Complementaries between policy actions in software production in emerging economies. The case of Argentina

Jorge Motta, Hernán Alejandro Morero, Carina Borrastero, Pablo Ortiz

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Complementarities between Policy Actions in Software Production in Emerging Economies. The case of Argentina. [ξ]

MOTTA, Jorge
jjmotta@eco.unc.edu.ar
Instituto de Economía y Finanzas – FCE –
– Universidad Nacional de Córdoba. Argentina.
MORERO, Hernán Alejandro
hernanmorero@eco.uncor.edu
Centro de Investigaciones y Estudios sobre Cultura y Sociedad (CIECS), CONICET
Facultad de Ciencias Económicas – Universidad Nacional de Córdoba. Argentina.
BORRASTERO, Carina
carinaborrastero@conicet.gov.ar
Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)
Argentina.
ORTIZ, Pablo
portiz@eco.unc.edu.ar
Facultad de Ciencias Económicas – Universidad Nacional de Córdoba. Argentina.

Abstract

This paper aims to analyze the presence of complementarity and substitutability relations between policy innovation actions in a Knowledge Intensive Business Services sector (KIBS) in an emerging economy, relevant issue to impulse its development process. Supermodularity and submodularity tests were performed with technological data from 257 software firms from Argentina, for the period 2008-2010. The results show that in this KIBS sector in an emerging economy, innovation policies aimed to encourage firms to become innovators serve as well as an incentive for firms that have already introduced innovations to also increase the intensity of its innovation level.

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Keywords: Knowledge Intensive Business Services; Software Sector; Argentina; Supermodularity; Innovation Policy.

1. Introduction

The software world market was about US$ 880 Billion in 2009 (ABES, 2011), and the industry leaders have remained in the developed world. However, over the 1990s many developing countries, especially from Asia, have catch up and gained a competitive position among the main global actors. This process has happened in three different waves (Arora, Arunachalam, Asundi, & Fernandes, 2001; Britto, Cassiolato, & Stallivieri, 2007; Niosi, Athreye, & Tschang, 2012).

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 (Niosi, et al., 2012).

The third wave involved Brazil and Argentina, among others countries (Malerba & Nelson, 2011; Niosi, et al., 2012). These economies, 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, especially regarding the dynamism in which embodied knowledge is converted into software products.

The growth and performance of knowledge intensive sectors is an important issue to the development process in emerging economies. In that sense, the software sector offers outstanding opportunities to increase the participation of knowledge sectors in emerging economies' production structures. However, the innovation capacity of firms is limited by a set of factors, some internal and others external, that appears as obstacles to the innovation and growth of software firms. That is the reason why governments from different countries try to stimulate the growth and consolidation of its domestic production of software through actions of innovation policy, with the objective to neutralize the obstacles to innovation or, at least, diminish their constraining effects, and the improvement of sectoral innovation policies is a major concern to governments and policy makers. There is a body of literature that illustrates the importance that different government give to innovation policies in the software and IT related services sector (Anchordoguy, 2000; Arora, et al., 2001; Breznitz, 2007; Mowery & Langlois, 1996; Storz, 2008).

But public policies are costly for society. In addition that they can generate unwanted distortions in the assignment of productive resources, they also demand important financial resources, in which each case must be carefully evaluated the convenience of its implementation. In fact, from a development perspective becomes extremely important to manage public resources, usually scarce related to the huge investments that development demands, in the most efficient way as possible. Even more related to the necessity of protect infant industries and sectors, as the historical analysis of catching-up process of the actual developed economies shows (Cimoli, Dosi, Nelson, & Stiglitz, 2006; Chang, 2006).

One important issue in this respect, although not always considered at the hour to decide policy applications, is if these policies are complementary or supplementary. When two policy actions are supplementary, it can be redundant to apply both of them. However, if they are complementary, in order to achieve their objectives, it is better if the two policies are applied simultaneously (Mohnen & Röller, 2005).

Precisely, the main objective of this paper is to analyze the presence of complementarity and substitutability relations between policy innovation actions in a Knowledge Intensive Business Services sector (KIBS) in an emerging economy; particularly, the software production sector in Argentina.

This paper is organized as follows: Section 2 presents our theoretical framework and a review of the main findings of the scarce empirical antecedents in the literature that follow this approach. Section 3 presents our methodology and data sources. In section 4 our main results are presented, and lastly, Section 5 presents our conclusions and final remarks. Additionally, at the end there is an Appendix, where the indicators used are described.

2. Theoretical framework AND EMPIRICAL ANTECEDENTS

There is an extant empirical literature from the economics of innovation perspective in the software industry. This literature could be classified into several groups: studies that focus on the characteristics of innovation capabilities and the role of tacit knowledge and experience in this sector (Grimaldi & Torrisi, 2001; Romijn & Albaladejo, 2002; Rousseva, 2008; Weterings & Boschma, 2009); studies that have focused on the influence of appropriability regimes on innovation (de Laat, 2005; Shen, 2005) and on the influence of new kinds of organizations like open source communities (Dahlander & Magnusson, 2005; Lakhani & von Hippel, 2003); studies on the trend or virtues of geographic concentration of production and innovative activity (Boschma & Weterings, 2005; Weterings & Boschma, 2009); and lastly an important group of studies that has focused on policy making and its structural characteristics at the national level or in product segments.

In this latter group, Mowery and Langlois (1996) studied the role of the federal government in the US on the emergence and development of the software sector for a period of 40 years beginning in 1950; Breznitz (2007) analyzed the impact of the technological and industrial policy in the evolution of the sector in Israel with a comparative analysis in Ireland; and there is a variety of studies focused on the role of innovation policy in the software sector in Japan, both in the software sector as a whole (Anchordoguy, 2000), and in the videogames segment (Storz, 2008). Moreover, there are studies in emerging economies such as India (Arora, et al., 2001).

This paper is related partially to this latter group, because it aims to contribute to the innovation policy making in the sector in an emerging economy, which is Argentina. It focuses on a particular issue: the complementarities that could arise between policy innovation actions in this sector.

In development terms, it is of particular interest, considering the need for emerging countries to optimize the allocation of resources to the promotion policy (Rosenthal, 1997) and the strong impact of the latter on three fundamental aspects: the technological capabilities of the firms, the economic signals they face, and how they interact with each other and with other institutions (Cimoli, et al., 2006). In short, institutions and policies always matter in any process of technological learning, and public programs aimed at innovation are an essential part of the innovative dynamic (Nelson, 2008). In this sense, the line of analysis we propose can contribute to theoretical and methodological concerns about how to provide the state with administrative capacity to design and implement policies efficiently.

We focus our study on the innovation policies in the software sector. For the purposes of this paper, we present an *ad hoc* conceptualization of policies, according to its scope or level of generality. We define an *innovation policy* in general terms as a set of government actions aimed at encouraging innovation in firms and institutions in a country. Usually, this set is organized into one or more “higher level institutions” (e.g. in the case of Argentina, the Ministry of Science, Technology and Innovation) from which more specific subsets of policies are implemented (e.g. in the case of Argentina, Sectoral Funds such as FONSOFT and FONTAR) that we can distinguish by their sectoral character and/or by the particular needs of firms/institutions that they try to address (in our case, it is mostly needs related to the increase of the innovation level, but also, could consider the increase in exports, etc., that may be indirectly related to the level of innovation). We call such subsets *policy instruments*. Similarly, these instruments are composed of a variety of specific *policy actions*, which we distinguish specifically by the type of innovation factors to promote (for example, credits aimed at funding innovative activities, subsidies for human resources training, etc.). Innovation policies, in general terms, are concerned with removing the obstacles that firms face to innovate.

There is an important empirical literature which analyzes the role of barriers or obstacles to innovation (D'Este, Iammarino, Savona, & von Tunzelmann, 2012)[12]. A first line of research focused on the factors affecting the perception of the importance of the barriers (Baldwin & Lin, 2002; Galia & Legros, 2004; Iammarino, Sanna-Randaccio, & Savonna, 2009). A second line focused on the impact of the obstacles on the intensity of innovation and/or the propensity to innovate (D'Este, et al., 2012; Madrid-Guijarro, et al., 2009; Mancusi & Vezzulli, 2010; Mohnen & Röller, 2005; Savignac, 2008; Strube & Resende, 2009; Tourigny & Le, 2004).

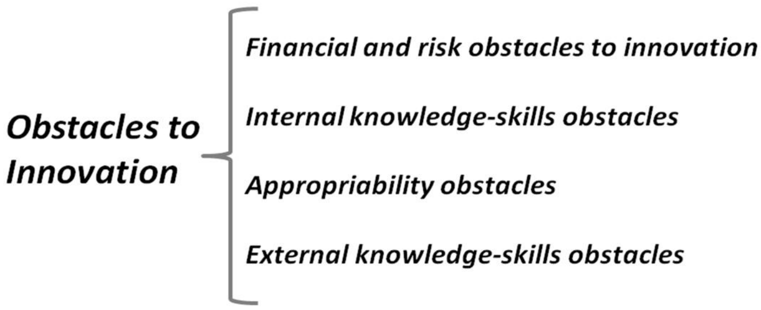
In this second line, some studies investigate the impact of obstacles to innovation on the propensity to innovate and/or the intensity of the innovativeness of firms, either on innovation inputs, namely innovative efforts of the firms, or innovation outputs (D'Este, et al., 2012; Madrid-Guijarro, et al., 2009; Mancusi & Vezzulli, 2010; Savignac, 2008). Mostly, these studies point out that there is an endogeneity of the perception of obstacles, as such, and the innovativeness degree of the firms[13]. Another group, analyzes the relation between obstacles and innovation output of the firms, assuming obstacles as failures, insufficiencies or lack of public policy (Mohnen & Röller, 2005; Strube & Resende, 2009). In this ocassion, we will follow this last perspective, and we will be concerned on what kind of complementarities or supplementarities could arise between obstacles to innovation, related directly with the innovation output of firms, resorting to an innovation survey data source.

[12] - A revision and a systematization of the literature regarding barriers to innovation also could be consulted in (Madrid-Guijarro, Garcia, & Van Auken, 2009).

[13] - That motivates D'Este, et al. (2012) to distinguish between perceived barriers to innovation in a discouraging or a deterring manner, from revealed barriers to innovation, when firms already done certain level of innovative activities of different kinds.

The innovation surveys, based on the innovation studies, have typically been concentrated in four kinds of obstacles to innovation. First, innovation could face *financial and risk obstacles to innovation*, addressing lack of appropriate sources of finance or formal restrictions to financial access; when the innovation costs seem to be very high or the pay-off period for the innovations is too long; when the interest rates are too high or the perceived risk seems to be excessive. Second, innovations could face *internal knowledge-skills obstacles*, when there is a lack of skilled human resources or it is too difficult to keep the more qualified personnel in the firm; when there is an internal lack of information on technologies or markets; when the costs of innovation are very hard to control, the capabilities of the firm offer a small innovation potential; or when there is a resistance to change in the organizational structure of the firm. Third, innovation could face *appropriability obstacles*; when the innovations in the sector are too easy to copy there is a lack of established appropriate property rights or a weak enforcement of norms; or when the *appropriability* mechanisms are too expensive, difficult or ineffective to protect the economic benefits of innovation. Fourth, innovation in the firms could face *external knowledge-skills obstacles*, when there are deficiencies in the availability or quality of external technical services; when there is a lack of technological or innovation opportunities in the market, the uncertainty of the demand is too high, there are scarce opportunities for cooperation with other firms or institutions or the institutional R&D network is very weak; or when there is no need to innovate due to earlier innovations.

Figure 1 – Typology of obstacles to innovation



These obstacles could appear jointly or separately, and could be more important in some instances of the innovation process than in others (i.e., it is harder to become an innovator, than to become more innovative). It could be assumed that innovation policy, through its policy instruments and action lines, has the objective of promoting innovation in firms, removing the obstacles to innovate that firms face, or removing the obstacles to improve the level of the innovation activities and innovation results. The policy, through its instruments and mechanisms, could be focused on jointly removing a group of obstacles, or to remove them separately. That is the reason why it is important to analyze the complementarities that could arise between diverse actions of innovation policy.

The framework developed by Mohnen and Röller (2005) allows to identify complementarities in innovation policies using discrete data through the innovation function[14]. It is assumed that innovation in a firm is characterized by an innovation function $I_i(a,\beta)$, where the government could choose a set J of policy variables denoted by $a=(a_1,a_2,...,a_J)$, and there is a set β of other firm-specific factors affecting innovation: firm-specific factor affecting innovation, like competences, linkages and innovative efforts as long structural aspects, like size, property of capital, etc.

Complementarities could be directly tested asking if the innovation function is supermodular in a (see follow). Unfortunately, the available data on innovation, particularly from innovation surveys, do not usually report government actions, nor offer exhaustive data about the government *promoting* mechanisms to benefit firms and innovation performance. Instead, data concerning the *obstacles* to innovation are usually available. Thus, assuming a monotone inverse relation between obstacles and policy actions, it is possible to evaluate complementarities between policies, through the data on obstacles (Mohnen & Röller, 2005). Defining the obstacles as $C=-a$, we can identify complementarities between policies, testing if $I(C,\beta)$ is supermodular in C

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[15]. Supermodular functions belong to a mathematical

[14] - This is a "direct objective function approach", as long it evaluates the complementarities in direct relation to innovation. Another alternative used to be the "correlation approach", computing simple correlations, entailing or not controls for other aspects, observed or not observed (Mohnen & Röller, 2005).
[15] - 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).

field known as *Lattice Theory*[16]. 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.

Assuming that innovation function depends, in addition to traditional explanatory factors, on the presence of obstacles to innovation, testing for the complementarities (substitutabilities) in innovation obstacles has particular policy implications.

Following Mohnen and Röller (2005), if two obstacles are substitutes, the presence of one obstacle moderates the negative effects on innovation of the other. In that case, removing one obstacle or diminishing its negative impacts on innovation, will exacerbate the negative effects of the other. That is the reason why it is convenient to engage both obstacles jointly, and because it could be said that the policy actions are complementary. Submodularity in innovation obstacles means supermodularity in innovation policy actions.

In the same way, if two obstacles are complementary, the obstacles reinforce each other. Removing one or diminishing the negative effects on innovation of one of them, will attenuate the other one. In this case, there are less arguments to remove both at the same time, and the supermodularity in innovation obstacles means submodularity in innovation policy actions. A mathematical example can illustrate this.

Assume we have two complementary obstacles. For example, lack of appropriate sources of finance and lack of innovation opportunities. In this case, the innovation level when both obstacles are not holding could be represented by $I(00)$, while if both

[16] - 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).

obstacles are holding, the innovations level is $I(11)$, and finally $I(10)$ and $I(01)$ represent the innovation levels when only one of the obstacles holds lack of appropriate sources of finance and lack of innovation opportunities, respectively. Following the supermodularity definition, we have that the obstacles will be complementary if $I(01)+I(10)\geq I(11)+I(00)$ holds. This inequality could be expressed alternatively as $I(01)-I(11)\leq I(00)-I(10)$. If we add on both sides of the inequality the term $[I(01)-I(11)]$ we have:

$$I(01)-I(11)+[I(01)-I(11)]\leq I(00)-I(10)+[I(01)-I(11)] \qquad [1]$$

Both members of the inequation show the effect on the level of innovation after applying policies to mitigate the effects of the obstacles in question. The first member corresponds to the impact on innovation after attacking both obstacles simultaneously, while the second corresponds to the effect on innovation if policy measures are in such a way that the obstacles are attacked one at a time. Since the second member is greater than the first, the impact on innovation will be more effective when the policies designated to remove the obstacles are not simultaneously implemented; that is, when the obstacles are complementary, the policies needed to attack the obstacles become supplementary.

Mohnen and Röller (2005) applied this methodology to test the complementarity relations between obstacles to innovation in European manufacturing firms during the nineties[17]. They distinguished two phases of the innovation process in firms: the phase of the decision to innovate or not, and the phase of how much to innovate. In these two phases, they tested the complementarities between four obstacles to innovation: legislation and norms, lack of cooperation opportunities, lack of skilled personnel and lack of appropriate sources of finance. Their findings point out that the complementarities between obstacles differ regarding the phase of the innovation process of the firm: in order to turn non-innovative firms into innovators, it is convenient to address a bunch of obstacles at the same time, thus to improve the level of innovation, the firm's innovation policy actions are to be focused on easing the access to finance, promoting external cooperation or making more skilled personnel available.

It seems a promising path to get useful insights to evaluate and to design sectoral innovation policies, particularly to the economies behind the international technological

[17] - In Innovation Economics, two important works that applied supermodularity tests were Miravete and Pernias (2006), that analyzed complementarities between product and process innovation, and Cassiman and Veugelers (2006), that analyzed the complementarity between in-house R&D activities and the external purchase of technology. Both empirical works were done with data about European firms.

frontier. However, the main findings are only concentrated in developed countries and the studies in emergent economies are incipient or inconclusive[18]. On the other hand, in general, there are no studies focused on the services sector, even less in KIBS sectors. Here emerges the main objective of the paper, which is to evaluate the complementarities between policy innovation actions in a KIBS sector in an emerging economy; particularly, software firms from Argentina.

3. Method AND DATA

In this section we present the methodological strategy that the paper adopted. In Section 3.1, we specify the characteristics of the statistical tests used in empirical work (complementarity and substitutability tests), and we present general econometric issues related to the regressions carried out. In Section 3.2, we describe our data sources and the main indicators developed for the analysis.

3.1. Econometric Issues and Complementarity Tests

To test the complementarity inequalities and to estimate the coefficients of the obstacles to innovations, an innovation function for each firm *i* is specified in [2], where I represents the intensity of innovation.

$$I_i = \sum_{l=0}^{2^k-1} \gamma_l s_{il} + \sum_{j=1}^{p} \beta X_{ij} + \varepsilon_i \qquad [2]$$

On the other hand, s_{il} represents a dummy related to the obstacle state *l*. Taking into account that there are $2^k - 1$ possible states, 16 dummies are defined (k=2) (see Appendix). The coefficients of these dummies (γ_{li}), will be necessary to carry out the complementarity tests.

Additionally, control variables are included, represented by X_i: the main determinants of innovation, as competences, linkages and innovative efforts (Albornoz, Milesi, & Yoguel, 2002; Erbes, Tacsir, & Yoguel, 2008; Motta, Morero, & LLinás, 2007), and the firm's structural aspects (size, origin of capital and exports).

[18] - A particular working paper should be pointed out. Strube and Resende (2009) tested complementarities between obstacles to innovation (lack of information on technology or on market, lack of cooperation opportunities, lack of skilled personnel and lack of finance sources), using data from PINTEC-2003, for Brazilian firms. Their preliminary results showed some particular complementarities in the stage of begin to innovate (between lack of information and skilled personnel, and lack of information and cooperation opportunities), and complementarities between all the obstacles, token by pairs, in order to improve the level of innovation. In that stage, also some substitutability between obstacles was found simultaneously.

With the purpose of testing the complementarity between obstacles, we will test the complementarity of each pair of obstacles separately. This contrast implies that for each comparison, one must conjunctively test a system of four equations. Employing the innovation function defined by [2] and the states of dummy variables, it is possible to define the following series of inequalities:

Comp. (1-2) $\gamma_{8+s} + \gamma_{4+s} \leq \gamma_{0+s} + \gamma_{12+s}$, where *s=0,1,2,3*

Comp. (1-3) $\gamma_{8+s} + \gamma_{4+s} \leq \gamma_{0+s} + \gamma_{1+s}$, where *s=0,1,4,5*

Comp. (1-4) $\gamma_{8+s} + \gamma_{2+s} \leq \gamma_{0+s} + \gamma_{9+s}$, where *s=0,2,4,6*

Comp. (2-3) $\gamma_{4+s} + \gamma_{2+s} \leq \gamma_{0+s} + \gamma_{6+s}$, where *s=0,1,8,9*

Comp. (2-4) $\gamma_{4+s} + \gamma_{1+s} \leq \gamma_{0+s} + \gamma_{5+s}$, where *s=0,2,8,10*

Comp. (3-4) $\gamma_{2+s} + \gamma_{1+s} \leq \gamma_{0+s} + \gamma_{3+s}$, where *s=0,4,8,12*

Moreover, as mentioned, the innovation function could be submodular, meaning that the obstacles are substitutes. The system of inequations to be tested would be analogous to the previous ones, 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_i`s. Having obtained these estimates, it will be possible to plant the adequate hypothesis for the comparison. For example, if one wanted to compare the complementarity between the obstacles 1 and 2, the following hypothesis would be defined:

$H_0 : h_0 \leq 0$ and $h_1 \leq 0$ and $h_2 \leq 0$ and $h_3 \leq 0$

$H_1 : h_0 > 0$ or $h_1 > 0$ or $h_2 > 0$ or $h_3 > 0$

Where $h_s = -\gamma_{0+s} + \gamma_{8+s} + \gamma_{4+s} - \gamma_{12+s}$ and *s=0,1,2,3*. Two important aspects should be taken into account. First, to reject H_0 does not imply that the two obstacles in question are substitutes. Second, H_1 implies that the inequations formed can have distinct signs. In this situation, complementarity nor substitutability do not exist.

The argument for the approach of the hypothesis in order to test if the existence of submodularity is analogous:

$H_0 : h_0 \geq 0$ and $h_1 \geq 0$ and $h_2 \geq 0$ and $h_3 \geq 0$

$H_1 : h_0 < 0$ or $h_1 < 0$ or $h_2 < 0$ or $h_3 < 0$

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

$$(S\tilde{\gamma} - S\hat{\gamma})'[S\,\mathrm{cov}(\hat{\gamma})S']^{-1}(S\tilde{\gamma} - S\hat{\gamma}) \qquad [3]$$

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 levels of importance normally used. Values of the Wald statistic that are inferior to the inferior critical limit will imply the acceptation of the defined null hypothesis; while if the statistic is superior to the superior critical limit, the null hypothesis should be rejected. When the value of test is found between the two critical limits, 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 equation [2] we test complementarity in the intensity of innovation. Nevertheless, considering that not all firms that comprise our sample innovate, and also that the effect of the obstacles on the intention to innovate may be different, we are interested in testing complementarity in the probability of innovating. For this purpose, we define a probit model:

$$PI_i = \sum_{l=0}^{2^k-1} \lambda_l s_{il} + \sum_{j=1}^{p} \omega X_{ij} + \upsilon_i \qquad [4]$$

Where PI_i is the latent variable corresponding to the probability to innovating, while X_{ij} and s_{il} are control and states of obstacles perception variables respectively, defined above. PI_i assumes positive values for innovating firms and negative values for those that do not innovate. In this case, the constraints and hypothesis test for complementarity is analogous in for the intensity of innovation, but the γ_l's are replaced by the corresponding λ_l's.

As mentioned earlier, modularity tests are based on consistent estimates of the γ_l (in the case of innovation intensity) and λ_l (in the case of propensity to innovation). In this regard, an important issue is that we can observe a firm's innovation activity only if this firm actually innovates, then we have left-censored observations on the firm's innovation performance. Additionally, by the way in which the intensity innovation indicator was constructed, it is right-censored. This is a potentially significant issue (Mohnen & Röller, 2005), thus, we performed maximum likelihood estimation of a generalized Tobit to obtain consistent estimates of the parameters in [2] and [4] (Amemiya, 1973). To carry out these regressions, ε_i and υ_i are assumed to be normally distributed with mean zero and variance-covariance matrix Σ[19].

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[20]. 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 data were used to construct a series of indicators to run the pertinent regressions required to test the supermodularity and submodularity between obstacles. The detailed construction of these indicators is available in the Appendix, but a brief characterization is presented as follows:

[19] - While it could be used generalized nonlinear models (*i.e.* Poisson or negative binomial) to model the innovation, the variation in innovation due to the presence of different obstacles combinations would not be so obvious as represented by the system of inequalities underlying to the hypothesis of complementarity (supplementary), as it is needed.

[20] "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).

As dependent variables we use two indicators of Innovation, one for each stage of the innovation process (namely, to begin to innovate, or to increase the intensity of innovation). For testing complementarities between obstacles on the propensity to innovate, a dummy indicator (*Innovation*) was calculated if the firm introduced or not new products or services in the period considered. Regarding the test of complementarities on the intensity of innovation a continuous variable was calculated (*Intensity of Innovation*), summing if the firm introduced new products, new processes, improved products, significant improved processes, organizational changes, or developed new commercial channels; all weighted according to the novelty degree of the innovation (new for the firm or new for the market). Table 1 shows some descriptive statistics of innovation in the sample. There, we can see that 64% of the sample firms innovate. As for the intensity of innovation, the observed mean is 7.13 (while the median is 7.00)[21].

Table 1 – Innovation in the sample

	Mean	Std. Dev.
Intensity of Innovation	7,13	4,72
Propensity to Innovate	0,64	0,48

As independent variables, a series of obstacles to innovation indicators were constructed. Four obstacles were taken into account, aiming to cover the different categories of obstacles (see Figure 1), with the available data. To examine *financial and risk obstacles to innovation* we selected the obstacle "lack of appropriate sources of finance" (obstacle 1), and to examine *internal knowledge-skills obstacles* we selected the obstacle "lack of skilled personnel" (obstacle 2), two very common obstacles used in previous empirical works of this kind. To examine *appropriability obstacles* we chose the obstacle of danger of copy of innovations by competitors, labeled "weakness of appropriability" (obstacle 3); and finally, to examine *external knowledge-skills obstacles to innovation* we selected the obstacle "lack of innovation opportunities due to demand" (obstacle 4), which more precisely represents the situation in which demand does not adequately appreciate the innovations, thus, there is a certain lack of technological or innovation opportunities in the market.

[21] - Propensity assumes values between 0 and 18.

The survey asks about the importance of these obstacles in a Lickert scale. As we need binaries indicators, the Lickert responses were converted into binary variables (see Appendix). In order to derive the inequality constraint underlying the supermodularity innovation function definition, consider *K* obstacles to innovation, which are assumed to be binary: 1 (high) or 0 (low). Then define C_j as a string of *K* binary digits, which represent each obstacle to innovation. Considering all possible combinations and ordering under "max" operation we obtain a set C with 2^K elements, which is a lattice. Examining our data set, as can be seen below, we have chosen four obstacles (*K=4*), the 16 elements in C would: (0000), (0001) ... (1111). For example, if the firm faces only the obstacle of lack of appropriate sources of finance (obstacle 1), the indicator (1000) adopts the modality 1; if the firm faces only two obstacles (1 and 2), the indicator (1100) adopts the modality 1, etc. As these indicators are mutually exclusive for each firm, when one of them assumes the value 1, the remaining adopts 0.

Based on the above specifications, we only need to carry out pair-wise comparisons and thus, using the supermodularity definition, we can determine $\binom{K}{2}$ comparisons with 2^{K-2} nontrivial inequalities for each. Particularly, with four obstacles (*K=4*), the 4 nontrivial inequality restrictions for obstacles 1 and 2 to be complementary in innovation, as defined above, can written as:

$$I(10XX,\beta)+I(01XX,\beta)\leq I(00XX,\beta)+I(11XX,\beta) \qquad [5]$$

Where $XX = \{00,01,10,11\}$. The comparisons between other obstacles are analogous; it is only necessary to change the position of arguments of C_j into $I(...,\beta)$ according to the position of obstacles to be compared. Complementarity over all obstacles is given, whenever all inequality constraints (24 in our case) are satisfied (Mohnen & Röller, 2005).

In reference to the obstacles considered, 12.3% of firms established that none of them has an important influence. Lack of appropriate sources of finance and innovation opportunities due to demand were seen as significant by just over 50% of the firms, while lack of skilled personnel and weakness of appropriability were identified as important by approximately 38% of the firms (see Table 2).

Table 2 – Obstacles to innovation in the sample (%)

No obstacle	12,3
Lack of appropriate sources of finance	51,6
Lack of skilled personnel	38,3
Weakness of appropriability	37,9
Lack of innovation opportunities due to demand	50,8

A first approach on complementarity (or substitutability) can be obtained by analyzing the frequency distribution of the firms considering their responses on the significance of obstacles to innovate jointly, i.e. C_j defined above. This frequency distribution can be seen in Table 3. For example, looking at this table, we can see some evidence of complementarity between obstacles 1 (lack of appropriate sources of finance) and 2 (lack of skilled personnel). To observe this, note that the occurrence of (0000) plus (1100) is more frequent than (0100) plus (1000), both taking into account all firms, as well just the innovators ones. Additionally, frequency of (0011) plus (1111) is greater than (0111) plus (1011). The remaining two comparisons that can be made around obstacles 1 and 2 are evident as complementarity when looking at firms that introduced innovations; while when all firms are considered, the complementarity relationship between these obstacles is less evident. However, carrying out this type of descriptive analysis for all possible comparisons of obstacles, is not conclusive on the supermodularity (or submodularity) of the innovation function. For this reason, in the next section hypothesis tests were developed to infer complementarity (or supplementary) with a certain level of confidence.

Table 3 – Indicators Obstacles to Innovation (%)

Obstacle State	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
All Firms	12,3	7,2	4,6	9,2	5,6	5,6	2,6	2,6	7,2	8,2	5,1	7,2	8,2	5,1	3,6	5,6
Innovators	11,7	8,8	5,1	7,3	5,8	2,2	3,6	2,9	7,3	9,5	3,6	8,0	8,0	5,8	4,4	5,8

Finally, as control, we considered typical structural variables (Size, Origin of Capital and Export Profile) and indicators of the main determinants of innovation (Internal Competences, External Linkages and Innovative Efforts). 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. As the main determinants of innovation, an ordinal indicator of *Internal Competences* was calculated taking into account the R&D structure of the firm, quality certifications and the qualification of the personnel; an ordinal indicator of *External Linkages* takes into account the interactions established by a firm with other firms or outside sources for collective R&D activities, technical and/or quality assistance; and an ordinal indicator of *Innovative Efforts*, that takes into account the quantity of the types of innovative activities that a firm has done over the period 2008-2010.

4. results

In this section, we present the quantitative analysis. In section 4.1, we show the regressions: related to the propensity to innovate, and related to the intensity of innovation. The regressions give us the coefficients of the variables of obstacles presented in the previous section. Then, in Section 4.2, we perform the Wald tests to supermodularity and submodularity of the innovation function in the obstacles, where we also discuss their results and policy implications, as well as their limitations.

4.1. Propensity to Innovate and the Intensity of Innovation

Table 4 shows the maximum likelihood estimates of the generalized Tobit models, both the propensity to innovate model and the intensity of innovation model. Both models show goodness of fit: the propensity of innovation model predicts around 68% of the cases and the correlation of predicted and observed observations of the intensity of innovation model is 0.54.

Table 4 - Maximum likelihood estimates of the generalized Tobit model

Variables	Propensity to Innovate			Intensity of Innovation		
	Coefficient ([1])		Sign.([2])	Coefficient ([1])		Sign.([2])
Controls						
Size	-0,0001	(0.3508)		0,0054	(0.0028)	*
Export Profile	-0,0017	(0.0135)		-0,3005	(0.0092)	
Origin of Capital	-0,3107	(0.1754)	*	-1,9767	(1.1803)	*
Internal Competences	0,0427	(0.0608)		1,6384	(0.4265)	***
Innovative Efforts	0,0754	(0.0495)		1,5715	(0.3420)	***
External Linkages	0,0796	(0.0535)		0,6257	(0.3712)	*
States						
0000	0,2625	(0.1593)	*	-1,5839	(1.1342)	
0001	0,4585	(0.1879)	**	-0,8216	(1.3452)	
0010	0,4144	(0.2253)	*	0,2184	(1.6015)	
0011	0,1816	(0.1879)		-2,4931	(1.2911)	*
0100	0,2725	(0.2157)		-0,7670	(1.5253)	
0101	-0,4612	(0.2367)	**	-3,7593	(1.4688)	**
0110	0,6080	(0.2898)	***	-2,4279	(2.0908)	
0111	0,3397	(0.3017)		-1,1699	(2.1527)	
1000	0,2169	(0.2022)		-0,5703	(1.4412)	
1001	0,3928	(0.1765)		-0,3897	(1,2651)	
1010	-0,0089	(0.2382)		-3,8512	(1,5621)	**
1011	0,2987	(0.1949)		-1,2399	(1.3797)	
1100	0,2549	(0.1794)		-1,1873	(1.2751)	
1101	0,3476	(0.2162)		-0,4856	(1.5635)	
1110	0,3998	(0.2529)		1,7400	(1.8155)	
1111	0,3060	(0.2080)		0,5398	(1.4807)	
Log-likelihood	-229,9			-667,0		
Wald-statistic	224,5			726,8		

P-Value	2,22E-16	2,22E-16
Perc. of Correct Predictions	0,68	------
Sq. Corr (obs. and pred.)	------	0,54

(1) Standard error in parentheses
(2) *** Significant at 1%; ** Significant at 5%; * Significant at 10%

Also, we can see that all the coefficient signs of the basic determinants of innovation are the expected ones: a positive relation between innovation and internal competences, innovative efforts and external linkages. However, the coefficients are statistically significant only related to the intensity of innovation. Both models show an inverse and statistically significant relation between foreign origin of capital and innovation. That is, the national firms have both a higher probability to become innovators, than to increase its innovation level, in respect to foreign firms. A significant, but very small, positive coefficient was found between size and the intensity of innovation. The sign and statistical significance of the coefficient of the obstacle indicators have no economic interpretation, and serve basically as a first step to perform the complementarity and substitutability tests that we present in next section.

4.2. The complementarity and substitutability between obstacles to innovation

First, we concentrate in the relations between obstacles to become an innovator. In that sense, the tests related to the propensity to innovate are presented below in Table 5. There are Wald statistics of each pair of obstacles, both for complementarity test (supermodularity) and substitutability tests (submodularity). Each test is accepted if the statistic is below 1,642 and is rejected if is above 7,094 (Kodde & Palm, 1986).

Table 5 – Complementarity and Substitutability Tests. Propensity to Innovate

Pair of Obstacles	1 - 2	1 - 3	1 - 4	2 - 3	2 - 4	3 - 4
Supermodularity Test	0,132	4,626	0,004	0,001	7,282	2,540
Submodularity Test	5,581	0,310	6,494	7,286	0,001	0,879

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

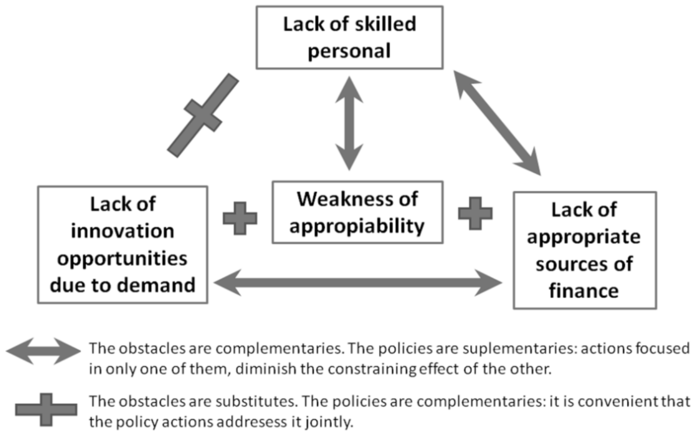
Obstacle definitions: 1= lack of appropriate sources of finance; 2= lack of skilled personnel; 3= weakness of appropriability; 4= lack of innovation opportunities due to demand.

Related to the propensity to innovate, the supermodularity and submodularity test found **complementarity** between obstacle 2 (lack of skilled personnel) and obstacle 3 (weakness of appropriability), rejecting also substitutability between these obstacles, and complementarity between obstacles 1 (lack of appropriate sources of finance) and 2 (lack of skilled personnel), and between obstacles 1 (lack of appropriate sources of finance) and 4 (lack of innovation opportunities due to demand). Regarding the submodularity tests, **substitutability** was found between obstacles 1 (lack of appropriate sources of finance) and obstacle 3 (weakness of appropriability), between obstacle 2 (lack of skilled personnel) and obstacle 4 (lack of innovation opportunities due to demand) that also rejects complementarity, and finally, between obstacle 3 (weakness of appropriability) and obstacle 4 (lack of innovation opportunities due to demand).

These relations, in terms of policy actions, should be interpreted in this sense. Innovation policy actions with the objective that firms begin to innovate should consider that there is a complementarity relation between the obstacles *lack of skilled personnel* and the *weakness of appropriability*. In this case, to improve the probability that firms become innovators, it can be enough to focus the policy actions on only one of these obstacles; that is, as it either eliminates or diminish its constraining effects of one obstacle, indirectly it will reducing the constraining effect of the other. These are reasons to support focused policy innovation actions in just one of the obstacles. The same situation appears between the *lack of appropriate sources of finance* and the *lack of skilled personnel*, and also, between the *lack of appropriate sources of finance* and the *lack of innovation opportunities due to demand*.

By contrast, innovation policy actions with the objective that firms begin to innovate should consider that is convenient that the obstacle *weakness of appropriability* and the *lack of appropriate sources of finance* be addressed jointly. Also, it is convenient that policy innovation actions with the objective to begin to innovate jointly address the obstacles *lack of skilled personnel* and the lack of innovation opportunities due to demand. And finally, it is convenient to simultaneously address the obstacles *weakness of appropriability* and the obstacle *lack of innovation opportunities due to demand*, to improve the probability that Argentinean software firms become innovators. These relations are presented in Figure 2 below.

Figure 2 – Complementarity and Substitutability between Policy Actions to Create Innovators



Next, we analyze these relations in the case of increase in the level of innovation. As Mohnen and Röller (2005) found it is a particularly important issue to distinguish between the stage of the innovation process of the firm. Below, Table 6 presents the related Wald statistics.

Table 6 – Complementarity and Substitutability Tests. Intensity of Innovation.

Pair of Obstacles	1 – 2	1 - 3	1 - 4	2 - 3	2 - 4	3 - 4
Supermodularity Test	0,349	4,100	0,532	1,308	3,984	3,833
Submodularity Test	7,273	2,196	5,923	7,563	1,395	1,504

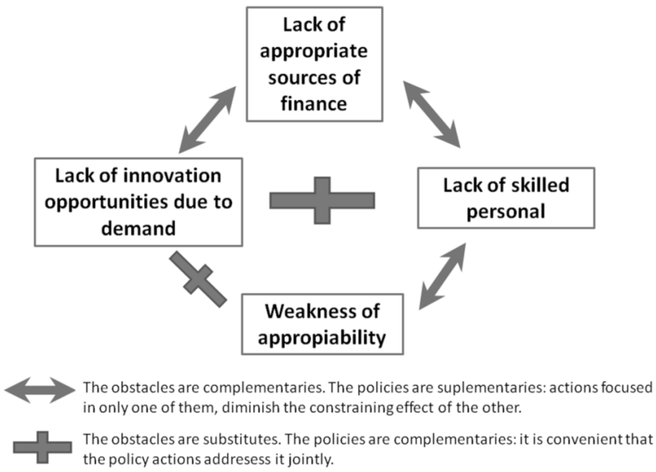
Note: The test is accepted if the Wald statistic is below the lower bound at 10% of significance (1,642), and is rejected if the statistic is above the upper bound (7,094) (Kodde & Palm, 1986). Obstacle definitions: 1= lack of appropriate sources of finance; 2= lack of skilled personnel; 3= weakness of appropriability; 4= lack of innovation opportunities due to demand.

Regarding the intensity of innovation, the supermodularity and submodularity tests found **complementarity** between obstacle 1 (lack of appropriate sources of finance) and obstacle 4 (lack of innovation opportunities due to demand); between obstacle 1 (lack of appropriate sources of finance) and obstacle 2 (lack of skilled personnel), also rejecting substitutability; and between obstacle 2 (lack of skilled personnel) and obstacle 3 (weakness of appropriability), that also rejects substitutability. On the other hand, **substitutability** was found between obstacle 2 (lack of skilled personnel) and obstacle 4 (lack of innovation opportunities due to demand), and between obstacle 3 (weakness of appropriability) and obstacle 4 (lack of innovation opportunities due to demand).

These relations, in terms of policy actions, should be interpreted in this sense. Innovation policy actions with the objective that firms increase the level of their innovation should consider that there is a complementarity relation between the lack *of appropriate sources of finance* and *the lack of innovation opportunities due to demand*, so policy actions focused on only one of these obstacles indirectly diminish the constraining effect of the other. Also, as long as there are complementarities between the l*ack of appropriate sources of finance* and *the lack of skilled personnel*, policy actions just focused on only one of these obstacles at least partially addresses the other. Finally, the obstacles *lack of skilled personnel* and *weakness of appropriability* showed to be complementary. Thus, in all of these cases, there are reasons to support focused policy innovation actions in one of the obstacles of each pair.

On the other hand, taking into account the obstacles to innovation that present substitutability, innovation policy actions with the objective that firms increase the level of innovation should consider jointly addressing the obstacles *lack of skilled personnel* and *lack of innovation opportunities due to demand.* Also, it is convenient to simultaneously address the obstacles *weakness of appropriability* and *the lack of innovation opportunities due to demand*, to improve the innovation intensity of Argentinean software firms. These relations are presented in Figure 3 below.

Figure 3 – Complementarity and Substitutability between Policy Actions to Increase Innovation



Our findings do not show that enormous differences arise in complementarity and substitutability between obstacles to innovate regardless the stage of the innovation process of the firm, as previous works have shown. This suggests that there could be specific differences related to KIBS sectors in emerging economies. In any case, it is worthy to point out in the particular case of the Argentinean software sector, that policy innovation actions aimed to create innovators are also useful to increase the level of innovation of firms that have already introduced innovations.

Conclusions and final REMARKS

Development requires sectoral promotion and support, particularly to competences and innovation capabilities building, in sectors with high potential to increase employment and growth throw dynamic competitive advantages creation. Software sector shows this potential in Argentina, as well in other emerging economies. For this reason, this paper aimed to contribute to the innovation policy making in the software industry in Argentina, as a case. With this purpose in mind, following the methodology developed by Mohnen and Röller (2005), we performed a series of complementarity tests between obstacles to innovation as an indirect method to evaluate the complementarity or supplementarity between distinct policy actions.

The results obtained show that the relations between complementarity and substitutability in obstacles to innovation tend to be very similar, independently to the phase of the analyzed process of innovation. Regardless if the firm is in the stage of begin (or not) to innovate, or if in the stage of increasing (or decreasing) the intensify of its innovation activity, there exist complementarity relations between the following three pairs of obstacles: *lack of appropriate sources of finance - lack of skilled personnel; lack of appropriate sources of finance - lack of innovation opportunities due to demand; and lack of skilled personnel - weakness of appropriability*. While between the pairs of obstacles *lack of skilled personnel* and *lack of innovation opportunities due to demand; weakness of appropriability* and *lack of innovation opportunities due to demand*, predominate supplementarity relations. The only divergence is in respect to the obstacles *lack of appropriate sources of finance* and *weakness of appropriability*, that have a supplementarity relation only when analyzing the propensity to innovate.

These results are useful for designing innovation policies where the existence of supplementarity relations between obstacles suggests the ease of attacking them simultaneously. Instead, when the obstacles are complementary, it appears more convenient to attack only one of them; thus, in the case that the obstacle is neutralized, the obstacle that remains loses importance.

At any rate, unless this type of study provides valuable insights into the design of an innovation policy, it is necessary to recognize that do not allow the identification of a set of optimal actions, nor determine a superior or necessarily more efficient policy package to the others. Instead, the results of the presented analysis can serve as justification for alternative designs in innovation policy. Thus, for example, analyzing the results of the Wald tests of supermodularity and submodularity in the function for the intensity of innovation, we find justification to an innovation policy that simultaneously combats only the obstacles *lack of skilled personnel, lack of innovation opportunities due to demand* and *weakness of appropriability,* since the remaining, *lack of appropriate sources of finance*, would lose importance as an obstacle to innovation in the measure that the associated problems become resolved combating the first two obstacles. But also similar results could be obtained by an innovation policy that tries to solve the problems associated exclusively with *lack of appropriate sources of finance, weakness of appropriability,* and *lack of innovation opportunities due to demand.* Or another concentrated in only nullifying the negative effects of *weakness of appropriability* and *lack of innovation opportunities due to demand*, since the success of this task would reduce the importance of the other remaining two obstacles.

Ultimately, at the hour to define the adequate design, the innovation policy maker must take into account not only the existence of the complementarity and substitutability relations between policies, but also, other aspects that stand among them: the relative importance of each obstacle, the viability or feasibility to design a policy in order to attack a determined objective, the financial and non-financial costs of the policy, the time needed in order for the policy to take effect, etc., between other factors.

APPENDIX: Construction of Indicators

Dependent Variables

Innovation

Dummy variable. Adopt 1 if the firm introduced new products or services in the period 2008-2010, or 0 if the firm does not.

Intensity of Innovation

Sum up if the firm introduced new products, new processes, improved products, significant improved processes, organizational changes, or developed 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; the indicator .

Independent Variables

Obstacles of innovation

16 C_j dummy indicators of obstacles to innovation were constructed, that represents the presence of 4 types of obstacles to innovation, in the way that summarizes Table 7. It takes into account these definitions:

- Obstacle 1= lack of appropriate sources of finance
- Obstacle 2= lack of skilled personnel
- Obstacle 3= weakness of appropriability
- Obstacle 4= lack of innovation opportunities due to demand

We define C_j as a string of K binary digits, which represent each obstacle to innovation. Considering all possible combinations and ordering under “max” operation we obtain a set C with 2^K elements, in this case we have chosen four obstacles ($K=4$), so the elements in C are: (0000), (0001) ... (1111).

Table 7 – Obstacle indicators

Obstacle Indicators	
0000	Adopts 1 if the firm does not face the obstacles to innovation considered
0001	Adopts 1 if the firm face only the obstacle 4
0010	Adopts 1 if the firm face only the obstacle 3
0011	Adopts 1 if the firm face the obstacles 3 and 4
0100	Adopts 1 if the firm face only the obstacle 2
0101	Adopts 1 if the firm face the obstacles 2 and 4
0110	Adopts 1 if the firm face the obstacles 2 and 3
0111	Adopts 1 if the firm face the obstacles 2, 3 and 4
1000	Adopts 1 if the firm face only the obstacle 1
1001	Adopts 1 if the firm face the obstacles 1 and 4
1010	Adopts 1 if the firm face the obstacles 1 and 3
1011	Adopts 1 if the firm face the obstacles 1, 3 and 4
1100	Adopts 1 if the firm face the obstacles 1 and 2
1101	Adopts 1 if the firm face the obstacles 1, 2 and 4
1110	Adopts 1 if the firm face the obstacles 1, 2 and 3
1111	Adopts all the obstacles to innovation considered

The importance of obstacles was answered on a Lickert scale in the survey. To convert to dummy variables, we consider the average value of each variable as a cutoff point, so that if the response of a particular firm is less than the average it takes the value 0, otherwise 1. Obstacles and their averages are: lack of appropriate sources of finance (3.37), lack of skilled personnel (4.05), lack of innovation opportunities due to demand (2.42) and weakness of appropriability (2.20).

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

Ordinal variable that, from the sum of three ordinal sub indicators: a qualification of the personnel sub indicator (that is based on a qualification of the human resources index that weights 0.35 the percentage of workers with postgraduate studies, 0.25 the percentage of workers with degree studies finalized, 0.20 the percentage of workers with degree studies in course, 0.15 the percentage of workers with superior non university studies finalized, and 0.05 the percentage of workers with only high school studies), that assumes 1 when the index is below 20%, assumes 2 when the index is between 19% and 23%, and assumes 3 when the index is between 22% and 50%; a quality certification sub indicator (assumes 1 when a firm does not certify any norm and does less than 7 kinds of quality activities or when a firm has only a Ticket or SLA certifications and does less than 6 kinds of quality activities, assumes 2 when a firm has CMM or ISO certification or does more than 6 kinds of quality activities besides having quality certifications, and assumes 3 when a firm has CMM3 or higher certification or ISO and does more than 8 kinds of quality activities); and a R&D structure sub indicator (assumes 3 when a firm has a formal team for R&D activities conformed at least by 8 workers or at least by 3 workers when a firm has 30 or less employees, assumes 2 in the other cases when a firm has a formal team, or when a firm has an informal team for R&D activities at least by 8 workers or at least by 3 workers when a firm has 30 or less employees, and assumes 1 in the other cases when a firm has an informal team, and when a firm does not have a team at all).

Innovative Efforts

Ordinal variable constructed using the sum of types of innovative activities (license acquisitions related to new products or processes, package or generic software bought that implied improvements to the firm, external acquisition of specific software for the firm, internal software development specific to the firm, implementation of continuum improvement programs, reverse engineering and adaptation, development of new products or processes, internal R&D, external R&D, contract of consultancies to product or process innovation, and innovation oriented training) done by the firm over the period 2008-2010: assumes 1 when the firm has done less than 4 types of activities, assumes 2 when the firm has done between 4 and 6 activities, and assumes 3 when the firm has done more than 6 innovative activities.

External Linkages

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

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