (633) adopts both in-house innovation strategies and outsourcing. Outsourcing innovation seems however to be the most common strategy. This is not surprising if we consider that in an era of increasingly specialized processes and products, firms have incentives to combine R&D internal and external resources (Cruz-Cázares et al., 2013). Moreover 3% of the firms (43) only innovates in-house and 46% (644) only outsource innovations.

INSERT HERE TABLE 4b

Independent variables

A description of the independent variables used in the model is presented in table 5 together with the explanation of the respective hypothesis we want to test using them. Means and standard deviations are presented in table 6. From the descriptive statistics it emerges that on average, almost all the firms involved in the EFIGE dataset have a broadband connection (mean 0.847 for the respective dummy variable), with a standard deviation of 0.360, and on average these firms are run as family firms (mean 0.749, standard deviation 0.434). The majority of them do not belong to group of firms (mean 0.174), and have an average a centralized management of the decision making process.

Control variables

The age of the firm can proxy its organisational complexity, potentially representing the experience, the knowledge accumulated throughout a firm's history, the "learning" process of the firm, the firm's entrepreneurial behaviour and the time since establishment (Avermaete et al., 2003; Galende and de la Fuente, 2003; Santamaría et al., 2009). The role of firm age has been however controversial in the literature. Some studies show the higher inclination to innovate by "old" firms, while some other considered "young" enterprises as more active in the direction of innovation (Pascucci et al., 2011). In this paper, AGE is measured as the number of years since the firm's establishment. Since the in-house innovation strategy requires high organizational capabilities to control the complex process of innovation, we make the hypothesis that younger firms with scant experience, a small knowledge base and

without routines rarely established will select the outsourcing innovation (Cruz-Cázares et al., 2013).

The role of firm size is another controversial issue in the literature (Avermaete et al., 2003; Traill and Meulenberg, 2002). In general, large firms have greater financial resources and more highly qualified personnel to innovate internally, while small firms are more likely to engage in less risky activities and to buy or outsource innovation (Cruz-Cázares et al., 2013; Love and Roper, 2001). Empirical evidence, however, is not clear cut, since some studies have found that large firms opt more for the in-house option as they want to take advantage of the economies of scale generated by internal R&D, marketing and production activities (Stock et al., 2002; Tsai, 2001), other studies have reached opposite conclusions (Love and Roper, 2001). Some studies (Veugelers and Cassiman, 1999) have also found that small firms prefer to restrict their R&D strategy to either make or buy, while large firms usually combine both strategies simultaneously, stressing for the complementarity of the two innovation strategies (Cruz-Cázares et al., 2013). Other authors claim that small and medium firms can more easily adapt to market conditions since they have a higher internal flexibility, a better flow of internal communication, greater specialization possibilities, as well as a higher informal and strategic control (Galende and de la Fuente, 2003). As a result, small and medium firms are expected to be more open to collaborative forms of innovation and outsourcing. In our model, therefore, we control for SME, a dummy variable capturing the effect of being a small-medium firm (less than 250 employees) on the decision to innovate in-house or to outsource.

Finally, legal status can be considered as another determinant of firm dynamism, also in the agri-food sector (Traill and Meulenberg, 2002). Privately owned firms are in general more dynamic and innovative than state owned enterprises. State ownership is particularly constraining to core innovation as well as to opening new plants and signing new joint ventures and licensing agreements (Ayyagari et al., 2006). Firms organized as corporations are more dynamic than firms organized as proprietorships, partnerships or cooperatives (Ayyagari et al., 2006). However, empirical evidence on the relationship between legal form and innovation strategies is lacking.

The context in which firms operate also represents a factor potentially influencing innovation sourcing decisions (Avermaete et al., 2003). In particular, the geographical location of food firms and the (technological and also political) environment in which they operate can be a key factor in explaining the different attitudes to innovativeness (Avermaete et al., 2003; Love and Roper, 2001; Pascucci et al., 2011, 2012). The specific location of a firm is important to

understand the opportunities to use local resources (e.g. research capital) as a source of knowledge and innovativeness (Capitanio et al., 2010). We control for public (government) and private (business) sector expenditures for research and development as a percentage of GDP in the region in which the firm is located (BUS_GERD_PER_REG and GOV_GERD_PER_REG), and for the presence of public incentives as financial aids the firms receive[5] (PUBL_INCENTIVES). Moreover, we control for the countries and the specific sector in which the firm operates by adding dummies.

INSERT TABLE 5 AND TABLE 6

4.3 Empirical methodology

A commonly used approach to estimate the probabilities of choosing between alternative strategies is to implement a discrete-choice model (Masten and Saussier, 2002). In this case the observed innovation strategy (i.e. in-house or outsourcing) is considered as an expression of a continuous latent variable reflecting the propensity to choose a specific option among different alternatives. The generic empirical model related to firm j to choose an innovation strategy s can be written as follow:

$$Y_{sj}^{*} = X_j'\beta_s + \varepsilon_{sj} \quad \forall s \in S \qquad (1)$$

$$Y_{sj} = 1 \; if \; Y_{sj}^{*} > 0 \quad \forall s \in S \qquad (2)$$

$$Y_{sj} = 0 \; otherwise$$

where Y_{sj}^{*} is the unobservable value of the strategy s for firm j (latent variable), Y_{sj} is the observable strategy choice, for s = 1 in case of in-house strategy and s = 2 in case of outsourcing strategy. X_j' is the vector of explanatory variables, as defined in section 4.2, for firm j, β_j a vector of coefficients for strategy s and ε_{sj} a vector of unobservable characteristics related to firm j and strategy s. We can derive the probability that strategy s is chosen by firm j (γ_{sj}) as a function of the potential explanatory variables:

$$\gamma_{sj} = P(Y_{sj} = 1) = P(Y_{sj}^{*} > 0) = P(X_j'\beta_s + \varepsilon_{sj} > 0) = P(\varepsilon_{sj} > -X_j'\beta_s) = F(X_j'\beta_s) \quad (3)$$

where F denotes the distribution function if the unobservable characteristics ε_{sj}. Different econometric strategies can be implemented accordingly to the nature of the strategic choice analysed and the distributional form it is assumed for F (Verbeek, 2004). A relatively common approach is to use separate logit/probit models to depict the basic binary choice of

[5] Not specific for innovation. Selection biases emerge if we use R&D specific incentives: only those firms declaring R&D activities show these incentives, for the other firms the data are missing.

(in our case) innovate through in-house or outsourcing strategies. This would lead to a system of (two) equations. The implicit assumption is that the probability of innovating in-house is independent from the probability of outsourcing. But there is a good chance that the firm likelihood to innovate in house is conditional to the decision whether or not to outsource innovation. In other word these decisions are likely to be interrelated. The usual alternative would be to estimate a bivariate probit model. For each choice (in-house or outsourcing) a probit model is estimated and it is assumed that the error terms for the two equations are correlated. The bivariate probit model enables us to model the decisions to choose more than one strategy simultaneously (Greene, 2008). Since the outcomes are treated as binary variables, any combination of strategies is possible. The strategies can be complements rather than substitutes only. The two equation model (one for s = 1and the other for s = 2) is featured by correlated disturbances, which (due to identification reasons) are assumed to follow a normal distribution (variance is normalized to unity). That is for each j_{th} firm:

$$E[\varepsilon_{1j}] = E[\varepsilon_{2j}] = 0 \qquad (4)$$

$$cov[\varepsilon_{1j}, \varepsilon_{2j}] = \rho = \{\rho_{12}\}$$

$$var[\varepsilon_{1j}] = var[\varepsilon_{2j}] = 1$$

where ρ is a vector of correlation parameters denoting the extent to which the error terms co-vary. Should this be the case, we would need to estimate the two equations jointly, following a bivariate normal distribution: $\{\varepsilon_1, \varepsilon_2\} = \phi_2(0,0,1,1,\rho)$. Because in this model we are interested in simultaneous strategic decisions, we have to define the joint probability. For example, the probability of firm j choosing in-house and outsourcing strategies at the same time ($Y_{1j} = Y_{2j} = 1$) would be:

$$\gamma_{sj} = P(Y_{1j} = 1, Y_{2j} = 1) = \int_{-\infty}^{\varepsilon_{1j}} \int_{-\infty}^{\varepsilon_{2j}} \phi_2(X_j'\beta_1, X_j'\beta_2, \rho) d\varepsilon_{1j} d\varepsilon_{2j} = \Phi_2(X_j'\beta_1, X_j'\beta_2) \quad (5)$$

In this model the log-likelihood is then a sum cross the four possible strategies variables (that is, four possible combinations of innovate ($Y_{1j} = Y_{2j} = 1$) and non-innovate ($Y_{1j} = Y_{2j} = 0$) times their associated probabilities (Greene, 2008). These probabilities may be drawn from (5) as well. The most relevant coefficients estimated in the model are β_1, β_2 and $\rho(\rho_{12})$. The latter, if significantly different from zero, will evaluate to which extent each pair of decisions are interrelated.

5. Results

Three bivariate probit models have been estimated: the pooled model, without distinguishing the effect of location and sectors, and two models adding firstly the country dummies, then

also the sector dummies. This last (complete) model will be commented in this section and the results are reported in table 7[6]. Table 8 reiterates the hypotheses and summarizes the results of the analysis.

When technological resources are captured by the ICT related variables, our results show that ICT endowment plays a role in stimulating both innovation in-house and outsourcing, therefore hypothesis 1 holds in both the directions suggested by the theoretical approaches (1a and 1b). Specifically, the results show that outsourcing is facilitated by a broadband connection and a good system of internal information management used in standard software and/or e-mailing systems, compared to a situation without internet connection. A firm is more likely to innovate in-house, when it presents IT solutions for the e-commerce (i.e., on-line purchasing or online sales systems) and the system to manage the sales/purchase network (suppliers' orders, customer service) is well developed as specific assets of the firm.

Companies with a high percentage of employees with a degree are more likely to innovate in-house to internalize the relative benefits, but the presence of a high percentage of employees dedicated to R&D activities makes no difference in terms of the strategy to adopt: the variable has a positive sign with respect to both the innovation strategies.

Table 7 shows that process innovation has a positive and significant impact on the decision to outsource innovation, while product innovation shows a significantly negative impact on the outsourcing decision. On the other hand, both product and process innovations are likely to be conducted in-house, as their positive and significant coefficients show. Therefore, it seems that for the sampled firms in-house and outsourcing strategies are used both in the case of process innovation, adding to the complementarity of the strategies when it comes to innovate in terms of processes; in-house is used only in the case of product innovation.

Result also show that the coefficient associated to the GROUP variable is not significant and shows a negative sign. Therefore, hypothesis 4 does not hold according to our empirical estimates. The empirical results conversely show quite surprisingly that the centralisation of the strategic decisions (namely, the fact that the CEO or the owner of the firm takes most decision in every area) is negatively correlated with in-house innovation, but the associated coefficient for the outsourcing strategy is not significant. Therefore, hypothesis 5 does not hold, since having a centralised decision-making system makes it less likely to innovate in house.

[6] The tables relative to the other models are available upon request.

When human resources are evaluated, in hypothesis 6 we stated that the influence of flexibility in employment contracting on the in-house or the outsourcing decision is uncertain. Results show that the coefficients associated to the two variables are not significant, therefore it is impossible to draw conclusions on the effect of this variable.

In hypothesis 7 we stated that the greater the commercial resources of the firms, the greater the probability of selecting the outsourcing strategy. The empirical results do not confirm this statement, since EXPORT shows a positive and significant coefficient only with respect to the in-house strategy: adaptation to foreign costumers' requirements and preferences is the main issue for food exporting companies, and this requires a highly targeted innovation process which may lead to internalization of R&D activities more than making use of outsourcing to the market (Pascucci et al., 2011).

When approximating the management strategies of a firm with the level of the proprietorship, we find that FAMILY is not significant in the model, i.e. according to our results this variable does not exert any impact on the decision of a firm to innovate in-house or outsourcing. Moreover, being a family-owned firm seems to indicate a lower probability to innovate through collaboration with other firms. Moreover, being a family-owned firm seems to indicate a lower probability to innovate through collaboration with other firms. Quality certification (QUALITY_CERT) has a significant positive effect on the in-house innovation strategy. The implementation of quality standards in EU food firms seems to result in more internal innovation activities and potentially leads to competitive advantages. Quality certification confirms to be part of firms' in-house innovation strategy and to help saving on transaction costs associated with the search of appropriate suppliers and customers, the negotiation of contracts and their control.

Among the control variables, results show that more experienced food firms (AGE) are more likely to innovate via outsourcing, maybe in view of the fact that although having more accumulated knowledge and tacit internal know-how, they suffer from routines and internal procedures which might reduce their likelihood to innovate internally. At the same time, more experience in the operating sector and cumulative knowledge create capabilities to use outsourcing strategies that younger food firms might not have (Pascucci et al., 2011). Small-medium firms and larger firms, then, do not differ when it comes to the decision of outsourcing innovation (the coefficient is not significant), however being a SME has a significantly negative impact on the decision to innovate in-house, probably due to the difficulties in approaching innovation only on the basis of internal resources. The legal form of a firm does not exert any impact on the strategy decision. Receiving financial incentives

from the public sector, even if not specific for research or innovation activities, has a positive impact on the decision to outsource innovation, while capital accumulation in the region does not show any influence.

Considering Hungary as a reference (the only Central European country), it seems that firms located in Germany are most likely to outsource innovation, while compared to the beverage sector, it seems that the dynamics in the meat sector and in the bakery sector are more conducive to outsourcing innovation.

Finally, the paper intends to verify whether in the agri-food sector innovation strategies are complements or substitutes. When we focus on the potential complementarity between in-house innovation and outsourcing in the European agri-food sector, the empirical results show that the two strategies are *not* correlated: the likelihood that a firm jointly considers both strategies is low, as the not-significant parameter rho in the model estimates suggests. In the bivariate probit model, rho is a correlation coefficient denoting the extent to which the two strategies co-vary. In our model rho is not statistically significantly different from zero (i.e. the null hypothesis cannot be rejected), so the two strategies can be considered as substitutes rather than complements.

INSERT HERE TABLE 7 AND TABLE 8

6. Discussion and concluding remarks

The aim of the paper has been to analyze which factors determine the decision of firms operating in traditional sectors. Particularly we focus on innovation strategies of firms operating in the agri-food industry in different European countries. The new elements that this study adds to the existing literature are the following. First, despite the large amount of empirical and theoretical studies on the issue of innovation in the manufacturing sector, less attention has been dedicated in the literature on traditional sectors, and particularly to the agri-food sector and its dynamics in terms of innovation strategies. Second, we pose a number of theoretical hypotheses in line with the relevant literature, which we address using a wide dataset containing data stratified by industry, region and firm structure fully comparable across seven European countries. The theoretical framework and the way the dataset has been explored in the paper represent an important novelty: to the best of our knowledge, this paper represents the first attempt to depict the status of the innovation activities in the agri-food sector covering seven European countries at the same time. Moreover, the information about the specific region and province of location let us analyse local conditions and their influence

on the food firms' behaviour. Finally, the paper adds insights into the debate about complementarity or substitutability between the two strategies, innovating in-house and outsourcing.

Using the unique dataset, we analysed companies' innovation strategies while taking into account technological, organizational and commercial aspects of the firm. The emerging picture is not clear nor univocal: a clear cut dynamic in innovating in-house and outsourcing is missing in the European agri-food sector. However, the combination of internal and external resources through outsourcing seems most common. A high level of human resources and the ICT use influence both the decision to innovate in-house and outsourcing, while organizational aspects, especially those related to the decision process within the firm, are relevant only for the in-house strategy; internationalised firms prefer the in-house strategy; the size of the firm is relevant only when it comes to decide to innovate in-house, however it emerges that small and medium sized firms are more likely to outsource innovation in the agri-food sector. Maybe this is to be attributed to their difficulties in approaching internal efforts for research (e.g. investments); however, size cannot explain the decision to outsource innovation in this model. The fact that a firm is already involved in product and process innovation, therefore is already in some way innovative, is conducive to both the strategies.

Although almost half of the sample of firms operating in the agri-food sector in Europe adopts both the strategies, it emerges from the data that innovating in-house and outsourcing are considered as substitutes more than complementary strategies. An analysis of the innovation project portfolio that firms might have is needed to investigate this finding in more depth.

As noted by (Hauser et al., 2006), the research stream on managing firms' innovation boundaries remains in its infancy, in particular in the agri-food domain, and asks for future researchers to expand the knowledge base on this subject. Here, we attempted to identify some unexplored issues and questions in this domain that represent potentially fruitful areas of research and useful applications in practice. First, it will be interesting to compare the dynamics of the agri-food sector with those of the other manufacturing sectors to verify whether the same hypotheses hold or not. On a more empirical side, future research should attempt to overcome some limitations of the present paper: (1) provide different and more solid definitions of in-house and outsourcing strategy, (2) add hypotheses coming from the property rights approach (e.g. using information about patents, copyrights, trademarks), (3) analyse different dynamics of the innovativeness of the agri-food sector, such as for example the impact of these strategies on the production of process or product innovation, or on innovation performances; (4) furthermore, efforts should be made to eliminate potential firm

specific fixed effects that might be driving some of the results; finally, extending the analysis to the individual project level instead of the firm level may extend insights into the complementarity of the in-house and outsourcing innovation strategies: the same firms could in fact use different strategies according to the specific project involved.

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Table 1. Distribution of firms by country and size class

Class size	AT	FR	DE	HU	IT	ES	UK	Total
Employees (10-19)	12	86	105	13	81	179	4	480
Employees (20-49)	12	54	126	29	115	197	18	551
Employees (50-249)	5	45	65	15	35	59	27	251
Employees (over 250)	4	27	34	5	7	24	10	111
Total	**33**	**212**	**330**	**62**	**238**	**459**	**59**	**1393**

Source: Authors elaborations of EFIGE data

Table 2. Distribution of firms by country and classes of turnover (2008)

Turnover classes	AT	FR	DE	HU	IT	ES	UK	Total
Less than 1 million euro	6	33	62	26	7	78	3	215
1-2 million euro	6	36	79	12	22	101	6	262
2-10 million euro	7	64	98	15	127	191	22	524
10-15 million euro	3	11	12	2	28	25	9	90
15-50 million euro	3	39	36	5	36	41	12	172
50-250 million euro	6	23	25	2	16	10	4	86
More than 250 million euro	-	5	6	-	2	13	3	29
(Missing values)	(2)	(1)	(12)	-	-	-	-	15
Total	**33**	**212**	**330**	**62**	**238**	**459**	**59**	**1393**

Source: Authors elaborations of EFIGE data.

Table 3. Distribution of firms by country and legal form (2008)

Legal form	AT	FR	DE	HU	IT	ES	UK	Total
Proprietorship/ownership	5	-	64	-	-	1	-	70
Partnership	3	31	36	1	1	175		247
Limited Liability corporation	20	84	193	52	220	265	58	892
Other	1	77	36	7	-	-	-	121
(Missing)	4	20	1	2	17	18	1	63
Total	**33**	**212**	**330**	**62**	**238**	**459**	**59**	**1393**

Source: Authors elaborations of EFIGE data

Table 4a. Descriptive statistics for the dependent variables

Dependent variable	Type	Value	Obs	Mean	Std. Dev.	Min	Max
INHOUSE	binary	0= no; 1=yes	1393	0.485	0.500	0	1

OUTSOURCING	binary	0= no; 1=yes	1393	0.917	0.276	0	1

Source: Authors elaborations of EFIGE data

Table 4b. In-house and Outsourcing innovation in the sample (agri-food domain)

In-house	**Outsourcing**		
	0	1	Total
0	73	644	717
1	43	633	676
Total	**116**	**1277**	**1393**

Source: Authors elaborations of EFIGE data

Table 5. Hypotheses tested, variables used and their description

Hypotheses tested	*Variables*	*Description*
Hypothesis 1. (1a) A sophisticated ICT system leads to in-house innovation to internalize benefits. (1b) On the other hand, complex ICT systems can also lead to outsourcing to share the management of complex systems	BROAD_BAND	Access to broadband connection
	IT_INFO_MNG	Firms' use of ICT solution for internal information management
	IT_ECOMMERCE	Firms' use of ICT solution for e-commerce
	IT_SALESPURCH	Firms' use of ICT solution for management of the sales/purchase network
Hypothesis 2. (2a) Companies with a high share of employees dedicated to R&D activities and with a high share of highly-skilled employees are more likely to innovate in-house to protect these specific assets. (2b) On the other hand, highly skilled or highly specialised employees can also lead to outsourcing of innovation for companies that want to exploit dynamic capabilities	PERC_EMPL_RD	Percentage of employees involved in R&D activities
	PERC_EMPL_DEGREE	Percentage of university graduates in the workforce in the home-country
Hypothesis 3. Process innovation is more likely to be outsourced than product innovation	PROD_INN	Firms carried out product innovation in 2007-2009
	PROC_INN	Firms carried out process innovation, in 2007-2009
Hypothesis 4. Firms that are part of a larger group of companies are more likely to outsource innovation activities and to access group resources	GROUP	Firms belong to a group, national or foreign
Hypothesis 5. Firms with a relatively high degree of decentralization of decision-making inside the firm are more inclined to outsource innovation activities	CENTRAL_DECISION	Strategic decisions are centralised (i.e. the CEO/owner takes most decisions in every area)
Hypothesis 6. The impact of flexibility in employment contracting on in-house and outsourcing innovation activities is uncertain	PERC_EMPL_FIXED	Percentage of employees working in 2008 with a fixed term contract
	PERC_EMPL_PARTIME	Percentage of employees working in 2008 with a part-time contract

Hypothesis 7. The higher the firm's degree of internationalization, the higher the probability of selecting the outsourcing strategy	EXPORT	Firms sold abroad some of their products/services in 2008 and were exporter before 2008
Hypothesis 8. Family owned firms are more likely to outsource innovation activities	FAMILY	Firms directly or indirectly controlled by an individual or family-owned entity
Hypothesis 9. Quality certification has a positive impact on in-house innovation activities	QUAL_CERT	Firms went through quality certification during 2009
	AGE	Age: foundation year minus 2014
	SME	Size: small-medium if < 250 employees
	LEGAL	Legal form of the firm
	PUBL_INCENTIVES	Firms benefitted from financial incentives provided by the public sector in 2009
	BUS_GERD_PER_REG	Total 2009 intramural R&D expenditure (GERD) by business sector and NUTS 2 regions as percentage of GDP
	GOV_GERD_PER_REG	Total 2009 intramural R&D expenditure (GERD) by government sector and NUTS 2 regions as percentage of GDP
	MEAT	Sector according to the NACE 2: production, processing, preserving of meat and meat products
	FISH	Processing and preserving of fish, crustaceans and molluscs
	FRUIT-VEG	Processing and preserving of fruit and vegetables
	VEG_ANIM_OIL	Manufacture of vegetable and animal oils and fats
	DAIRY	Manufacture of dairy products
	GRAIN	Manufacture of grain mill products
	BAKERY	Manufacture of bakery and farinaceous products
	OTHER_FOOD	Manufacture of other food products
	ANIM_FEED	Manufacture of prepared animal feeds

BEVERAGES	Manufacture of beverages
AUT	Firms location: Austria
FRA	France
GER	Germany
HUN	Hungary
ITA	Italy
SPA	Spain
UK	the United Kingdom

Table 6. Descriptive statistics of the variables used

Independent variables	Type	Value	Obs.	Mean	Std. Dev.	Min.	Max.
BROADBAND	binary	0= no; 1=yes	1393	0.847	0.360	0	1
IT_INFO_MNG	binary	0= no; 1=yes	1393	0.488	0.500	0	1
IT_ECOMMERCE	binary	0= no; 1=yes	1393	0.186	0.389	0	1
IT_SALESPURCH	binary	0= no; 1=yes	1393	0.464	0.499	0	1
PERC_EMPL_FIXED	continuous	0-100%	1381	32.573	39.402	0	100
PERC_EMPL_PARTIME	continuous	0-100%	1388	10.101	16.338	0	100
PERC_EMPL_RD	continuous	0-100%	1391	6.616	13.788	0	100
PERC_EMPL_DEGREE	continuous	0-100%	1393	7.944	11.029	0	100
PROD_INN	binary	0= no; 1=yes	1393	0.513	0.500	0	1
PROC_INN	binary	0= no; 1=yes	1393	0.450	0.498	0	1
GROUP	binary	0= no; 1=yes	1393	0.174	0.379	0	1
CENTRAL_DECISION	binary	0= no; 1=yes	1353	0.729	0.444	0	1
EXPORT	binary	0= no; 1=yes	1393	0.419	0.494	0	1
FAMILY	binary	0= no; 1=yes	1392	0.749	0.434	0	1
QUAL_CERT	binary	0= no; 1=yes	1393	0.383	0.486	0	1

Controls							
AGE	continuous	0-N	1390	47.027	37.857	6	172
SME	binary	0= no; 1=yes	1393	0.920	0.271	0	1
LEGAL_FORM	categorical	1 = proprietorship or ownership; 2 = partnership; 3 = limited liability corporation; 4 = other	1330	2.800	0.669	1	4
PUBL_INCENTIVES	binary	0= no; 1=yes	1393	0.212	0.409	0	1
BUS_GERD_PER_REG	continuous	0-100%	1393	1.086	0.893	0.05	3.86
GOV_GERD_PER_REG	continuous	0-100%	1387	0.252	0.191	0	1.2
MEAT	binary	0= no; 1=yes	1393	0.235	0.424	0	1
FISH	binary	0= no; 1=yes	1393	0.024	0.154	0	1
FRUIT-VEG	binary	0= no; 1=yes	1393	0.086	0.281	0	1
VEG_ANIM_OIL	binary	0= no; 1=yes	1393	0.016	0.125	0	1
DAIRY	binary	0= no; 1=yes	1393	0.065	0.246	0	1
GRAIN	binary	0= no; 1=yes	1393	0.031	0.173	0	1
BAKERY	binary	0= no; 1=yes	1393	0.243	0.429	0	1
OTHER_FOOD	binary	0= no; 1=yes	1393	0.112	0.315	0	1
ANIM_FEED	binary	0= no; 1=yes	1393	0.049	0.216	0	1
BEVERAGES	binary	0= no; 1=yes	1393	0.139	0.346	0	1
AUT	binary	0= no; 1=yes	1393	0.024	0.152	0	1
FRA	binary	0= no; 1=yes	1393	0.152	0.359	0	1
GER	binary	0= no; 1=yes	1393	0.237	0.425	0	1
HUN	binary	0= no; 1=yes	1393	0.045	0.206	0	1
ITA	binary	0= no; 1=yes	1393	0.171	0.377	0	1
SPA	binary	0= no; 1=yes	1393	0.330	0.470	0	1
UK	binary	0= no; 1=yes	1393	0.042	0.201	0	1

Table 7. Results from the bivariate probit model

	In-house				Outsourcing			
	Coefficient	**Robust Std. Err.**	**P>z**		**Coefficient**	**Robust Std. Err.**	**P>z**	
BROADBAND	0.120	0.118	0.306		0.300	0.141	0.033	***
IT_INFO_MNG	0.138	0.096	0.153		0.316	0.145	0.030	***
IT_ECOMMERCE	0.329	0.114	0.004	***	-0.138	0.160	0.387	
IT_SALESPURCH	0.193	0.088	0.028	***	0.237	0.128	0.064	**
PERC_EMPL_RD	0.015	0.004	0.000	***	0.028	0.011	0.007	***
PERC_EMPL_DEGREE	0.011	0.005	0.028	***	0.006	0.007	0.404	
PROD_INN	0.779	0.084	0.000	***	-0.201	0.108	0.063	**
PROC_INN	0.413	0.087	0.000	***	0.261	0.122	0.033	***
GROUP	-0.002	0.126	0.986		-0.056	0.161	0.725	
CENTRAL_DECISION	-0.227	0.097	0.019	***	-0.009	0.133	0.944	
PERC_EMPL_FIXED	-0.001	0.002	0.514		0.003	0.002	0.208	
PERC_EMPL_PARTIME	-0.002	0.003	0.469		0.003	0.004	0.436	
EXPORT	0.401	0.089	0.000	***	0.101	0.129	0.435	
FAMILY	0.026	0.108	0.809		-0.082	0.136	0.544	
QUAL_CERT	0.238	0.088	0.007	***	0.011	0.122	0.927	
Control variables								
AGE	0.001	0.001	0.568		0.005	0.002	0.007	***
SME	-0.767	0.184	0.000	***	0.038	0.260	0.884	
LEGAL	0.104	0.068	0.127		0.096	0.095	0.314	
PUBL_INCENTIVES	0.054	0.101	0.597		0.403	0.160	0.012	***
BUS_GERD_PER_REG	0.040	0.059	0.494		0.014	0.081	0.858	
GOV_GERD_PER_REG	0.352	0.242	0.146		-0.113	0.348	0.746	

AUT	0.676	0.347	0.051	***	0.159	0.578	0.783	
FRA	0.843	0.231	0.000	***	-0.064	0.269	0.811	
GER	0.188	0.244	0.441		0.673	0.318	0.035	***
ITA	0.767	0.230	0.001	***	-0.313	0.283	0.270	
SPA	0.627	0.250	0.012	***	-0.036	0.314	0.908	
UK	0.625	0.306	0.041	***	0.018	0.373	0.962	
Meat	-0.434	0.152	0.004	***	0.551	0.210	0.009	***
Fish	-0.209	0.289	0.470		0.081	0.338	0.810	
Fruit and Vegetables	-0.186	0.181	0.304		0.014	0.234	0.953	
Vegetal and Animal oil	-0.318	0.283	0.261		-0.535	0.369	0.147	
Dairy	-0.157	0.200	0.434		0.241	0.264	0.361	
Grain	-0.283	0.263	0.281		-0.012	0.348	0.972	
Bakery	-0.459	0.151	0.002	***	0.402	0.207	0.052	***
Othe food	-0.038	0.172	0.825		0.337	0.235	0.152	
Animal Feed	-0.367	0.204	0.072	***	0.152	0.288	0.597	
Constant	-1.206	0.420	0.004	***	-0.179	0.511	0.726	
n. observation			1272					
Wald chi2(72)			476.2					
Loglikelihood			-947.901					
Prob > chi2			0.000					
rho			0.089					
Wald test of rho=0			1.174		(Prob > chi2 = 0.2785)			
Multicollinearity condition number			39.938					

Table 8. Hypotheses tested and outcome

Hypotheses tested	*Outcome*
Hypothesis 1. (1a) A sophisticated ICT system leads to in-house innovation to internalize benefits. (1b) On the other hand, complex ICT systems can also lead to outsourcing to share the management of complex systems	(1a) – (1b) verified. ICT endowment plays role in stimulating both innovation in-house and outsourcing
Hypothesis 2. (2a) Companies with a high share of employees dedicated to R&D activities and with a high share of highly-skilled employees are more likely to innovate in-house to protect these specific assets. (2b) On the other hand, highly skilled or highly specialised employees can also lead to outsourcing of innovation for companies that want to exploit dynamic capabilities	Verified in part. PERC_EMPL_RD significant and positive for in-house and outsourcing , PERC_EMPL_DEGREE only for in-house
Hypothesis 3. Process innovation is more likely to be outsourced than product innovation	Verified in part. Both strategies are used if PROC_INN, in-house only if PROD_INN
Hypothesis 4. Firms that are part of a larger group of companies are more likely to outsource innovation activities and to access group resources	Rejected. GROUP variable is not significant
Hypothesis 5. Firms with a relatively high degree of decentralization of decision-making inside the firm are more inclined to outsource innovation activities	Rejected. CENTRAL_DECISION is negatively related to in-house innovation, no significant effect on outsourcing
Hypothesis 6. The impact of flexibility in employment contracting on in-house and outsourcing innovation activities is uncertain	Not verified. PERC_EMPL_FIXED and PERC_EMPL_PARTIME not significant, however negatively related to outsource
Hypothesis 7. The higher the firm's degree of internationalization, the higher the probability of selecting the outsourcing strategy	Rejected. EXPORT significant and positive only for in-house
Hypothesis 8. Family owned firms are more likely to outsource innovation activities	Not verified. FAMILY not significant
Hypothesis 9. Quality certification has a positive impact on in-house innovation activities	Verified. QUALITY significant and directly related to innovating in-house