Make or Buy to innovate in the Software sector [ξ]

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Resumen

En el contexto de profundo crecimiento económico que han atravesado los países latinoamericanos, el grado de innovación en sectores de alta tecnología, como los Knowledge Intensive Business Services (KIBS), resulta clave para la construcción de una senda de desarrollo virtuoso. En ese sentido, la innovación exitosa en las empresas depende del desarrollo e integración de nuevos conocimientos en el proceso innovativo. En este trabajo se analiza la existencia de complementariedad entre las fuentes internas y externas de conocimiento para actividades de innovación en las empresas del sector de software de Argentina, tomando cuenta del escaso tratamiento de estas cuestiones en los estudios de innovación de estos sectores en economías emergentes. El marco teórico se basa en la literatura Make and Buy, los estudios de innovación y la literatura KIBS, y el herramental econométrico involucra una serie de estimaciones de la función de la innovación (Probit Ordenado, Tobit, OLS y Probit). Los resultados nos permiten afirmar la existencia de relaciones de complementariedad entre las fuentes de conocimiento internas y externas, independientemente del modelo de regresión considerado, lo cual remarca la solidez del ejercicio cuantitativo.

Palabras clave: Industria del software; Complementariedad; Innovación, I+D, Adquisición de Tecnologías.

Abstract

In the context of profound economic growth that has been taking place in Latin American countries, the extent of innovation in high technology sectors such as Knowledge Intensive Business Services (KIBS), is considered fundamental to build a virtuous developing path. In this sense, successful innovation in business depends on the development and integration of new knowledge in the innovation process. This paper analyzes the existence of complementarity between internal and external sources of knowledge for innovation activities in firms from the software industry of Argentina, taking account of the limited treatment of these matters in studies of innovation of these sectors in emerging economies. The theoretical framework is grounded on the Make and Buy literature, innovation studies and KIBS literature; and the econometric tools involves a group of estimates of the role of innovation (Ordered Probit, Tobit, OLS and Probit). The results allow us to state the existence of complementary relations between internal and external knowledge sources, regardless the regression model considered, which underline the robustness of the quantitative exercise.

Key words: Software industry; Complementarity; Innovation; R&D; Technology Acquisition

Clasificación JEL: D21, O31, O32.

1. Introduction and Motivation of the study

The economies of Latin America experienced a profound economic growth in the last decade. In that context, it is important to analyze the extent that emerging catching up processes in high tech sectors, as for example *Knowledge Intensive Business Services* (KIBS), opens a way to a virtuous developing path.

The software and IT services is one of the more important KIBS. Besides that the leaders of the sector have remained in the developed world, over the 1990s many developing countries have catch up and gained a competitive position among the main global actors[1]. Brazil and Argentina, following the Asian model, have recognized the importance of intangible goods - such as software and services in general - for their potential of direct economic impact. Therefore, policy makers and scholars in the region have become interested in the innovation process in the software industry.

Nowadays, the understanding of the innovation process implies the recognition that firms do not innovate in isolation but there are external influences by mean of complementary information and knowledge that may become key drivers of firms' performance. Closed innovation views has been losing effectiveness due to a series of aspects (the reduction of the innovations life cycle, the innovation-based competition, etc.), enlarging the necessity of firms to expand their access to new knowledge. The new models of innovation explain the predominance of open firms' strategies that leads to the study of complementarity, underlining the fact that this is a context-specific aspect (A. Arora, Gambardella, & Torrisi, 2004; Cassiman & Veugelers, 2006; Chesbrough, 2003; Laursen & Salter, 2006; Mohnen & Röller, 2005). Successful innovation in firms depends upon the development and integration of new knowledge into the innovation process though diverse innovative activities, internal and external to the firm (Cassiman & Veugelers, 2002).

With this background, it became more and more important to establish if these activities are complementary or substitute related to the innovation performance of the firm, to approach a better understanding of the nature of innovation processes in diverse production activities. Moreover, the empirical research has been focused on manufacturing sectors. However, the economic literature on services point out that the characteristics of the innovation process are essentially different in this kind of economic activity (Drejer, 2004).

Innovation studies on services tends to point out that there are specific aspects on the nature itself of production in these sectors that particularize its innovation processes (Drejer, 2004; Gallouj & Savona, 2009): immateriality, co-production and a profound interactivity with external actors. Software production is a complex activity that involves an essentially creative-stage –development– which in turn involves conceptualization, requirements analysis and high-level design. Less creative activities are low-level coding design, testing and technical support, which are sometimes

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[1] This process has happened in three different waves (Ashish Arora, Arunachalam, Asundi, & Fernandes, 2001; Britto, Cassiolato, & Stallivieri, 2007). The first wave was led by India. Due to its strong competitive advantage in skilled human capital and knowledge of the English language, both integrated in Business Process Outsourcing. The second wave included China and the Philippines: China took advantage of its large domestic market and became a major player, and the Philippines imitated India's strategy, becoming experts in Business Process Outsourcing. The last wave involved Brazil and Argentina, among others countries (Malerba & Nelson, 2011).

outsourced by development firms. On the other hand, software services involve fully customized solutions, and other routinized ones. They involve implementation and customization of third party products, consulting, training, and tasks associated with installation, operation and maintenance of software. In any case, software activities seem to imply certain combination of internal and external knowledge sources. That allows to hypothesize that a complementarity relation could arise between internal and external innovative activities, which is the main working hypothesis of the paper.

As the nature of innovation differs in these sectors, there are also reasons to consider that complementarities between innovative activities could differ in this type of sectors, mostly on KIBS. The objective of this paper is to evaluate the existence of complementarity between internal and external sources of knowledge in relation to innovation results, in a KIBS sector from an emerging economy: the software and IT services case from Argentina. The paper intends to be a first step to further ongoing research on the degree that complementarity relations between innovation activities are influenced by diverse characteristics of the firms and contextual aspects.

In this paper, we will follow the empirical rigorous method presented by Cassiman and Veugelers (2006) to test the existence of complementarity in the innovation strategies of Argentinean firms from the software sector. It intends to be a first step to further ongoing research on the degree that complementarity relations between innovation activities are influenced by diverse characteristics of the firms and contextual aspects.

The paper is structured as follows: In section two, we present the theoretical background that frames the hypotheses development. In section three, we present the methodology and the description of the data, the construction of the indicators and the econometrical methods used. Section four discusses the main results of the quantitative analysis, and section five presents some main concluding remarks.

2. Theoretical Framework and Antecedents

In this section we present the main theoretical and empirical antecedents. Section 2.1 presents the main theoretical arguments related to the complementarity between internal and external sources to innovation in the literature and reviews the empirical research in the subject. Afterwards, section 2.2 presents a brief review of innovation literature on KIBS and, particularly, on the software sector, as well the statement of the principal hypothesis of the paper.

2.1 – Research on complementarities between internal and external sources to innovation

In a global world, the competition selection mechanisms challenge the knowledge management of firms to innovate, to grow, to survive. Successful innovation in firms depends upon the development and integration of new knowledge into the innovation process (Cassiman & Veugelers, 2002) by different sources: internal creation of knowledge, external acquisition of technology in diverse forms through market channels (buy of licenses, patents, etc.), linkages and informal knowledge flows and incoming spillovers (Cassiman & Veugelers, 2002; Jaffe, 1986; Veugelers, 1997; Veugelers & Cassiman, 1999; von Hippel, 1987, 2007). We will focus on the relation between in-

house innovative activities, and the external acquisition by market channels. Largely, industrial and innovation economics' literature studied the issue of the degree in which internal and external innovative activities, namely knowledge sources, are complementary or substitutes for innovation.

Theoretically, there are opposed arguments. On the tradition of transaction cost theory (Arrow, 1962; Coase, 1937; Williamson, 1985) and property right theory (Grossman & Hart, 1986), the main prediction is the existence of substitutability between the internal development of innovative activities and the external acquisition of knowledge. As external acquisition could have large *ex-ante* transactional costs regarding searching and bargaining, while large *ex post* costs are regarding the execution and enforcement of contracts; a substitutability effect between internal and external innovative activities seems to prevail.

On the other hand, it is also plausible to think that these knowledge sources may be complementary for a successful innovative performance. For instance, as there is necessary to have internal competences that allow to effectively absorb external knowledge, internal R&D develops the firm's ability to "(…) identify, assimilate, and exploit knowledge from the environment" (Cohen & Levinthal, 1989), what is known as absorptive capacity of the firm. From a management perspective, as David J. Teece (1986) points out, the complementary assets may be crucial for the successful commercialization of an innovation. The key argument is that firms need to expand their access to external sources, and collaboration with external agents is seen as a way to achieve a better competitive position, as a source of higher efficiency lead by a better exploitation of economies of scale and dynamic capabilities, making innovation activities more flexible and dynamic (David J. Teece, 1986; David J Teece, Pisano, & Shuen, 1997). In sum, these kind of arguments of authors from recourse-based view of the firm approaches, argue that internal knowledge creation activities usually reduces the inefficiencies of external acquisition and allows to modify and improve the absorption of knowledge from outside the firm. In that sense, it could arise complementarity relations between internal and external knowledge sources for innovation. Thus, this is a controversial topic because opposed arguments can be found in the literature that allow us to expect both substitutability and complementarity relations.

To deal quantitatively with the issue of complementarities, it could be found two econometrical strategies (Mohnen & Röller, 2005)[2] [3]. The most common econometric strategy has been the so called correlation approach in which simple correlations between the variables, with or without controls, are analyzed. In this line, some studies found that internal and external innovative activities tend to be substitutes; evidence is provided for the US (Blonigen & Taylor, 2000), and similar results are found for some emerging economies such as the Indian case (Basant & Fikkert, 1996). Alternatively, others found complementarity relations between knowledge sources, being diverse the focus of their analysis: some findings correspond to developed countries such as the US,

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[2] - Also there is another strategy, the *reduced form approach* (v.gr: Deolalikar and Evenson, 1989). However, this strategy has identification problems and the antecedents in this line are minor.

[3] - There are also a group of argetinean innovation studies that, following diverse methodological strategies, tends to suggest and point out the existence of a better performance of manufacturing firms that adopts balanced innovative strategies (G. Lugones, Anlló, Bianco, & Raffo, 2002; Gustavo Lugones, Suárez, & Le Clech, 2007; Suárez, 2009).

Japan and some European countries (Ashish Arora & Gambardella, 1990; Cassiman & Veugelers, 2002), and others found complementarity as well between internal and external sources in some emerging economies such as Brazil and India (Braga & Willmore, 1991; Deolalikar & Evenson, 1989)[4]. Thus, the empirical literature in this line does not reach conclusive results.

These studies account for the co occurrence of external and internal knowledge sources, but do not test directly their complementarity in relation to innovation results. Another empirical strategy adopts a direct approach (Mohnen & Röller, 2005) and tries to cover this gap, some empirical studies being concerned with the study of complementarities in relation to the performance effects. The direct approach just recently has been applied in the innovation literature. In particular, Mohnen and Röller (2005) evaluate the complementarity between obstacles to innovation in European firms, and Miravete and Pernias (2006) apply this approach to analyze to complementarities between product and process innovations in Spanish firms. Nonetheless, regarding the particular issue of complementarity between internal and external sources, the antecedents using discrete data are relatively scarce. One of the most influential paper in this line is the work of Cassiman and Veugelers (2006) applying this method to analyze complementarity between external knowledge buy and internal R&D activities in Belgium firms. Their results point out that these activities are complementary to innovation, and this is sensitive to contextual aspects.

In sum, the available empirical literature has not reached conclusive results and the evidence that applies the more modern techniques is scarce. This is especially true for emerging economies, where a notable gap in the literature can be detected. On the other hand, the research has been focused on manufacturing sectors, and there are not antecedents of this kind of testing on KIBS sectors. As the economic literature on services point out that the characteristics of the innovation process is essentially different in this kind of economic activity (Drejer, 2004), there are reasons to consider that complementarities between innovative activities could differ in this type of sectors, mostly on KIBS.

In that sense, emerges the main objective of the paper that is to evaluate the existence of complementarity between internal and external sources of knowledge in relation to innovation results in a KIBS sector from an emerging economy. For the case, we will consider the software and IT services sector from Argentina. Next, a brief review of the innovation literature in the software sector is presented.

2.2 – Innovation on KIBS and the Software Sector

In recent decades, there has been an increasing interest on the KIBS and their role as servers of other high-tech and low-tech industries. KIBS are characterized by concentrate its production on providing intangible inputs to knowledge-intensive business processes in other organizations, both public and private, and by heavily depending on specialized knowledge and typically, such firms have high levels of qualified staff (Miles, 2005; Miles, Kastrinos, Flanagan, Bilderbeek, & den Hertog, 1995; Muller & Doloreux, 2009). Some kind of KIBS is based on legal, administrative

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[4] - In particular, Audretsch, Menkveld, and Thurik (1996) find out in the case of Germany that internal and external activities are substitutes in the *low tech* sectors, while there is complementarity in *high tech* sectors.

or commercial knowledge, while others rely particularly on scientific and technological knowledge. The last kind of KIBS sectors are among the most active innovators in developed economies, according to various reports based on technological surveys (DTI, 2003; Tether & Swan, 2003). Within the KIBS sectors, the software and related IT services sector is one of the most innovative in developed economies and in some catching-up economies as well (DTI, 2003; Niosi, Athreye, & Tschang, 2012; Tether & Swan, 2003).

The global software industry market – including packaged products, custom products, related software services and embedded software products – was estimated in 880 Bi [USD] for year 2009, with an important share owned by developing countries, mostly Asian but more recently, by Latin American countries as well, such as Argentina and Brazil (ABES, 2011; Malerba & Nelson, 2011; Niosi et al., 2012). The software industry generates related products for several other industries, including high-tech and non-high-tech sectors and where knowledge is the most important resource and production factor. In this sense, many studies have shown the presence and extent of the role of the software industry in economic performance and in the competitiveness of regions and nations (Antonelli, 2000; Miles, 2004; Tomlimson, 2000).

Moreover, there is extant literature from the economics of innovation perspective in the software industry: an important group of studies that has focused on policy making and its structural characteristics at the national (Anchordoguy, 2000; Ashish Arora et al., 2001; Baba, Takai, & Mizuta, 1995; Breznitz, 2007; Mowery & Langlois, 1996), at local level (Parthasarathy & Aoyama, 2006) or in product segments (Klincewicz & Miyazaki, 2011; Storz, 2008); a group of studies that have focused on the influence of appropriability regimes on innovation (de Laat, 2005) and on the influence of new kinds of organizations like open source communities (Dahlander & Magnusson, 2005; Lakhani & von Hippel, 2003); studies of the trend or virtues of geographic concentration of production and innovative activity (Boschma & Weterings, 2005; Weterings & Boschma, 2009); and a group of studies that focus on the characteristics of innovation capabilities and the role of tacit knowledge and experience on the sector (Grimaldi & Torrisi, 2001; Romijn & Albaladejo, 2002; Rousseva, 2008; Weterings & Boschma, 2009).

This paper is related partially to the latter group. There are studies, as Grimaldi and Torrisi (2001), that engage the internal organization of the knowledge inside firms; others that analyze the determinants of the recurrence to diverse external knowledge sources (Matusik & Heeley, 2005; Segelod & Jordan, 2004); and studies that focus on the impact of internal activities on innovation, by one side, and from external activities, by other (Romijn & Albaladejo, 2002). That is, the innovation studies on software sector does not dealt directly with the issue of complementarity and/or substitutability **between** internal and external innovation activities of the firm jointly, and that is the contribution of the paper. The working hypothesis of the research (H1) is that *there is a complementary relationship between internal and external sources of knowledge that positively impact firms' innovation results.*

On the other hand, the innovation studies on the software sector of Argentina dates mostly from the 2000's. These studies could be classified as follow: a group of studies that analyzes the historical emergence of the sector, their structural characteristics, potential and policy instruments at a national level (Barletta, Pereira, Robert, & Yoguel, 2013; Daniel Chudnovsky & López, 2005; D. Chudnovsky, López, & Melitsko, 2001;

Erbes, Robert, & Yoguel, 2006; Uriona, Morero, & Borrastero, 2013) or at a local level (J. Motta & Borrastero, 2012; Pujol, 2006); other studies focused on the export potential of the sector (Correa, 1996; López, 2003); a group is concentrated on the analysis of Clusters (López, Ramos, & Starobinsky, 2009; Pujol, 2006; Tigre et al., 2011); some studies were concerned with the characteristics of the labor relations in the sector and work organization (Borello, Erbes, Robert, Roitter, & Yoguel, 2005; Novick, 2002); and other studies analyses the nature of linkages and their obstacles in this sector (Miozzo & Grimshaw, 2008). The main concern of the research was not directly engaged in these studies, and the paper tries to contribute with particular insights about the issue of complementarity between internal and external innovation activities in the software sector from Argentina.

3. Methodology and Data Source

Testing for complementarities between two variables when the nature of the available data regarding the key variables is discrete, implies testing if the objective function is supermodular in these arguments[5]. Supermodular functions belong to a mathematical field known as *Lattice Theory*[6]. A real function $I(x)$ defined in the lattice X is supermodular in x if $I(x') + I(x'') \leq I(x' \vee x'') + I(x' \wedge x'')$ is satisfied by all x' and x'' in X. When the inequality is inverse, $I(x)$ is submodular. The condition of supermodularity between two arguments implies that the function shows complementarity between these arguments, and the condition of submodularity shows substitutability (Milgrom & Roberts, 1990; Topkis, 1998).

This specification of the function allows, besides complementarities, the existence of indivisibilities, increasing scale returns, synergy and systemic effects, as long as the function cannot be convex, concave, differentiable nor even discontinuous in some points (Milgrom & Roberts, 1990, 1995). In that sense, to specify that an innovation function is supermodular or submodular in some arguments, imposes relatively scarce restrictions concerning the nature of the innovation process itself.

For instance, can be assumed that innovation function depends on the recurrence to knowledge sources, in addition to traditional structural factors. In Section 3.1, as follows, we present the specification of the innovation function and the econometric issues related to the complementarity tests. Next, in Section 3.2 the data sources and main characteristics of the sample are presented.

3.1 - Econometric Issues and Complementarity Tests

To estimate the coefficients of the sources of knowledge for innovation to test the complementarity inequalities, an innovation function for each firm i is specified [1],

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[5] - When continuous data about independent variables are available, an alternative in the "direct objective function approach" is to regress the innovation variable with a cross variable of the dependent variables that we want to test their complementarity, besides the controls. Examples of this exercise in innovation economics are Lokshin, Belderbos, and Carree (2008) and Hou and Mohnen (2011).

[6] - A Lattice is a partially ordered set, where there is a binary relation that is reflexive, anti-symmetric and transitive; and where for each pair of elements there is a supremum by pairs ($x' \vee x''$, the join) and a infimum ($x' \wedge x''$, the meet), that are contained inside the set (Milgrom & Roberts, 1995; Topkis, 1998).

where I^* represents an index underlying the ordinal responses observed (*i.e. it is an unobserved latent variable*).

$$I^{*i}(A_1^i, A_2^i, X^i, \gamma, \beta) = (1-A_1^i)(1-A_2^i)\gamma_{00} + A_1^i(1-A_2^i)\gamma_{10} + A_2^i(1-A_1^i)\gamma_{01} + A_1^i A_2^i \gamma_{11} + \beta X^i + \varepsilon^i \quad [1]$$

There, A_1^i and A_2^i are dummy variables that represents the recurrence to knowledge sources to innovation (for instance, internal and external), γ their coefficients (necessary to carry out the complementarity tests), and X^i a set of control variables (*Size, Property of Capital, Age, Specialization, Exports, Linkages and Competences*).

Testing the complementarity between knowledge sources A_1 and A_2, implies to contrast the inequality:

$$\gamma_{11} - \gamma_{10} \geq \gamma_{01} - \gamma_{00} \quad [2]$$

If [2] holds the innovation function is supermodular in A_1 and A_2, and these knowledge sources are complementaries. Moreover, the innovation function could be submodular, meaning that the obstacles are substitutes. The inequation to be tested would be analogous to [2], but the inequality would be presented in opposite signs.

The possibility to carry forward hypothesis tests around super- and submodularity will be feasible if the estimates are consistently counted in γ. Obtained these estimates, it will be possible to establish the adequate hypothesis, as follows. The hypothesis that the innovation function is supermodular in knowledge sources A_1 and A_2 is:

$$H_0: \quad ks \leq 0$$

$$H_1: \quad ks > 0$$

Where $ks = \gamma_{00} + \gamma_{11} - \gamma_{10} - \gamma_{01}$. However, it must be pointed out that rejecting H_0 does not imply that the two sources in question are substitutes or supplementary. To test this issue, we have to see if the innovation function is submodular in sources A_1 and A_2, and the hypothesis is analogous in this way:

$$H_0: \quad ks \geq 0$$

$$H_1: \quad ks < 0$$

In order to contrast these hypotheses, the so called *Wald Test* for inequality restrictions is applied:

$$(S\tilde{\gamma} - S\hat{\gamma})'[Scov(\hat{\gamma})S']^{-1}(S\tilde{\gamma} - S\hat{\gamma}) \quad [3]$$

Where $\hat{\gamma}$ is a consistent estimator of γ, S represents a matrix that summarizes the imposed restrictions for the defined inequalities, and $\tilde{\gamma}$ is the vector that minimizes the expression [3] below H_0. Kodde and Palm (1986) have tabulated the inferior and superior critical limits of this Wald statistic for different significance levels commonly used. Values of the Wald statistic that are inferior to the lower bound critical value will imply the acceptation of the defined null hypothesis; while if the statistic is superior to the upper bound critical value, the null hypothesis should be rejected. When the test value is found between the two bound critical values, the test will be inconclusive. Lastly, the situation can present itself in that it accepts the null hypothesis of supermodularity, and also of submodularity; the reason being that the inequalities of H_0 are not strict, and in this case one can say that neither supermodularity nor

submodularity exist in a strict manner. In that case, and additional Wald test could be made, with null hypothesis equal to zero.

As we worked with an ordinal variable of innovation, we defined an ordered probit model, to estimate the coefficients of recurrence to internal and external knowledge sources:

$$I^{*i}(KS^i_{int}, KS^i_{ext}, Z^i, \delta, \mu) = (1 - KS^i_{int})(1 - KS^i_{ext})\delta_{00} + KS^i_{int}(1 - KS^i_{ext})\delta_{10} + KS^i_{ext}(1 - KS^i_{int})\delta_{01} + KS^i_{int}KS^i_{ext}\delta_{11} + \mu Z^i + \omega^i$$

[4]

Where I^* represents a unobserved index underlying the ordinal responses observed (*i.e.* it is a latent variable[7]), , while KS^i_{int} is the recurrence of firm i to internal knowledge sources, KS^i_{ext} is the recurrence of firm i to external knowledge sources, both binary variables), δ their coefficients , and Z^i a set of control variables (*Size*, *Property* of *Capital*, *Specialization*, *Exports, Age, Linkages and Competences*).

Equation [1] will be estimated by maximum likelihood and the coefficients δ allows to carry out the supermodularity and submodularity tests (that are Wald inequality restriction tests). As a robustness check, we redefine the response variable, the innovation variable *I,* in order to carry out other regression models, thus Ordinal Least Squares, Tobit and a Probit model was specified from the equation [1], considering the same explanatory variables.

3.2 - Data Source and Indicators

We used a primary data source based on a survey from the research project *"Capacity of Absorption and Production Systems Connectivity and Local Innovation"* from the Carolina Foundation[8]. Thus, the data come from a specific technological survey done over 2011, to 257 software and related services producer firms from Argentina. The survey covers the period 2008-2010, and asks about the general structural aspects of the firms (size, origin of capital, exports, sales, employment, type of production, etc.); their demand structure and product destination; external linkages and relationships with different types of actors and objectives (technical assistance, quality management, joint venture, finance or R&D); innovative activities (types of innovations introduced, degree of novelty, etc.); capabilities (organization of the work process, quality management, training structure, etc.); appropriability issues and the impact of public policies.

The design of the sample is based on a previous work of specification of the Universe of the sector, coordinated along the Employment and Entrepreneurial Dynamics Observatory from the Ministry of Labor from Argentina (Barletta, Pereira, Robert, & Yoguel, 2012; Barletta et al., 2013). The sample considers representativeness according the firm size and the national public programs use distribution in the Universe. A population of 1.600 firms from the sector (excluding micro firms)

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[7] We consider I^* as a latent variable underlying the ordinal variable of innovation used. In our models, innovation takes 3 levels, so that instead of observing I^* we observe: $I = 1$ if $I^* \leq \tau_1$; $I = 2$ if $\tau_1 \leq I^* \leq \tau_2$; *and* $I = 3$ if $\tau_2 \leq I^*$. The τ's are unknown "threshold" parameters that must be estimated along with other parameters of de models.

[8] "Capacity of Absorption and Production Systems Connectivity and Local Innovation". Carolina Foundation (id. 386317). The project was carried out under the direction of Gabriel Yoguel (UNGS).

employing around 57.000 workers was estimated by 2010 in Argentina, and 22% of which was covered by national public policy (Barletta et al., 2012). The sample also includes 57 firms from the video games sector. On average, the firms of the sample employ around 50 workers and they show a high external market insertion. Mostly are national firms. Related to their geographical distribution, most are located in Buenos Aires (75,4%), and the remainder is distributed between the provinces of Córdoba (17,85%) and Santa Fe (6,75%).

The data were used to construct a series of indicators to run the pertinent regressions required to test the supermodularity and submodularity between knowledge sources. The detailed construction of these indicators is available in the **Appendix A**, but a brief characterization is presented as follows below.

The dependent variable in the ordered probit model is an ordinal indicator of *Innovation* (it assumes values between 1 and 3) that takes into account if the firm introduced new products, new processes, improved products, significant improved processes, organizational changes, or developed new commercial channels; weighted according to the novelty degree of the innovation (new for the firm or new for the market). Table 1 summarizes the level of innovation according to this indicator.

Table 1. Innovation Levels in the sample

	All Sample		
	Low	**Medium**	**High**
Innovation Indicator	30,85%	49,46%	19,68%

The regressions performed to robustness check the results involved (OLS, Probit and Tobit) involved a dummy and a continuous variables of innovation. These variables are variations of the ordinal variable presented here, but can be seen the detail in the Appendix.

The independent variables engage the recurrence of the firm to diverse innovative activities, distinguishing the recurrence to internal from external activities. The internal innovative activities considered comprise basically internal R&D. On the other hand, the external innovative activities comprise external R&D, buy of licenses or specific software for the firms, and contract of consultancies to innovate. The coefficients necessary to perform the tests requires dummies of the recurrence to innovative activities. The binary variables reflect if the firm recurs neither to internal nor to external knowledge sources (*Not Internal Not External*), if it does to internal knowledge sources but does not to external ones (*Only Internal*), if the firm resorts to external knowledge sources but it does not to the internal (*Only External*), and if the firm recurs jointly to both of them (*Internal & External*). Table 2 shows the frequency of these indicators for the complete sample. These indicators constitute the independent variables of the Model and its coefficients are necessary to perform the super and submodularity tests.

Finally, as control, we considered typical structural variables (Size, Origin of Capital, Specialization and Export Profile) and indicators of the other main determinants of

innovation besides innovative activities (Internal Competences and External Linkages). As structural indicators, *Size* is considered by the number of employees in 2010; *Export Profile* considers the percentage of sales coming from exports in 2010, and *Origin of Capital* is a dummy variable, adopting the value 1 if the firm is mainly foreign; and *Specialization* is considered by three dummies distinguishing if the firm is specialized in products, services, or it is diversified. As the other main determinants of innovation, an indicator of *Internal Competences* was calculated taking into account the R&D structure of the firm, quality certifications and management activities, the qualification of the workers and training structure; and an ordinal indicator of *External Linkages* takes into account the interactions established by a firm during the period with other firms or outside sources for collective R&D activities, technical and/or quality assistance.

Table 2. Recurrence to Internal and External Knowledge Sources. Complete Sample.

	Frequency
Not Internal Not External	3,89%
Only Internal	6,61%
Only External	22,18%
Internal & External	66,93%

Note: 1 case missing

4. Results and Discussion

In this section, we discuss the results obtained from the quantitative analysis. Table 3 shows the estimates of different specified models. In all cases, a series of regressions were made with alternative dependent variables of innovation, and also different combinations of control variables were explored, and the results presented here correspond to those that have a better fit, using as alternative indicators according to the characteristics of the model in consideration (AIC, R^2, etc.)[9].

The estimated coefficients of the models are expressed as the deviations of the coefficient of *Not Internal and Not External* knowledge sources recurrence to avoid collinearity problems with the others dummies for knowledge sources. Besides the recurrence to knowledge sources indicators to perform the supermodularity tests. It must be noted that Ordinal Probit and Probit models shows a proportion of correct prediction of 0.52 and 0.70, respectively, while Tobit Model show a correlation of 0.49 between observed and predicted values – OLS model is the lowest performance according to R^2 and adjusted R^2 –. In all cases, there is a positive and significant relation between the *latent innovation* (I^*) and *Linkages* and *Competences*. This result would reveal that a high level of *Linkages* and *Competences* makes more likely to get a higher level of innovation.

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[9] - These estimation results can be obtained from authors upon request.

Table 3. Estimates of the models specified.

	Ordinal Probit			Probit			OLS			Tobit	
	Coefficient [1]	Sign.[2]		Coefficient [1]	Sign.[2]		Coefficient [1]	Sign.[2]		Coefficient [1]	Sign.[2]
Knowledge Sources Dummies											
(intercept)	---	---		-1,594	0,6282	**	-1,6322	1,9472		---	---
Not Internal Not External	---	---		---	---		---	---		---	---
Only Internal	0,4124	(0,5554)		0,2456	(0,5931)		1,2517	(1,8860)		1,5596	(2,0494)
Only External	0,3317	(0,4873)		0,2330	(0,5105)		0,8327	(1,6150)		1,0895	(1,7646)
Internal & External	0,9093	(0,4764)	*	0,8233	(0,5022)		3,2630	(1,5809)	*	3,8383	(1,7235)
Controls											
Size	0,0002	(0,0007)		-0,0009	(0,0008)		0,0022	(0,0024)		0,0015	(2,5045)
Origin of Capital	-0,3529	(0,2920)		-0,2040	(0,3514)		-1,5973	(1,0690)		-1,7944	(1,1346)
Export Profile	0,002	(0,0025)		0,0027	(0,0030)		0,0070	(0,7087)		0,0077	(9,8069)
Specialized in Services	-0,1568	(0,2118)		-0,3059	(0,2574)		-1,2405	(0,7806)		-1,5291	(8,2992)	*
Specialized in Products	-0,1622	(0,1982)		-0,2647	(0,2454)		-0,8433	(0,7274)		-1,0068	(7,7073)
Age	0,0146	(0,0103)		0,0078	(0,0125)		0,0533	(0,0371)		0,0468	(3,9297)
Linkages	0,2525	(0,0972)	***	0,3123	(0,1211)	***	1,0163	(0,3587)	***	1,0767	(3,7906)	***
Competences	0,4044	(0,1949)	**	0,4685	(0,2305)	**	2,1573	(0,0093)	***	2,6442	(7,5831)	***
/cut 1	1,6316	(0,5824)	***								
/cut 2	3,109	(0,5996)	***								
Log-likelihood	-227,85										
R^2	---			---			0,245			---		
R^2 adj	---			---			0,209			---		
AIC	481,71			---			---			---		
Prob > chi2	---			0,0001			---			0,0000		
Corr (obsv'd and pred'd values)	---			---			---			0,4939		
Perc. of Correct Predictions	0,5247			0,7037			---			---		

[1] Standard error in parentheses

[2] *** Significant at 1%;   ** Significant at 5%;   * Significant at 10%

To perform the test of complementarity and substitutability the dummy variables of knowledge sources of innovation are taken into account. In particular, when the Wald statistic is below 1,642, the corresponding test is accepted, and when the statistic is above 7,094 the test is rejected (Kodde & Palm, 1986). Table 4 shows the tests for the two models.

Table 4. Complementarity and Substitutability Tests. Wald Statistics.

	Ordinal Probit	Probit	OLS	Tobit
Supermodularity Test	7,79E-20	8,81E-26	5,36E-24	1,12E-24
Submodularity Test	2,04163	1,918098	1,547316	2,613098

Note: The test is accepted if the Wald statistic is below the lower bound at 10% of significance (1,642), and it is rejected if the statistic is above the upper bound (7,094) (Kodde & Palm, 1986).

It can be seen that the results are conclusive regarding the relation between internal and external knowledge sources for innovation: the supermodularity test is accepted and the submodularity test is not accepted for all models considered. This indicates that for firms in the software sector from an emerging economy as Argentina, internal and external knowledge sources are complementary to be more likely for getting a higher level of innovation. Note also that the Wald tests to super and submodularity are robust to the variations of the different models and the hypothesis acceptance holds in each case.

5. Final Remarks

This paper analyzes the existence of complementarity between internal and external sources of knowledge for innovation in firms from the software sector of Argentina. This is an issue that has received attention in the innovation literature but most of the evidence has been generated with firm level data analysis for developed countries. The empirical evidence presented tries to contribute to cover this detected lack in the literature[10].

Estimations of the innovation function were performed (Ordered Probit, Tobit, OLS and Probit) with the same independent variables, with acceptable adjustment levels and expected and significant signs of the typical determinants of innovation (a positive relation with Competences and Linkages).

Following a previous accepted empirical method applied to the study of complementarity, the results allows us to state the existence of complementary relations between internal and external knowledge sources, now in a service sector. Supermodularity tests between internal and external innovative activities were accepted, regardless the regression model considered, which remarks the robustness of the quantitative exercise.

In sum, the findings tend to support empirically the "Make & Buy" argument in the related literature, confirming the idea that successful innovation requires to complement internal knowledge sources (namely, 'making technology') with external knowledge sources (namely, 'buying technology') in a KIBS sector, a process that can be of particular relevance in the context of emerging economies.

On the other hand, these results intend to be an opening path to further research on the degree that complementarity relations between innovation activities are influenced by diverse characteristics of the firms and contextual aspects, following the line recognized and pointed out by Cassiman and Veugelers (2006). The next step should be going on further analysis of the issue, indentifying the main structural firm's characteristics and ambient aspects that affect complementarity.

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[10] - Recently, efforts were also done in this line with firm data level from manufacturing sectors from Argentina Álvarez, Morero, and Ortiz (2013), and testing complementarities between obstacles to innovation with the same sample of this paper J. J. Motta, Morero, Borrastero, and Ortiz (2013).

APPENDIX: Construction of Indicators

Dependent Variables

Innovation

Three innovation variables were considered. An ordinal variable to carry out an Order Probit regression, a dummy variable to carry out a Probit regression, and a continuous variable to carry out an OLS and a Tobit regression. The detail as follow.

Continuous Variable. Sum up if the firm introduced new products, new services, improved products, significant improved processes, organizational changes, or developed of new commercial channels; and weighting 1 if the innovation was new only for the firm, and 3 if the innovation was new also for the market.

Ordinal variable. The indicator establish three modalities according to the sum from the continuous variable: 1 (low) for a sum between 0 and 5; 2 (medium) for a sum between 6 and 11; and 3 (high) for a sum between 12 and 18.

Dummy Variable. Assumes 0 when the ordinal variable of innovation takes the value low; 1 otherwise.

Independent Variables

To perform the independent dummy variables, first, on the one hand, a dummy of recurrence to internal sources is performed (if the firm does internal R&D activities); and, on the other hand, a dummy of recurrence to external knowledge sources (if the firm does external R&D, buy of licenses or specific software for the firms, or contract of consultancies to innovate). Secondly, four dummies are calculated according to the combination of recurrence to both sources, as follow:

Not Internal Not External. Dummy variable. Assumes 1 if the firm has neither recur to internal nor external innovative activities; 0 otherwise

Only Internal. Dummy variable. Assumes 1 if the firm only recur to internal innovative activities; 0 otherwise.

Only External. Dummy variable. Assumes 1 if the firm only recur to external innovative activities; 0 otherwise.

Internal And External. Dummy variable. Assumes 1 if the firm recur both to internal and external innovative activities; 0 otherwise

Control Variables

Size

Continuous indicator that reflects the number of employees in a firm.

Origin of Capital

Dummy variable. Adopt 1 if the firm has more than 50% in foreign capital ownership and 0 if the firm has less.

Export Profile

Continuous variable that measures the percentage of the sales in 2010 coming from exports.

Internal Competences

Continuous variable. Varies between 1 and 3. It is an average of five ordinal sub-indicators with three modalities each (1=low, 2=medium, and 3=high):

- *R&D structure indicator* (1= with no structure, 2=with informal structure, and 3=with formal structure)

- *Quality standards indicator* (1= does not have any standards, 2=does have one standard, and 3=does have 2 or more standards)

- *Training structure indicator* (1= with no structure, 2=with informal structure, and 3=with formal structure)

- *Quality management indicator* (1= does not perform quality management activities, 2=perform 2 or 3 quality management activities , and 3=perform 4 or more quality management activities)

- *Worker's qualification indicator* (1= with university graduates below the average in the sample (38,42%), 2= with university graduates above the average in the sample (38,42%) and no postgraduates, and 3= with university graduates above the average in the sample (38,42%) and no postgraduates, or postgraduates over 30% of payroll)

External Linkages

Ordinal variable taking into account the interactions established by a firm to collective R&D activities, collective commercial actions, technical or quality assistance. The indicator assumes 3 (high) if the firm interacts with other agents for three or four kinds of interactions, assumes 2 (medium) if the firms interacts for two of the three types, and assumes 1 (low) if the firms interacts only in one kind of these types of linkages, or does not interacts with other agents at all.

Specialization

As is a nominal variable. Three dummies were constructed according to the productive specialization of the firms, taking into account the origin of its sales

Specialized in Products.

Dummy variable. Adopt 1 if the firm has more than 60% of its sales coming from its own products sales.

Specialized in Services.

Dummy variable. Adopt 1 if the firm has more than 60% of its sales coming from services provision.

Diversified

Dummy variable. Adopt 1 if the firm has more sales between 40% and 60% coming from services provision and sales between 40% and 60% coming from its own products sales.

Age

Continuous Variable. Age in years to 2011.

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