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# Captive or non-captive: Knowledge sourcing strategies and innovation performance

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**Abstract**

Prior literature has argued that, although both captive knowledge sourcing (CKS) and non-captive knowledge sourcing (NCKS) are effective strategies for enhancing firm innovativeness, the former plays a more defined role in determining the likelihood of a firm achieving product innovations. However, we contend that the focus should not only be on the decision to innovate but, more importantly, on the profitability firms derive from such innovations. Given that knowledge acquired from external sources can provide firms with ideas that differ from their existing competencies, NCKS may be more advantageous, as the resulting innovations are likely to exhibit higher levels of novelty. Additionally, we examine the complementarity or substitutability between CKS and NCKS in driving innovation. Our findings for Spanish firms suggest that NCKS yields greater benefits than CKS. Moreover, adopting both strategies simultaneously does not result in higher benefits; instead, a minimum threshold of NCKS, above the median, is necessary to realize observable gains. This indicates that firms must demonstrate a substantial level of commitment to NCKS to effectively exploit its potential for generating returns from their most novel innovations.

**Keywords:** Radical Innovation, Captive Knowledge Sourcing; Non-Captive Knowledge Sourcing; Spanish firms; Panel data; Complementarity/Substitutability.

**JEL Classification:**

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## 1. Introduction

During the last two decades, researchers have stressed the importance for firms to access external-to-firm knowledge. Two possible reasons for looking at others' inventions are, first, being aware of the market novelties and, second, increasing firms' internal capabilities (Cohen and Levinthal, 1990). The central argument is that, in a globalized world, no organization can rely exclusively on internal approaches and perspectives, so that processes such as the external acquisition of knowledge have been proved to be of high relevance for companies (Chesbrough, 2003). The R&D offshoring literature stresses that such strategy allows firms to take advantage of knowledge specificities in which other enterprises present a comparative advantage, in which the firm does not necessarily need to be specialized (Rosenbusch et al., 2019; Steinberg et al., 2017; Un and Rodríguez, 2018). This could be translated into increases in productivity, since the firm could focus more intensively on core activities (Belderbos et al., 2013). Moreover, knowledge sourcing allows for cost reductions—specifically when offshored from other countries—as well as having access to a skilled labor force (Lewin et al., 2009; Youngdahl and Ramaswamy, 2008).

When outsourcing others' knowledge, firms can purchase it from third party organizations (non-captive knowledge sourcing, NCKS) or from other companies that belong to the same group of firms, known in the literature as captive knowledge sourcing (CKS) (Nieto and Rodríguez, 2011; Steinberg et al., 2017).[1] It is a general consensus that the use of knowledge suppliers leads enterprises to tackle different perspectives and ideas which might be considered desirable since they strengthen the capacity of firms to better benefit from their core knowledge (Cohen and Levinthal, 1990; Spithoven and Teirlinck,

[1] Notice that we are not differencing between national or international purchase of knowledge as some of the references do. Additionally, we are not referring to other possible modes of accessing external knowledge as for instance, external collaborations or joint ventures.

2015). However, which of these two outsourcing strategies provides a greater boost to a firm's innovative performance, and under what conditions do these strategies become complementary or substitutive in driving innovation?

On the one hand, captive modes of knowledge acquisition can be highly profitable for firms in order to develop innovations since they imply the access to external knowledge while avoiding the knowledge leakage that tend to exist when the exchange of technology happens among third party organizations. Internal modes of knowledge transmission between headquarters and their affiliates enjoy greater levels of confidence (Nieto and Rodríguez, 2011). Additionally, CKS may present better integrative capabilities since subsidiaries work with the same organizational and management processes as the headquarters (Gertler, 1997) which could facilitate the transference of knowledge of modular technology as in the case of R&D offshoring. This approach may help a firm avoid becoming a hollow corporation, as acquiring knowledge from a subsidiary enables it to exploit different technologies while simultaneously enhancing its overall R&D capabilities and competitiveness (Kotabe, 1989).[2] Furthermore, this allows firms to take advantage from the expertise of third-party organizations leading foreign markets as stressed by Steinberg et al. (2017). However, firms looking for positioning their affiliates abroad to take advantage of foreign local knowledge may not gain access to such a knowledge as efficiently as other local firms do.

On the other hand, NCKS may enable firms to access technologies that differ from their existing competencies, which would imply the development of a novel type of innovation. Indeed, we may argue that, to obtain knowledge new enough as to lead to

[2] A "hollow corporation" refers to a firm that outsources so extensively that it loses critical internal capabilities and knowledge, potentially undermining its long-term competitiveness and innovation capacity (Kotabe, 1989).

highly novel innovations, the new knowledge should come from a different environment.[3] Therefore, acquiring it from third party organizations ensures higher degrees of dissimilarity of technologies than when it comes from firms belonging to the same group, with the consequent likely higher degree of novelty of the resulting innovations, and therefore, a higher economic value.

Since both modes of accessing external knowledge seem to be beneficial, one could ask whether the effect of using both at the same time would surpass the effect of the two strategies done separately. Indeed, a complementary relationship has been found in previous literature between internal and external knowledge acquisition for Belgian enterprises (Cassiman and Veugelers, 2006) and in the case of R&D offshoring from high income countries to emerging countries in low- and medium-technological sectors (D'Agostino et al., 2013). However, several papers have also provided findings in favor of a substitution effect between different external collaborative modes, and external/internal R&D modes, probably due to the higher costs of managing very different sources of knowledge (Haus-Reve et al., 2019; Laursen and Salter, 2006; Love and Roper, 2001). Therefore, we will examine whether the returns obtained from CKS are enhanced when firms simultaneously utilize NCKS.

Our paper makes four key contributions to the literature. First, it studies the effects of CKS and NCKS modes on the benefit firms take from product innovations, and not only on the likelihood of getting product innovations, as mainly done in previous literature (Bertrand and Mol, 2013; Nieto and Rodríguez, 2011, among others).[4] Indeed, we argue that the profitability firms derive from their innovations is the critical factor, rather than the mere act of innovating. This is particularly relevant in the current

[3] Notice that we are not referring to "environment" in a geographical manner, but in a cognitive one.
[4] Except for Steinberg et al., (2017), which study this effect on the benefit in sales obtained from product innovation.

competitive landscape, where it can determine whether a firm gains or loses market position relative to its competitors. Second, and following with the reasoning above, to gain market position, not all the innovations are equally relevant, nor do they have the same technological and economic impact. Actually, innovations that include a high level of novelty can be considered to be of a more radical or breakthrough nature and, as witnessed by the report of the World Intellectual Property Organization (WIPO, 2015) there seems to be a strong link between economic growth and breakthrough innovations. Therefore, the heterogeneity in the quality of the innovation made needs to be considered, as we do in this study. Third, we believe that understanding how these two strategies (CKS and NCKS) coexist and integrate into the innovative process of firms can be relevant for efficiency considerations. To this end, we examine whether these strategies exhibit a complementary or substitutive relationship, shedding light on how their interplay influences the innovation process. Finally, it is plausible that deriving benefits from such strategies necessitates exceeding a certain threshold level of investment or effort, in the sense of having accumulated certain experience and expertise that allow firms to benefit from them, an aspect that is also examined in our analysis. We provide empirical evidence on these aspects for Spanish firms in the period 2004-2015.

This paper is organized as follows. In section 2 we offer the analytical part of the study. Thereafter, section 3 describes the dataset, while the methodology is offered in section 4. Section 5 gives the results, and finally, we conclude.

## 2. Knowledge sourcing and firms' innovation performance

### 2.1. Does CKS provide a superior advantage over NCKS?

Previous literature highlights both the advantages and drawbacks of captive and non-captive knowledge sourcing, including uncertainty in the innovation process, moral hazard, transference of core competencies, dependency on external suppliers, and lack of control over the R&D process (Buss and Peukert, 2015; Kotabe et al., 2007; Nieto and Rodríguez, 2011). Uncertainty and moral hazard can lead to competitors accessing valuable information, which may be copied or sold to other firms (Narula, 2004). Dependency on external knowledge can reduce internal capabilities, as external knowledge may substitute internal R&D, and firms risk losing control over the innovation process. Although outsourcing knowledge can lead to loss of know-how, Kotabe (1989) argues that it can enhance R&D and competitiveness, especially when utilizing technologies from subsidiaries.

This supports the idea of CKS as a superior strategy, as internal connections between a company's headquarters and subsidiaries enable better control over processes. Joint innovation development between the headquarters and affiliates prevents loss of valuable resources and specific knowledge while acquiring external knowledge (Nieto and Rodríguez, 2011). Transaction cost theory (Williamson, 1977) suggests external knowledge acquisition is only profitable when transaction costs—such as opportunism, R&D sunk costs, and uncertainty—are low, and external knowledge can substitute internal R&D (Ulset, 1996). In such cases, CKS transactions are more efficient than NCKS, preventing the loss of internal capabilities.

On the other hand, there are compelling arguments favoring NCKS strategies over CKS. When firms aim to access a new local market, engaging in R&D projects with partners through collaboration agreements or knowledge sourcing strategies may be more profitable in the short term than establishing a subsidiary, due to the substantial financial and time costs of the latter (Van Beers and Zand, 2014). While subsidiaries can benefit from shared organizational processes, facilitating knowledge transfer in modular technologies (D'Agostino et al., 2013), cultural differences, labor market variations, and industrial specialization can increase transaction costs (Gertler, 1997), making NCKS strategies more cost-effective. NCKS allows firms to exploit third-party expertise and networks in foreign markets, enhancing knowledge acquisition (Steinberg et al., 2017). On top of that, firms attempting to access local knowledge through subsidiaries may face barriers, such as cultural and social differences, leading to inefficiencies and delays, particularly when compared to local firms (Schmidt and Sofka, 2009), positioning NCKS as a more efficient strategy in some cases.

### 2.2. The role of CKS and NCKS in driving radical innovation

Despite much of the existing literature on captive and non-captive knowledge sourcing strategies focuses on their effect on the likelihood of innovation (Bertrand and Mol, 2013; Cusmano et al., 2009; Nieto and Rodríguez, 2011), we argue that the benefits derived from innovations are more critical than simply achieving them. Innovation reaches its full potential when it transitions to the commercial stage—when firms successfully translate innovation into higher sales or increased productivity. Therefore, the key factor is not only the generation of innovation, as most prior studies emphasize, but the successful commercialization of these innovations. This success is often enhanced when the innovation is novel and radical in nature. Given these considerations, this study focuses on the impact of knowledge sourcing on the benefits firms obtain from innovation, particularly in terms of sales growth resulting from the introduction of new product innovations.

Previous literature in the geography of innovation domain has signaled that combining different capabilities, despite implying higher costs and risks, can result more easily in the production of radical innovations, that is, innovation with a high technological and economic impact (Boschma, 2017). Knowledge producers who source for new and unusual components may arrive at less useful innovations on average, but with large variability, which results in turn in both failure and breakthrough inventions (Fleming, 2001). If successful, we can think that knowledge coming from sources external to the firm can become related in the form of a new invention that paves the way for future technological developments and further innovation, leading to 'new operational principles, functionalities and applications' (Castaldi et al., 2015, p. 770).

As noted by Van Beers and Zand (2014), radical innovations are inherently riskier and require greater resources, including financing and, crucially, external knowledge that may not be available through internal knowledge generation alone. This necessity arises from the higher product complexity, increased global competition, and rapid market changes, driven by time-to-market pressures. The need to be the first to market may drive shifts in the market lifecycle, including the rejuvenation of older technologies through the integration of newer knowledge, which leads to product innovations via a re-combinatory process. This process, where new and existing knowledge are combined to create novel solutions, is essential for achieving breakthroughs and sustaining competitive advantages in rapidly changing markets (Chesbrough, 2003). Consequently, radical innovations often necessitate combining diverse knowledge elements to achieve a significant breakthrough. In this context, radical innovations not only enhance firm performance but also improve its competitive position in the market. Furthermore, they can create entirely new markets, offering the first mover a monopoly advantage (Beck et al., 2016).

Overall, knowledge sourced externally, particularly through NCKS, can expand a firm's access to diverse sources of innovation necessary to challenge established market ideas, potentially leading to breakthrough innovations (Laursen and Salter, 2006). Moreover, managerial experience with external knowledge suppliers, strong contractual agreements, and well-defined formal and informal property rights (Buss and Peukert, 2015; Spithoven and Teirlinck, 2015) can enable firms to achieve significant returns from NCKS. This is especially relevant in regions with robust intellectual property laws, such as the European Union (EU), which protect knowledge and reduce the risk of leakage, thus enhancing the profitability of external knowledge sourcing. By minimizing these risks, firms are incentivized to access novel and diverse knowledge sources, fostering higher levels of innovation. These insights lead to the formulation of our first hypothesis:

**Hypothesis 1**. *Outsourcing external knowledge from firms that do not belong to the same group allows firms to get higher benefits than the ones obtained from captive knowledge outsourcing. This is especially true in the case of innovations that incorporate a high degree of novelty.*

### 2.3. Complementarity/substitutability relationship between CKS and NCKS

We now turn to examining how these two strategies—CKS and NCKS—coexist and integrate into the firms' innovation processes. As noted earlier, literature on the relationship between internal and external R&D strategies presents mixed findings regarding their complementarity or substitutability, with results varying across time periods and countries. For instance, Cassiman and Veugelers (2006) provide robust evidence of a complementary relationship between internal and external knowledge generation for Belgian firms, a finding echoed by Beneito (2006) and Añón Higón et al.

(2014) in the context of Spain. However, D'Agostino et al. (2013) argue that such a complementary relationship between internal and external R&D efforts is more pronounced in low- and medium-tech sectors, suggesting that the dynamics may differ depending on the technological intensity of the industry.

Radical innovations inherently involve higher risks and uncertainties, often resulting in unsuccessful or abandoned projects. Consequently, firms may need to explore entirely new business models and technologies, which are more likely to be found beyond the firm's boundaries. However, the literature emphasizes not only the importance of exploration but also the value of exploiting existing knowledge within the firm. Haus-Reve et al. (2019) highlight that organizational learning theory views the exploration and exploitation of new business models as complementary pathways to accessing external knowledge. Building on this perspective, CKS and NCKS can be seen as complementary strategies. NCKS facilitates the exploration of diverse technologies, while CKS allows for the integration of such knowledge through familiar application and experience with similar technologies. Therefore, enterprises may access a different technology that may be easily integrated exploiting the collective knowledge from the group. As such, firms may enhance innovation performance by combining both sourcing strategies, rather than relying exclusively on one, to maximize the potential of different knowledge sources.

On the other hand, the resources allocated to searching, mapping, negotiating, and implementing external knowledge may exceed the anticipated benefits for firms, resulting in what is known as the over-search effect. When resources are limited, the capacity to identify, acquire, process, and implement knowledge from one sourcing partner reduces the resources available for engaging with others. This leads to a situation where firms cannot use multiple knowledge sources simultaneously, incurring diseconomies and suboptimal resource utilization. A similar effect has been observed in collaboration strategies. Belderbos et al. (2006) find that small firms in the Netherlands, pursuing multiple R&D collaboration strategies, experience a substitution effect primarily due to the challenges of managing multiple partners. Haus-Reve et al. (2019) report similar findings for Norwegian firms, where collaborations with suppliers and scientific partners often increase search costs because these partners may lack the ability to fully understand scientific knowledge. Laursen and Salter (2006) also identify a substitution effect between external search breadth and internal R&D, further influenced by the "not-invented-here syndrome".[5]

Due to the existence of theoretical and empirical arguments supporting both complementarity and substitutability, selecting only one hypothesis risks overlooking the complex conditions under which each relationship may hold. By empirically testing these competing hypotheses, we aim to provide a more comprehensive understanding of how firms optimize their external knowledge sourcing strategies to maximize innovation benefits. Therefore, our next two competing hypotheses are:

**Hypothesis 2a**. *Acquiring external knowledge through CKS implies higher benefits for firms that also use NCKS, and vice versa.*

**Hypothesis 2b**. *Acquiring external knowledge through CKS implies lower benefits for firms that also use NCKS, and vice versa.*

### 2.4. Exploiting intensity for CKS and NCKS effectiveness

Finally, we examine whether the impact of CKS and NCKS modes of knowledge sourcing depends on their intensity. Previous literature suggests that a certain level of

[5] This concept connects to the idea of regretting to implement external knowledge by the internal R&D personal.

expertise is necessary to fully realize the benefits of external knowledge, especially when sourced from organizations that are structurally or culturally distinct. However, excessive reliance on R&D outsourcing or offshoring can pose significant risks. Grimpe and Kaiser (2010) argue that very high levels of outsourcing may expose firms to shared knowledge vulnerabilities in the market while weakening their integrative capabilities. Similarly, Mihalache et al. (2012) highlight that excessive R&D offshoring can impair the firm's ability to absorb geographically and culturally distant knowledge effectively.

At low levels of R&D outsourcing, however, the integration of external knowledge may be suboptimal due to underdeveloped communication channels between partners (Un and Rodríguez, 2018). Conversely, higher levels of outsourcing can foster better coordination and a willingness to share knowledge, enabling firms to achieve novel re-combinations through enhanced routines and skills (Martinez-Noya et al., 2012). While this reasoning applies to both CKS and NCKS, it is likely to be more relevant for NCKS due to the greater diversity of external partners previously highlighted in section 2.1. This diversity allows firms engaging in NCKS to access knowledge that is not only more novel but also disconnected from their existing knowledge base, which is critical for achieving breakthrough innovations. Moreover, partnerships with external organizations often bring specialized expertise, unique problem-solving approaches, and access to broader networks, all of which are less likely to be found within the relatively homogeneous context of CKS. As a result, the transformative potential of NCKS in fostering radical innovations is inherently greater. These arguments lead us to propose the following hypothesis.

**Hypothesis 3.** *The benefits derived from radical innovations are positively associated with the level of resources allocated to CKS and NCKS, with this effect being particularly pronounced for NCKS.*

## 3. Database and variables

### 3.1. Database

The empirical analysis is based on the Technological Innovation Panel (PITEC) which is an unbalanced panel tracing the innovation activity of Spanish enterprises from 2003 until 2015. It uses two surveys: the first—Survey on Technological Innovation of Firms—is the Spanish counterpart to the Community Innovation Survey (CIS) from the Eurostat, following the guidelines of the Oslo Manual; the second is the Statistics on R&D Activities. The PITEC database offers direct measures of the innovation output as product and process innovations—instead of relying only on measures of semi-output, such as patents, or on inputs, such as R&D expenditures.

The PITEC is representative of small and medium-size, as well as large firms; using different samples of firms: enterprises with internal R&D expenditures, as well as those small and medium-size enterprises (SMEs) with external R&D expenditures without having internal R&D; and finally, those SMEs without any expenditures on innovation. The stratification of the sample is for all the business sectors that are included in the National Classification of Economic Activities (NACE two-digit level); and the representativeness of the panel is assured thanks to the annual inclusion of firms with similar characteristics to those that disappear from the sample. The response rate is very high since it is mandatory for firms, ruling out the risk of non-response bias. Although the PITEC is a survey in which values are self-reported, in this kind of survey, where anonymity is a legal concern, there is not a systematic propensity for over- or under-reporting the innovation that is carried out by the enterprise (Aarstad et al., 2016).

The sample in this study covers the period 2004-15, with around 12,000 enterprises. However, after deleting missing values, dropping those firms that declare having product innovations while not presenting innovative expenditures, as well as those outliers with more than 20 percent of market share in a given sector, the final sample is around 8,200 enterprises.

Spain is an open economy that is well integrated in the EU, which implies solid laws of intellectual property rights which may lead to substantial benefits from knowledge sourcing, the focus of this paper. Additionally, Spain offers a unique and valuable context for this analysis due to the high quality and mandatory nature of its firm-level data, which as previously highlighted, is collected annually—providing a more comprehensive temporal coverage than datasets such as the biannual CIS. As one of the largest economies within the EU, Spain serves as a representative case for countries with similar economic structures, making the findings broadly applicable to other economies.

### 3.2. Variables

In the PITEC survey, firms are asked whether they have developed product innovations. Using this information, we proxy for the innovative output of enterprises which is our first dependent variable (*PI dummy*). This variable is equal to one in case the enterprise developed product innovations in the current year or in the previous two years, and zero otherwise (Bertrand and Mol, 2013; Cusmano et al., 2009; Nieto and Rodríguez, 2011).

Firms are also asked whether these product innovations are new to the market or only new to the firm. Similarly, they are asked which share of their sales are due to these new product innovations, which can be understood as a proxy for the economic benefit obtained from them. Therefore, our main dependent variable considers the share of sales that are due to product innovations (*PI share*), and due to product innovations that are new to the market (*RI share*) (Grimpe and Kaiser, 2010). We will use the latter as a proxy for the benefit obtained from radical innovations, since we want to focus on innovation that can be considered to include a high level of novelty. Whereas the former would be a proxy for the benefit obtained from all product innovations (Steinberg et al., 2017).

Our key independent variables are measured as firms' R&D expenditures on external acquisition of knowledge per worker, both in the case of *CKS* and *NCKS*. To control for other firm characteristics we use *Collaboration* which captures whether the firm acquires external knowledge through other channels, and it is measured as a dummy variable equal to one if the firm cooperates in the current year or in the previous two years with other organizations and zero otherwise (Robin and Schubert, 2013). For accounting for internal capabilities of firms, we use the amount of internal R&D as a share over total sales (Cassiman and Veugelers, 2006; Spithoven and Teirlinck, 2015). In addition, *Size* accounts for the number of total workers measured in logs. *Group* measures whether the company belongs to a group of enterprises, which could facilitate more favorable financial and innovative environments being a dummy variable equal to one in case the firm belongs to a group of firms and zero otherwise.

Additionally, to capture the importance of accessing foreign markets with the idea that a firm facing more competition tends to be more innovative and more competitive, we create a categorical variable with four categories representing Regional, National, EU, and Rest of the World firm's markets with Regional being the base category. In addition, *Permanent* equals one if the firm reported that it performed internal R&D continuously and zero otherwise; whereas *Openness* counts the number of sources of information that the company has: (from within the firm or group, suppliers, clients, competitors, private R&D institutions, conferences, scientific reviews or professional associations) (Laursen and Salter, 2006; Robin and Schubert, 2013) going from zero (any) to eight (the firm uses all types of information).[6] Finally, *Demand Pull* is a variable that proxies for the objectives of product innovations: accessing new markets; gaining market share; or having greater quality of products; being equal to one if at least one of the demand-enhancing objectives for the firm's innovations is given the highest score [number between 1 (not important) and 4 (very important)]; zero otherwise.

We introduce time and sectoral dummy variables for accounting for possible knowledge specificities at the level of industries. All variables are one year lagged to lessen simultaneity problems.

## 4. Methodology and specification

Since the dependent variable is the percentage of sales due to radical product innovations, running from zero—those firms not presenting expenditures on innovation and thus, not having sales from innovative products in the sample—to one hundred, we use a random effects Tobit model as in Grimpe and Kaiser (2010). Using an OLS estimation would end in inconsistent parameters because the censored sample—those observations with value of zero—are not representing the population (Cameron and Trivedi, 2009). Additionally, the similarity of the observations ($t$) belonging to the same firm ($i$) would be taken as independent. Accordingly, our general specification is as follows:

[6] We acknowledge that the openness variable could be constructed differently to account for the varying significance of different information sources. We thank one of the reviewers for highlighting this point. While this approach would offer an alternative perspective, it would require assigning weights to information sources, which introduces a level of discretionality not yet standardized in the literature. For consistency and comparability with prior studies, we have adhered to the conventional measure widely used in the field.

$$y_{it}^{*} = \beta_0 + \beta_1 CKS_{it-1} + \beta_2 NCKS_{it-1} + \beta_3 CKS_{it-1} * NCKS_{it-1} + \sum_{m=4}^{M} \beta_m x_{mit-1} + \sum_{t=1}^{T} \gamma_t \tau_{it} + \sum_{s=1}^{S} \delta_s k_{is} + \mu_i + \varepsilon_{it} \quad (1)$$

$$y_{it} = \begin{cases} y_{it}^{*} & if\ 0 < y_{it}^{*} < 100 \\ 0 & if\ y_{it}^{*} \leq 0 \\ 100 & if\ y_{it}^{*} \geq 100 \end{cases} \quad (2)$$

where $y_{it}^{*}$ is a continuous unobserved latent variable that is related to the observed outcome $y_{it}$ (e.g., *RI share*); $\beta_1$, $\beta_2$ $and$ $\beta_3$ represent the parameter for our focal variables (*CKS* and *NCKS*) and their interaction term, being the rest of parameters the ones referring to the firm level controls *(*$x_m$, with *m=4 to M*). Moreover, $\gamma_t \tau_{it}$ as well as $\delta_s k_{is}$ are the vectors of time and sectoral dummy variables and their associated coefficients. Finally, $\mu_i \sim N(0, \sigma_\mu)$ is the unobserved heterogeneity of the firm, which is assumed independent of the covariates, while $\varepsilon_{it} \sim N(0, \sigma_\varepsilon)$ is the random error term.

The literature has adopted various approaches to analyze the relationship of complementarity or substitutability among different strategies. For instance, Arora and Gambardella (1990), for a sample of pharmaceutical enterprises study whether collaborating with other firms, universities, having participations on other firms capital, as well as the acquisition of firms, are complementary activities by looking at the correlation of the errors of different models. Cassiman and Veugelers (2006), in order to study the complementarity relationship in Belgian enterprises between external and internal R&D, use the correlation between the error terms previously explained as well as a super modularity test (Milgrom and Roberts, 1990), and pairwise interactions between the strategies (Arvanitis et al., 2015; Haus-Reve et al., 2019). The super modularity test relies on particular combinations of different strategies which are subsequently evaluated using several inequalities typically applied to combinations of two strategies at a time, with the central premise that the inclusion of one strategy increases the return of the other (Belderbos et al., 2006; D'Agostino et al., 2013; Love et al., 2014). In our case, we will analyze the nature of the relationship through pairwise interactions.

## 5. Results

### 5.1. Descriptive analysis

Between 2004 and 2015, 31% of the Spanish enterprises doing R&D offshoring used both strategies (captive and non-captive), a share which increased 2pp during such period. Table 1 shows a descriptive of the variables in our empirical analysis for the group of firms doing CKS and NCKS, separately, —as well as for firms engaged in both, and those not engaged in either—being both groups mutually exclusive.[7] The first observation is the statistical differences between both groups when examining the variables that serve as proxies for innovation performance. For instance, those firms acquiring external knowledge through non-captive modes declare an average of 3% higher share of sales due to product innovation. More importantly, the difference increases until 25%, again higher for those developing NCKS, when looking at the share of sales due to product innovations that are new not only to the firm but also to the market, which we consider to be of a more breakthrough nature. With respect to firms' expenditure in innovation activities, on average we observe that firms doing NCKS allocate four times more resources to internal R&D and they collaborate with other organizations 14% more than firms engaged in CKS. Additionally, firms engaged in CKS and NCKS also differ in other

[7] The mutually exclusivity refers only to Table 1 to show the differences between the two groups of firms in column (11). However, for the empirical analysis we also include the other groups, that is, those firms engaged (and not engaged) in both strategies at the same time.

characteristics: CKS firms are larger than NCKS firms, likely due to the inclusion of multinational companies (headquarters and their affiliates) in the former group. These firms are also generally better positioned in international markets, whereas firms sourcing knowledge through non-captive modes tend to derive greater benefits from national or regional markets. Finally, CKS are less open to external knowledge sources and place less emphasis to demand enhancing objectives compared to NCKS firms.

[Table 1 around here]

### 5.2. Empirical results

Table 2 shows our main results. In the first two columns, the dependent variable is a dummy variable indicating the presence of product innovations, such that the estimation method employed is a logit model. In the first column, we observe that the probability of a firm engaging in product innovation is higher for firms that outsource, regardless of whether the outsourcing is captive or non-captive—measured by the expenditures on external acquisition of knowledge per worker, both, within and outside the group, respectively. The effect is higher for the former, confirming previous literature findings that outsourcing knowledge from external sources can result in a loss of control over the R&D process, leading to uncertainty and moral hazard problems. As a result, firms may be more inclined to innovate when the outsourcing is conducted with companies within the same group. Indeed, the null hypothesis of no differences between the coefficients of CKS and NCKS is rejected. Interestingly, when we analyze the effect of these two outsourcing strategies on the probability of a firm doing a product innovation which is new to the market (second column), which we understand to incorporate a higher degree of novelty, the result reverses, such that only outsourcing knowledge to external sources has a positive and significant effect. This is likely because radical/breakthrough innovations require firms to access a broader range of knowledge which is essential for challenging established market ideas.

[Table 2 around here]

We now take a step forward and analyze whether the firm is able to transform these innovations into commercialized new products, such that the dependent variable in the following columns of Table 2 refers to the share of sales due to product innovations. In all these cases, we use a random effects Tobit model (see Grimpe and Kaiser, 2010; Steinberg et al., 2017). Colum 3 shows the effect these two strategies have on the benefits obtained in terms of sales thanks to product innovations, which is positive and significant for the case of NCKS, while it is not significant for the case of CKS. Again, when we look at the impact of the different modes of outsourcing on the share of sales thanks to product innovations that are new to the market (proxy for the benefits from radical innovations), the access to sources external to the firm seems to have a significant effect, a finding that is not obtained when it is sourced from other firms belonging to the same group. Therefore, it appears that allocating more resources to acquiring external knowledge from third-party organizations (NCKS) yields greater benefits than investing those resources in acquiring knowledge from firms within the same group (CKS), thereby providing strong support for our first hypothesis.

We now turn to test our competing hypotheses about a complementarity or substitutability relationship between CKS and NCKS (column 5). As shown, NCKS remains positive and statistically significant, while the effect of CKS is not significant. However, the coefficient for the interaction term between these two strategies is also not statistically significant. This result may suggest that both arguments for complementarity and substitutability are at play, with the impact of one strategy potentially offsetting the effect of the other. Therefore, we can conclude that in the Spanish context, firms engaged in both strategies do not derive any additional advantage (neither disadvantage) from simultaneously employing both strategies compared to firms adopting only one. Therefore, we find no evidence to support either of our second hypotheses (H2a and H2b).

Finally, as remarked in our third hypothesis, we acknowledge that the effect of CKS and NCKS may be nonlinear, that is, the size of the effect may vary depending on the intensity of the resources allocated to both strategies. Therefore, we divide CKS and NCKS into quartiles taking the first one as the reference category in both cases.[8] As shown in column 6 of Table 2, most of the findings remain consistent, with CKS having no effect on the benefits derived from radical innovations, while NCKS demonstrates a positive impact. Notably, this effect is stronger as the resources dedicated to external knowledge sources increase. This threshold lies above the median, indicating that a considerable investment of resources is needed for firms to obtain benefits from radical innovation, thereby supporting Hypothesis 3.

Table 2 also shows that all control variables present their expected sign even though not all of them are statistically significant. Engaging in internal R&D as well as collaborating on R&D projects with external partners have a positive and significant effect on the share of sales that firms obtain from radical innovations. Not surprisingly, selling their products in the national and international markets—EU and Rest of the World—with the regional market serving as the base category—is also beneficial for the firm. Permanent innovation, the degree of openness as well as demand pull are also found to be significant. However, firm size or affiliation with a group does not appear to result in any significant difference in the firms' sales obtained from radical innovations.

[8] Notice that due to the large number of zeroes—firms not doing external knowledge sourcing—, we force the first category to have all the zeros, constructing the rest of the quartiles for the positive values of each variable.

### 5.3. Robustness checks and sensitivity analysis

We conduct a series of robustness analyses. First, Table 3 shows the results of our main model (in Table 2) only for manufacturing and services sectors excluding Agriculture, Mining and extraction, Energy water and sanitation, and Construction sectors. These excluded sectors present different levels of concentration as well as differences in expenditure for both strategies. For instance, Mining and extraction are mainly composed of few big firms with several subsidiaries across the world (Petroleum firms), which may imply an important transference of knowledge among them—the average firm within this sector expend around 24 times more per worker in CKS than in NCKS. Despite the exclusion of these sectors, we do not observe any difference from the general results commented above.

[Table 3 around here]

So far, the estimations provided were obtained with a random effect Tobit model, given the nature of the dependent variable, with values between 0 and 100. However, we additionally perform estimations including fixed effects (FE) (Table 4). This allows to perfectly control for unobserved time invariant firm characteristics—although the within variation of our dependent variables is lower than the between variation, making the inclusion of fixed effects less necessary. In this manner, we facilitate causal estimations, as the subject-level confounding is eliminated by construction, leading to unbiased estimates.[9] The dependent variable is a logit transformation of our main dependent

[9] Of course, this does not preclude possible reverse causality problems. However, as Cassiman and Veugelers (2006) and Love et al. (2014) highlight, the use of exogenous instruments has rarely succeeded when using CIS type data as it is in our case. In any case, we have lagged the explanatory variables to lessen the possibility of simultaneity problem.

variable (*RI share*).[10] As shown in Table 4, our main results remain consistent when a FE estimation is used.

[Table 4 around here]

The Tobit model makes the strong assumption that the probability mechanisms of the zeroes and the positives values are the same. Given this, we find it necessary to relax this assumption using a two steps model to control for sample selection (Cameron and Trivedi, 2009). This approach enables the detection and control of sample selection using the methodology developed by Semykina and Wooldridge (2010) as well as by Wooldridge (1995) (see also Wooldridge, 2010. Chapter 19).[11] Consequently, we estimate a first stage using a Probit model for the decision to be an innovator—(*PI dummy*) in our case—including some exclusion restrictions, and using the inverse Mill's ratios calculated from the first stage into the second stage, which is our main equation with a dependent variable as in Table 4 (see previous paragraph description).

The exclusion restrictions we use come from the related literature (Archibugi et al., 2013; Belderbos et al., 2013): *Cost obstacles* (Sum of the scores of importance that the firm attributed [number between 1 (high) and 4 (not used)] to the following factors that hampered its innovation activities: lack of funds within the enterprise or enterprise group; lack of finance from sources outside the enterprise; innovation costs too high. Rescaled from 0 (unimportant) to 1 (crucial)); *Risk obstacles* (Sum of score of importance

[10] The dependent variable is a logit transformation $log\left(\frac{y_{it}}{1-y_{it}}\right)$ where $0 \leq y_{it} \leq 1$. Since the log of the bounds of $y_{it}$ (especially for the case of zero) are not defined, we apply a winsorizing process for the extreme values, assigning 0.9999 to 1 and 0.0001 to 0. For a similar approach see: Klomp and Van Leeuwen ( 2001), Mohnen et al. (2006), Raymond et al. (2010) and Robin and Schubert (2013). Because of perfect multicollinearity with the firms' fixed effects, the sectoral dummy variables are not included.

[11] In this case, the sample selection problem arises from the observation that firms with zero outcomes may not be innovative firms, as our hypotheses are tested exclusively for innovative firms. The second reason, as highlighted by Cameron and Trivedi (2009), concerns potential violations of normality assumptions in the Tobit model, which necessitates the use of a sample selection model. This model first estimates the probability of being an innovator in the initial step.

that the firm attributed [number between 1 (high) and 4 (not used)] to the uncertain demand for innovative goods or services and to the market dominated by established enterprises as factors that hampered its innovation activities—rescaled from 0 (unimportant) to 1 (crucial)); *Knowledge obstacles* (Sum of the scores of importance that the firm attributed [number between 1 (not important) and 4 (very important)] to the following factors that hampered its innovation activities: lack of qualified personnel; lack of information on technology; lack of information on markets; difficulty in finding cooperation partners for innovation, which is rescaled from 0 (unimportant) to 1 (crucial)). This approach allows us to account for the firm's perception of the barriers to innovation. The results (column 1 from Table 5) confirm the existence of a sample selection problem while supporting the main finding above. However, since the results show only minimal qualitative and quantitative changes (see Table 4), our results can be interpreted as unchanged by sample selection.[12]

An additional important check involves examining the non-linearity for CKS and NCKS. To gain more insights, we perform an analysis for ensuring the functional form in both cases (Table 5). Therefore, we first include the squared term of both variables, where we see that while CKS is not significant, only the positive part of NCKS is significant (column 2). Next, we include a cubic term (Steinberg et al., 2017), but in this case, none of the variables are significant (even though the quadratic and cubic term of the CKS are marginally significant). However, we also disaggregate both measures into 10 dummy variables (deciles, being the base category not doing CKS/NCKS), evincing that the pattern is like the logarithmic one.

[Table 5 around here]

[12] Due to space limitations, we leave the first stage result upon request from the authors.

Because not all firms may have access to both types of strategies—as a firm that does not belong to a group can only utilize NCKS—, we decided to test the results, specifically the complementarity/substitutability analysis analyzed in hypotheses 2a and 2b only for firms that belong to a group of firms (Table 6). Our main findings remain unchanged.

[Table 6 around here]

Next, we would like to disentangle whether the effect comes from the governance mode—difference between CKS and NCKS—or from the different nature of the knowledge provider—firms versus other organizations such as universities (Table 7). Therefore, we exclude universities and research centers from the measurements, whose knowledge may have a more scientific nature, and therefore more prone to contribute to radical innovations. As can be seen, the results confirm our main findings in Table 2.

[Table 7 around here]

Finally, to further explore the complementarity or substitutability relationship between CKS and NCKS, we divided the analysis by typology of sectors, their technological classification, and firm size. This allowed us to examine whether the significance of the interaction term varies across firms with different technological orientations and size. Despite these divisions, the interaction between CKS and NCKS remained statistically not significant across most of all classifications. This suggests that the dynamics between CKS and NCKS may not be as context dependent as previously anticipated.[13,14]

[13] We thank one of the reviewers for suggesting a deeper exploration of the interaction between CKS and NCKS across different dimensions.
[14] Further details on these robustness checks can be requested from the authors.

## 6. Conclusions

Prior literature has argued that even though captive and non-captive modes of knowledge acquisition are good strategies for firm's innovativeness, the former tends to have a greater impact. As argued, this can be a result of the knowledge leakage that may appear when the interchange of technology happens among third party organizations, while internal modes of knowledge transmission between headquarters and their affiliates enjoy greater levels of confidence. Much of the literature has considered, though, the impact of these two strategies of knowledge acquisition on the probability of innovation. Although we acknowledge that this is a valid concern, we believe that it is even more important to examine the benefits of innovation in terms of sales. In this context, we argue that non-captive modes may be more significant, as the knowledge acquired from external sources can introduce a higher degree of novelty. Moreover, when focusing on the generation of radical or breakthrough innovations, it becomes evident that utilizing diverse and disconnected pieces of knowledge is essential—knowledge that goes beyond what can be acquired from firms within the same group. Our findings for Spanish firms support this hypothesis.

Additionally, although there are theoretical arguments both pointing to a complementary and substitutability relationship between captive and non-captive modes of knowledge sourcing, the results do not allow us to conclude in favor of any of them. Therefore, we can conclude that in the case of Spain, firms engaging in both strategies do not derive any additional advantage (neither disadvantage) from simultaneously employing both strategies compared to firms adopting only one. Finally, we observe that the effect of NCKS is nonlinear, being positive and higher the higher the resources dedicate to it. However, as highlighted by Un and Rodríguez (2018) for the case of R&D

outsourcing—although, in their case, without differencing between captives or non-captives modes—, our findings show that while there is a threshold level below which NCKS is not profitable, this threshold lies above the median. This indicates that firms must demonstrate a substantial level of commitment to NCKS to effectively exploit its potential for generating returns from their most novel innovations. Such a commitment likely entails allocating sufficient resources and fostering robust external partnerships to integrate diverse and unconnected knowledge effectively. These results highlight the importance of strategic planning and resource investment in NCKS to ensure its contribution to radical innovation performance.

Finally, the study has some limitations. First, we do not have information on the outsourced knowledge at the project-level, therefore, we cannot differentiate between cost-driven and knowledge-driven motives, which should be tested in future research using other databases. However, we think that the expenditure on the external R&D—as it is used in this study—might be a good proxy for the value added. Another limitation arises from the lack of distinct categories of external R&D in the data—such as R&D, design, and marketing—which could account for their varying impacts. Finally, knowing the countries from where outsourced knowledge comes might enrich the analysis.

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Table 1. Descriptive analysis for CKS and NCKS firms

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Only CKS | | | | | Only NCKS | | | | | | CKS and NCKS | | | | | Nore CKS/NCKS | | | | |
| VARIABLES | mean | sd | N | min | max | mean | sd | N | min | max | diff | mean | sd | N | min | max | mean | sd | N | min | max |
| Product Innovation (dummy) | 0.706 | 0.456 | 1,982 | 0 | 1 | 0.727 | 0.445 | 23,144 | 0 | 1 | -0.21** | 0.820 | 0.385 | 2,433 | 0 | 1 | 0.368 | 0.482 | 90,000 | 0 | 1 |
| Product Innovation (share) | 27.42 | 36.02 | 1,982 | 0 | 100 | 29.49 | 36.13 | 23,144 | 0 | 100 | -2.069** | 30.35 | 34.79 | 2,433 | 0 | 100 | 14.95 | 30.59 | 90,000 | 0 | 100 |
| Radical Innovation (dummy) | 0.599 | 0.490 | 1,408 | 0 | 1 | 0.649 | 0.477 | 16,880 | 0 | 1 | -0.049*** | 0.686 | 0.464 | 1,995 | 0 | 1 | 0.491 | 0.500 | 33,437 | 0 | 1 |
| Radical Innovation (share) | 15.21 | 26.87 | 1,408 | 0 | 100 | 18.96 | 28.33 | 16,880 | 0 | 100 | -3.751*** | 16.28 | 25.21 | 1,995 | 0 | 100 | 14.57 | 26.51 | 33,437 | 0 | 100 |
| CKS | 4,699 | 11,364 | 1,982 | 2.670 | 246,362 | 0 | 0 | 23,144 | 0 | 0 | | 4,750 | 20,257 | 2,433 | 0.336 | 513,079 | 0 | 0 | 89,996 | 0 | 0 |
| NCKS | 0 | 0 | 1,982 | 0 | 0 | 4,307 | 42,554 | 23,144 | 0 | 5.731e+06 | | 6,326 | 29,232 | 2,433 | 0.319 | 578,048 | 0 | 0 | 89,996 | 0 | 0 |
| Collaboration | 0.523 | 0.500 | 1,982 | 0 | 1 | 0.595 | 0.491 | 23,144 | 0 | 1 | -0.072*** | 0.744 | 0.437 | 2,433 | 0 | 1 | 0.276 | 0.447 | 56,083 | 0 | 1 |
| Size (log) | 5.256 | 1.380 | 1,982 | 0 | 10.13 | 4.174 | 1.572 | 23,144 | 0 | 10.63 | 1.081*** | 5.328 | 1.630 | 2,433 | 0 | 10.63 | 4.090 | 1.743 | 89,996 | 0 | 10.63 |
| Internal R&D | 0.0364 | 0.177 | 1,982 | 0 | 2 | 0.148 | 0.360 | 23,128 | 0 | 2 | -0.112*** | 0.118 | 0.316 | 2,432 | 0 | 2 | 0.0492 | 0.206 | 89,920 | 0 | 2 |
| Group | 1 | 0 | 1,982 | 1 | 1 | 0.400 | 0.490 | 23,144 | 0 | 1 | 0.6*** | 1 | 0 | 2,433 | 1 | 1 | 0.379 | 0.485 | 90,000 | 0 | 1 |
| Regional market | 0.0303 | 0.171 | 1,982 | 0 | 1 | 0.0595 | 0.237 | 23,144 | 0 | 1 | -0.029*** | 0.0349 | 0.184 | 2,433 | 0 | 1 | 0.135 | 0.342 | 90,000 | 0 | 1 |
| National market | 0.126 | 0.332 | 1,982 | 0 | 1 | 0.209 | 0.407 | 23,144 | 0 | 1 | -0.083*** | 0.133 | 0.340 | 2,433 | 0 | 1 | 0.312 | 0.463 | 90,000 | 0 | 1 |
| EU market | 0.161 | 0.368 | 1,982 | 0 | 1 | 0.150 | 0.357 | 23,144 | 0 | 1 | 0.011 | 0.140 | 0.347 | 2,433 | 0 | 1 | 0.160 | 0.366 | 90,000 | 0 | 1 |
| Rest of the World market | 0.683 | 0.466 | 1,982 | 0 | 1 | 0.582 | 0.493 | 23,144 | 0 | 1 | 0.101*** | 0.692 | 0.462 | 2,433 | 0 | 1 | 0.393 | 0.488 | 90,000 | 0 | 1 |
| Permanent | 0.840 | 0.367 | 1,126 | 0 | 1 | 0.838 | 0.369 | 20,447 | 0 | 1 | 0.002 | 0.912 | 0.283 | 2,267 | 0 | 1 | 0.746 | 0.435 | 34,995 | 0 | 1 |
| Openness | 5.370 | 2.769 | 1,982 | 0 | 8 | 6.097 | 2.295 | 23,143 | 0 | 8 | -0.726*** | 6.625 | 2.029 | 2,433 | 0 | 8 | 4.647 | 2.832 | 56,082 | 0 | 8 |
| Demand pull | 0.688 | 0.463 | 1,982 | 0 | 1 | 0.743 | 0.437 | 23,138 | 0 | 1 | -0.054*** | 0.797 | 0.403 | 2,433 | 0 | 1 | 0.594 | 0.491 | 56,072 | 0 | 1 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Column (11) is the statistical difference between the average of Only CKS (column 1) and Only NCKS (column 6).

Table 2. Main results

| VARIABLES | (1)<br>Logit FE<br>PI<br>(dummy) | (2)<br>Logit FE<br>RI<br>(dummy) | (3)<br>Tobit<br>PI (share) | (4)<br>Tobit<br>RI (share) | (5)<br>Tobit<br>RI (share) | (6)<br>Tobit<br>RI (share) |
|---|---|---|---|---|---|---|
| CKS (log) | 0.051*** | 0.018 | 0.258 | -0.004 | 0.051 | |
| | (0.014) | (0.013) | (0.182) | (0.151) | (0.226) | |
| NCKS (log) | 0.019*** | 0.027*** | 0.350*** | 0.327*** | 0.333*** | |
| | (0.006) | (0.007) | (0.099) | (0.089) | (0.091) | |
| CKS (log) * NCKS (log) | | | | | -0.012 | |
| | | | | | (0.036) | |
| 2nd quartile CKS | | | | | | -1.460 |
| | | | | | | (1.447) |
| 3rd quartile CKS | | | | | | 1.825 |
| | | | | | | (1.554) |
| 4th quartile CKS | | | | | | -0.409 |
| | | | | | | (1.848) |
| 2nd quartile NCKS | | | | | | 0.421 |
| | | | | | | (0.820) |
| 3rd quartile NCKS | | | | | | 1.951** |
| | | | | | | (0.774) |
| 4th quartile NCKS | | | | | | 3.722*** |
| | | | | | | (0.901) |
| Collaboration | 0.296*** | 0.225*** | 3.972*** | 2.996*** | 2.990*** | 3.009*** |
| | (0.041) | (0.046) | (0.731) | (0.646) | (0.645) | (0.646) |
| Internal R&D | 0.125 | 0.162 | 10.269*** | 9.831*** | 9.833*** | 9.763*** |
| | (0.080) | (0.108) | (1.628) | (1.472) | (1.472) | (1.472) |
| Size (log) | 0.281*** | 0.231*** | 0.881** | -0.458 | -0.458 | -0.357 |
| | (0.049) | (0.061) | (0.394) | (0.366) | (0.366) | (0.370) |
| Group | 0.091 | -0.076 | -0.601 | -0.021 | -0.023 | -0.025 |
| | (0.072) | (0.082) | (1.024) | (0.951) | (0.951) | (0.951) |
| National Market | -0.169 | 0.021 | 1.465 | 5.655*** | 5.658*** | 5.596*** |
| | (0.109) | (0.147) | (2.016) | (2.004) | (2.004) | (2.008) |
| EU Market | 0.077 | -0.046 | 4.129* | 5.327*** | 5.333*** | 5.230** |
| | (0.119) | (0.156) | (2.117) | (2.059) | (2.059) | (2.063) |
| Rest of the World Market | 0.110 | -0.046 | 4.723** | 6.234*** | 6.237*** | 6.141*** |
| | (0.122) | (0.158) | (2.083) | (2.037) | (2.036) | (2.040) |
| Permanent | 0.336*** | 0.236*** | 6.745*** | 5.217*** | 5.213*** | 5.211*** |
| | (0.045) | (0.056) | (0.882) | (0.803) | (0.803) | (0.803) |
| Openness | 0.039*** | 0.036*** | 0.804*** | 0.414*** | 0.414*** | 0.415*** |
| | (0.008) | (0.010) | (0.160) | (0.149) | (0.149) | (0.149) |
| Demand pull | 0.467*** | 0.169*** | 10.398*** | 3.947*** | 3.945*** | 3.949*** |
| | (0.040) | (0.050) | (0.807) | (0.701) | (0.701) | (0.701) |
| Constant | | | -41.520*** | -16.883*** | -16.875*** | -17.115*** |
| | | | (5.187) | (5.659) | (5.660) | (5.659) |
| Observations | 27,117 | 20,760 | 52,517 | 37,663 | 37,663 | 37,663 |
| Sectoral dummy variables | Yes | Yes | Yes | Yes | Yes | Yes |
| Wald Test Time dummy variables | 1169*** | 148*** | 254.2*** | 46.78*** | 46.67*** | 47.11*** |

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3. Manufacture and service sectors

| VARIABLES | (1)<br>Logit FE<br>PI (dummy) | (2)<br>Logit FE<br>RI (dummy) | (3)<br>Tobit<br>PI (share) | (4)<br>Tobit<br>RI (share) | (5)<br>Tobit<br>RI (share) | (6)<br>Tobit<br>RI (share) |
|---|---|---|---|---|---|---|
| CKS (log) | 0.048*** | 0.016 | 0.175 | -0.062 | -0.047 | |
| | (0.015) | (0.013) | (0.185) | (0.155) | (0.227) | |
| NCKS (log) | 0.015** | 0.025*** | 0.338*** | 0.341*** | 0.342*** | |
| | (0.006) | (0.007) | (0.102) | (0.090) | (0.093) | |
| CKS (log) * NCKS (log) | | | | | -0.003 | |
| | | | | | (0.036) | |
| 2nd quartile CKS | | | | | | -2.270 |
| | | | | | | (1.456) |
| 3rd quartile CKS | | | | | | 1.468 |
| | | | | | | (1.589) |
| 4th quartile CKS | | | | | | -0.686 |
| | | | | | | (1.895) |
| 2nd quartile NCKS | | | | | | 0.546 |
| | | | | | | (0.841) |
| 3rd quartile NCKS | | | | | | 2.089*** |
| | | | | | | (0.792) |
| 4th quartile NCKS | | | | | | 3.891*** |
| | | | | | | (0.920) |
| Collaboration | 0.303*** | 0.215*** | 3.840*** | 2.700*** | 2.698*** | 2.707*** |
| | (0.043) | (0.047) | (0.744) | (0.657) | (0.657) | (0.657) |
| Internal R&D | 0.135 | 0.170 | 10.338*** | 10.106*** | 10.107*** | 10.035*** |
| | (0.083) | (0.109) | (1.652) | (1.499) | (1.498) | (1.499) |
| Size (log) | 0.341*** | 0.223*** | 0.942** | -0.494 | -0.494 | -0.392 |
| | (0.052) | (0.062) | (0.401) | (0.373) | (0.373) | (0.377) |
| Group | 0.042 | -0.058 | -0.576 | 0.322 | 0.322 | 0.319 |
| | (0.074) | (0.083) | (1.045) | (0.968) | (0.968) | (0.967) |
| National Market | -0.163 | 0.036 | 0.900 | 6.105*** | 6.105*** | 6.030*** |
| | (0.115) | (0.151) | (2.110) | (2.115) | (2.115) | (2.119) |
| EU Market | 0.107 | -0.062 | 3.814* | 5.586*** | 5.587*** | 5.475** |
| | (0.125) | (0.159) | (2.203) | (2.164) | (2.164) | (2.169) |
| Rest of the World Market | 0.139 | -0.056 | 4.338** | 6.577*** | 6.577*** | 6.469*** |
| | (0.128) | (0.161) | (2.167) | (2.144) | (2.144) | (2.148) |
| Permanent | 0.334*** | 0.228*** | 6.584*** | 4.993*** | 4.992*** | 4.982*** |
| | (0.047) | (0.057) | (0.902) | (0.818) | (0.818) | (0.818) |
| Openness | 0.041*** | 0.034*** | 0.754*** | 0.375** | 0.375** | 0.375** |
| | (0.008) | (0.010) | (0.164) | (0.152) | (0.152) | (0.152) |
| Demand pull | 0.455*** | 0.182*** | 9.894*** | 3.791*** | 3.791*** | 3.792*** |
| | (0.041) | (0.051) | (0.825) | (0.716) | (0.716) | (0.715) |
| Constant | | | -18.653*** | -22.626*** | -22.628*** | -22.768*** |
| | | | (3.401) | (3.169) | (3.168) | (3.172) |
| Observations | 25,273 | 20,170 | 49,500 | 36,135 | 36,135 | 36,135 |
| Sectoral dummy variables | Yes | Yes | Yes | Yes | Yes | Yes |
| Wald Test Time dummy variables | 1125*** | 138.6*** | 228.3*** | 41.06*** | 40.99*** | 41.39*** |

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4. Fixed effects models

| VARIABLES | (1) PI (share) | (2) RI (share) | (3) RI (share) | (4) RI (share) |
|---|---|---|---|---|
| CKS (log) | 0.029 | -0.000 | 0.003 | |
| | (0.020) | (0.018) | (0.027) | |
| NCKS (log) | 0.028*** | 0.031*** | 0.031*** | |
| | (0.011) | (0.011) | (0.011) | |
| CKS (log) * NCKS (log) | | | -0.001 | |
| | | | (0.004) | |
| 2nd quartile CKS | | | | -0.217 |
| | | | | (0.162) |
| 3rd quartile CKS | | | | 0.193 |
| | | | | (0.177) |
| 4th quartile CKS | | | | 0.032 |
| | | | | (0.218) |
| 2nd quartile NCKS | | | | 0.068 |
| | | | | (0.094) |
| 3rd quartile NCKS | | | | 0.216** |
| | | | | (0.089) |
| 4th quartile NCKS | | | | 0.339*** |
| | | | | (0.109) |
| Collaboration | 0.383*** | 0.250*** | 0.250*** | 0.250*** |
| | (0.079) | (0.075) | (0.075) | (0.075) |
| Internal R&D | 0.569*** | 0.511*** | 0.511*** | 0.506*** |
| | (0.180) | (0.189) | (0.189) | (0.189) |
| Size (log) | 0.266** | 0.219* | 0.219* | 0.229** |
| | (0.109) | (0.114) | (0.114) | (0.114) |
| Group | 0.130 | -0.018 | -0.018 | -0.016 |
| | (0.145) | (0.147) | (0.147) | (0.147) |
| National Market | -0.043 | 0.439 | 0.439 | 0.433 |
| | (0.235) | (0.281) | (0.281) | (0.281) |
| EU Market | 0.109 | 0.331 | 0.331 | 0.322 |
| | (0.254) | (0.291) | (0.291) | (0.292) |
| Rest of the World Market | 0.097 | 0.372 | 0.372 | 0.364 |
| | (0.257) | (0.294) | (0.294) | (0.294) |
| Permanent | 0.474*** | 0.285*** | 0.285*** | 0.285*** |
| | (0.095) | (0.091) | (0.091) | (0.091) |
| Openness | 0.031* | 0.027 | 0.027 | 0.026 |
| | (0.017) | (0.017) | (0.017) | (0.017) |
| Demand pull | 0.571*** | 0.208*** | 0.208*** | 0.208*** |
| | (0.082) | (0.076) | (0.076) | (0.076) |
| Constant | -4.506*** | -6.162*** | -6.162*** | -6.189*** |
| | (0.508) | (0.543) | (0.543) | (0.543) |
| Observations | 52,517 | 37,663 | 37,663 | 37,663 |
| R-squared | 0.018 | 0.007 | 0.007 | 0.007 |
| Sectoral dummy variables | No | No | No | No |
| Wald Test Time dummy variables | 30.49*** | 5.874*** | 5.863*** | 5.892*** |

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 5. Sample Selection and non-linear shape

| VARIABLES | (1)<br>RI (share) | (2)<br>RI (share) | (3)<br>RI (share) | (4)<br>RI (share) |
|---|---|---|---|---|
| CKS (log) | -0.021 | 0.054 | -2.852 | |
| | (0.018) | (0.606) | (1.818) | |
| CKS (log) squared | | -0.009 | 0.798* | |
| | | (0.077) | (0.478) | |
| CKS (log) cubic | | | -0.053* | |
| | | | (0.031) | |
| NCKS (log) | 0.027** | -0.428 | 0.943 | |
| | (0.011) | (0.347) | (1.025) | |
| NCKS (log) squared | | 0.098** | -0.277 | |
| | | (0.044) | (0.270) | |
| NCKS (log) cubic | | | 0.025 | |
| | | | (0.018) | |
| Collaboration | 0.214*** | 3.025*** | 3.033*** | 3.026*** |
| | (0.081) | (0.646) | (0.646) | (0.645) |
| Internal R&D | 0.549*** | 9.620*** | 9.602*** | 9.749*** |
| | (0.191) | (1.473) | (1.471) | (1.473) |
| Size (log) | 0.097 | -0.331 | -0.344 | -0.357 |
| | (0.125) | (0.371) | (0.371) | (0.371) |
| Group | -0.093 | -0.030 | -0.050 | -0.043 |
| | (0.147) | (0.951) | (0.952) | (0.952) |
| National Market | 0.431 | 5.597*** | 5.593*** | 5.639*** |
| | (0.277) | (2.003) | (2.003) | (2.006) |
| EU Market | 0.327 | 5.250** | 5.279** | 5.273** |
| | (0.289) | (2.057) | (2.057) | (2.063) |
| Rest of the World Market | 0.421 | 6.160*** | 6.179*** | 6.191*** |
| | (0.293) | (2.035) | (2.035) | (2.040) |
| Permanent | 0.257*** | 5.215*** | 5.215*** | 5.203*** |
| | (0.098) | (0.803) | (0.803) | (0.803) |
| Openness | 0.023 | 0.418*** | 0.416*** | 0.415*** |
| | (0.018) | (0.149) | (0.149) | (0.149) |
| Demand pull | 0.253*** | 3.949*** | 3.969*** | 3.950*** |
| | (0.087) | (0.701) | (0.701) | (0.701) |
| 2nd decile CKS | | | | -2.798 |
| | | | | (2.022) |
| 3rd decile CKS | | | | -1.369 |
| | | | | (2.260) |
| 4th decile CKS | | | | -0.332 |
| | | | | (2.373) |
| 5th decile CKS | | | | 2.229 |
| | | | | (2.355) |
| 6th decile CKS | | | | 0.482 |
| | | | | (2.286) |
| 7th decile CKS | | | | 3.418 |
| | | | | (2.671) |
| 8th decile CKS | | | | 2.673 |
| | | | | (2.763) |
| 9th decile CKS | | | | -1.969 |
| | | | | (2.936) |
| 10th decile CKS | | | | -2.639 |
| | | | | (3.015) |
| 2nd decile NCKS | | | | 1.359 |
| | | | | (1.238) |
| 3rd decile NCKS | | | | 0.474 |
| | | | | (1.175) |
| 4th decile NCKS | | | | -0.473 |
| | | | | (1.057) |
| 5th decile NCKS | | | | 1.765 |
| | | | | (1.086) |
| 6th decile NCKS | | | | 1.551 |
| | | | | (1.096) |
| 7th decile NCKS | | | | 2.204** |
| | | | | (1.074) |
| 8th decile NCKS | | | | 2.883** |

| | | | | |
|---|---|---|---|---|
| | | | | (1.159) |
| 9th decile NCKS | | | | 4.273*** |
| | | | | (1.169) |
| 10th decile NCKS | | | | 4.227*** |
| | | | | (1.443) |
| Constant | -6.921*** | -17.210*** | -17.202*** | -17.121*** |
| | (0.864) | (5.659) | (5.658) | (5.662) |
| | | | | |
| Observations | 52,517 | 37,663 | 37,663 | 37,663 |
| Wald Test Time dummy variables | 31.38* | 47.08*** | 46.91*** | 46.85*** |
| Sectoral dummy variables | Yes | Yes | Yes | Yes |
| Test lambdas (Sample Selection) | 21.65** | | | |

Table 6. Only firms pertaining to a group of firms

| VARIABLES | (1)<br>Logit FE<br>PI (dummy) | (2)<br>Logit FE<br>RI (dummy) | (3)<br>Tobit<br>PI (share) | (4)<br>Tobit<br>RI (share) | (5)<br>Tobit<br>RI (share) | (6)<br>Tobit<br>RI (share) |
|---|---|---|---|---|---|---|
| CKS (log) | 0.048*** | 0.010 | 0.190 | -0.047 | -0.135 | |
| | (0.014) | (0.014) | (0.177) | (0.144) | (0.216) | |
| NCKS (log) | 0.021** | 0.022** | 0.114 | 0.251* | 0.229* | |
| | (0.010) | (0.011) | (0.146) | (0.129) | (0.138) | |
| CKS (log) * NCKS (log) | | | | | 0.019 | |
| | | | | | (0.036) | |
| 2nd quartile CKS | | | | | | -2.074 |
| | | | | | | (1.383) |
| 3rd quartile CKS | | | | | | 1.120 |
| | | | | | | (1.484) |
| 4th quartile CKS | | | | | | -0.312 |
| | | | | | | (1.765) |
| 2nd quartile NCKS | | | | | | -1.422 |
| | | | | | | (1.012) |
| 3rd quartile NCKS | | | | | | 2.623** |
| | | | | | | (1.097) |
| 4th quartile NCKS | | | | | | 3.723*** |
| | | | | | | (1.349) |
| Collaboration | 0.326*** | 0.186*** | 4.823*** | 1.218 | 1.239 | 1.266 |
| | (0.068) | (0.070) | (1.070) | (0.932) | (0.930) | (0.930) |
| Internal R&D | -0.197 | 0.447** | 7.785*** | 6.718** | 6.692** | 6.492** |
| | (0.174) | (0.225) | (3.002) | (2.890) | (2.887) | (2.890) |
| Size (log) | 0.266*** | 0.271*** | 0.055 | 0.450 | 0.448 | 0.705 |
| | (0.081) | (0.092) | (0.520) | (0.453) | (0.453) | (0.459) |
| National Market | -0.099 | -0.282 | 2.184 | -0.777 | -0.789 | -0.912 |
| | (0.219) | (0.253) | (3.335) | (3.747) | (3.745) | (3.752) |
| EU Market | 0.048 | -0.382 | 2.234 | -2.086 | -2.113 | -2.338 |
| | (0.231) | (0.263) | (3.378) | (3.685) | (3.683) | (3.694) |
| Rest of the World Market | 0.079 | -0.485* | 2.077 | -1.617 | -1.636 | -1.880 |
| | (0.233) | (0.267) | (3.379) | (3.666) | (3.664) | (3.673) |
| Permanent | 0.294*** | 0.105 | 6.187*** | 3.843*** | 3.862*** | 3.819*** |
| | (0.081) | (0.097) | (1.434) | (1.267) | (1.267) | (1.265) |
| Openness | 0.036*** | 0.044*** | 0.939*** | 0.705*** | 0.706*** | 0.709*** |
| | (0.013) | (0.015) | (0.239) | (0.221) | (0.221) | (0.220) |
| Demand pull | 0.401*** | 0.295*** | 9.698*** | 4.897*** | 4.904*** | 4.907*** |
| | (0.067) | (0.080) | (1.191) | (1.012) | (1.013) | (1.011) |
| Constant | | | -21.875*** | -17.230** | -17.229** | -18.188** |
| | | | (7.652) | (7.424) | (7.424) | (7.409) |
| Observations | 9,843 | 8,911 | 22,418 | 16,644 | 16,644 | 16,644 |
| Sectoral dummy variables | Yes | Yes | Yes | Yes | Yes | Yes |
| Wald Test Time dummy variables | 419.1*** | 48.50*** | 67.36*** | 23.11** | 23.20** | 23.77*** |

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 7. Dropping universities and research center from NCKS

| VARIABLES | (1)<br>PI<br>(dummy) | (2)<br>RI<br>(dummy) | (3)<br>PI (share) | (4)<br>RI (share) | (5)<br>RI (share) | (6)<br>RI (share) |
|---|---|---|---|---|---|---|
| CKS (log) | 0.051*** | 0.018 | 0.239 | -0.001 | -0.001 | |
| | (0.014) | (0.013) | (0.183) | (0.151) | (0.206) | |
| NCKS (log) | 0.021*** | 0.023*** | 0.479*** | 0.287*** | 0.287*** | |
| | (0.007) | (0.007) | (0.107) | (0.093) | (0.096) | |
| CKS (log) * NCKS (log) | | | | | -0.000 | |
| | | | | | (0.038) | |
| 2nd quartile CKS | | | | | | -1.218 |
| | | | | | | (1.448) |
| 3rd quartile CKS | | | | | | 1.928 |
| | | | | | | (1.550) |
| 4th quartile CKS | | | | | | -0.399 |
| | | | | | | (1.852) |
| 2nd quartile NCKS | | | | | | -0.476 |
| | | | | | | (0.840) |
| 3rd quartile NCKS | | | | | | 1.174 |
| | | | | | | (0.842) |
| 4th quartile NCKS | | | | | | 3.886*** |
| | | | | | | (0.975) |
| Collaboration | 0.305*** | 0.239*** | 4.130*** | 3.218*** | 3.218*** | 3.237*** |
| | (0.041) | (0.046) | (0.726) | (0.639) | (0.638) | (0.639) |
| Internal R&D | 0.125 | 0.167 | 10.265*** | 9.901*** | 9.901*** | 9.841*** |
| | (0.080) | (0.108) | (1.626) | (1.475) | (1.474) | (1.475) |
| Size (log) | 0.281*** | 0.234*** | 0.855** | -0.481 | -0.481 | -0.374 |
| | (0.049) | (0.061) | (0.393) | (0.366) | (0.366) | (0.368) |
| Group | 0.089 | -0.074 | -0.602 | -0.015 | -0.015 | -0.032 |
| | (0.072) | (0.082) | (1.023) | (0.951) | (0.951) | (0.951) |
| National Market | -0.170 | 0.021 | 1.481 | 5.682*** | 5.682*** | 5.615*** |
| | (0.109) | (0.147) | (2.012) | (2.005) | (2.005) | (2.007) |
| EU Market | 0.079 | -0.045 | 4.159** | 5.380*** | 5.380*** | 5.264** |
| | (0.119) | (0.156) | (2.114) | (2.059) | (2.059) | (2.062) |
| Rest of the World Market | 0.111 | -0.047 | 4.729** | 6.276*** | 6.276*** | 6.167*** |
| | (0.122) | (0.158) | (2.080) | (2.036) | (2.036) | (2.039) |
| Permanent | 0.339*** | 0.238*** | 6.780*** | 5.275*** | 5.275*** | 5.278*** |
| | (0.045) | (0.056) | (0.881) | (0.804) | (0.804) | (0.803) |
| Openness | 0.039*** | 0.037*** | 0.806*** | 0.427*** | 0.427*** | 0.428*** |
| | (0.008) | (0.010) | (0.160) | (0.149) | (0.149) | (0.149) |
| Demand pull | 0.467*** | 0.170*** | 10.392*** | 3.964*** | 3.964*** | 3.970*** |
| | (0.040) | (0.050) | (0.807) | (0.701) | (0.701) | (0.700) |
| Constant | | | -41.141*** | -16.517*** | -16.517*** | -16.758*** |
| | | | (5.172) | (5.656) | (5.657) | (5.647) |
| Observations | 27,117 | 20,760 | 52,517 | 37,663 | 37,663 | 37,663 |
| Sectoral dummy variables | Yes | Yes | Yes | Yes | Yes | Yes |
| Wald Test Time dummy variables | 1170*** | 150*** | 254.2*** | 47.78*** | 47.77*** | 48.16*** |

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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