Complementarities between innovation policies in emerging economies. The case of Argentina's software sector

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Abstract: This paper analyses the presence of complementarity and substitutability relations between innovation policies in the software sector from Argentina. Supermodularity and submodularity tests between obstacles to innovation were performed with technological data from 257 Argentinean software firms, for the period 2008 to 2010. This research adds empirical evidence on the complementarities and supplementarities of innovation policies in an emerging economy and in a knowledge intensive business services sector. This kind of analysis allows to evaluate the convenience to attack jointly or separately a set of obstacles or separately. The results show multiple feedback relations between diverse obstacles and consequently between policies, and the main finding is that, in this emerging economy, innovation policies aimed to encourage firms to become innovators serve as well as an incentive for innovative firms to increase and intensify its innovation performance.

Keywords: knowledge intensive business services; KIBS; software sector; Argentina; supermodularity; innovation policy.

Reference to this paper should be made as follows: Motta, J.J., Morero, H.A., Borrastero, C. and Ortiz, P.A. (2013) 'Complementarities between innovation policies in emerging economies. The case of Argentina's software sector', *Int. J. Technological Learning, Innovation and Development*, Vol. 6, No. 4, pp.355–373.

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This paper is a revised and expanded version of a paper entitled 'Complementarities between policy actions in software production in emerging economies. the case of Argentina' presented at XVIII Reunión Anual Red Pymes Mercosur, Resistencia, Argentina, 25–26 September 2013.

1 Introduction

As innovation process of the firms is constrained by diverse barriers, governments try to stimulate the growth and consolidation of strategic sectors through innovation policies with the objective to neutralise the obstacles to innovation or, diminish their constraining effects. Assuming a monotone inverse relation between obstacles and innovation policies, it is possible to evaluate complementarities between policies through the data on obstacles. Following a rigorous and previously accepted method developed by Mohnen and Röller (2005), the paper will analyse the presence of complementarities and supplementarities between innovation policies in the software production sector in Argentina.

The available empirical literature that applies this technique is scarce, especially for emerging economies, where a notable gap in the literature can be detected. On the other hand, the empirical studies have been focused on manufacturing sectors. Thus, the main contribution of this paper is two-fold: to highlight the existence of complementarities and supplementarities of innovation policies in an emerging economy, and in a particular knowledge intensive business services (KIBS) sector, the software production.

Besides the global leaders of the software sector have remained in the developed world, over the 1990s many developing countries, especially from Asia, have catch up and gained a competitive position among the main global actors (Malerba and Nelson, 2011; Niosi et al., 2012).[1] Brazil and Argentina, following the Asian model, have recognised the importance of intangible goods – for their potential of direct economic impact.

In Argentina, the software sector is composed of around 1,600 companies with five or more employees (Barletta et al., 2013), who occupy about 80,000 workers. This activity has shown a high dynamism. Between 2003 and 2012 employment, sales and exports have grown at an annual average rate of 17%, 16.6% and 18.6%, respectively (OPSSI, 2013). Among the reasons for this strong growth, it should be noted a set of public policies aimed at promoting quality certification, export activity, the formation of qualified human resources, infrastructure development and innovative activity. These policies include the Software Act (2004), the Trust Fund for the Promotion of the Software Industry (FONSOFT), the promotion of careers in computer science, etc. The interest of the article lies on some aspects of public policies for the promotion of innovation in the sector. In spite of the significant effort performed by the Argentine Government to foster innovation, the funds allocated for this purpose are limited, so that there is implicitly a competition for funds between different policies.

As the attenuation of an obstacle can diminish the negative effects of a complementary obstacle, it reinforces the reasons to consider less likely to remove both at the same time, meaning that policies are supplementary. Thus, the issue if the policies are complementary or supplementary is not trivial and has implications to the efficiency in the innovation policy design. In that sense, the paper also contributes with practical implications arising from the complementarities existent between obstacles.

This paper is organised as follows. Section 2 presents our empirical and theoretical background, focused on innovation studies on services, KIBS and the software sector and the literature about obstacles to innovation and policy complementarities. Section 3 presents our research design and methods, focused on econometric issues and complementarity tests, and the data source and indicators used. In Section 4, we present our main empirical findings and offer some implications for policy makers. Section 5 presents our conclusions and final remarks.

2 Empirical and theoretical background

2.1 Innovation studies on services, KIBS and the software sector

From late ‘90s, diverse authors worked on a demarcation vision between innovation on services respect from manufacturing sectors (Djellal and Gallouj, 2001; Gallouj and Weinstein, 1997). Innovation studies on services pointed out that there are particular aspects in the nature of the services production itself which distinguishes their innovation process respect to the manufacturing industry (Drejer, 2004; Gallouj and Savona, 2009; Miles, 2004): inmateriality, continuous reconfiguration of supply, coproduction, simultaneity of provision and consumption (Gallouj and Savona, 2009).

In recent decades, there has been an increasing interest on a special kind of services: the KIBS. These intensive knowledge services are characterised by concentrate its production on providing intangible inputs to knowledge-intensive business processes in other organisations, both public and private, and by heavily depending on specialised knowledge and typically, such firms have high levels of qualified staff (Muller and Doloreux, 2009; Miles, 2005; Miles et al., 1995). Some kind of KIBS is based on legal, administrative 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 (Tether and 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 (Tether and Swan, 2003; Niosi et al., 2012). As well a part of the literature has been interested on addressing public policy and KIBS (Miles, 2005), there are also in the innovation studies of the software sector an important group focused on policy making and its structural characteristics at the national level or in product segments (Anchordoguy, 2000; Arora et al., 2001; Breznitz, 2007; Mowery and Langlois, 1996).

This paper is partially related to this group because it aims to contribute to innovation policy making in the software sector in an emerging economy, focusing on the complementarities that could arise between policy innovation actions in this sector.

2.2 Obstacles to innovation and policy complementarities

There is an important empirical literature which analyses the role of obstacles to innovation (D'Este et al., 2012).[2] A first line of research focuses on the factors affecting the perception of the importance of the barriers (Galia and Legros, 2004; Iammarino et al., 2009). A second line focuses on the impact of the obstacles on the intensity of innovation and/or the propensity to innovate (Mohnen and Röller, 2005; Savignac, 2008; Tourigny and Le, 2004; Madrid-Guijarro et al., 2009; Strube and Resende, 2009; D'Este et al., 2012). In this 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, or innovation outputs (D'Este et al., 2012; Madrid-Guijarro et al., 2009; Mancusi and Vezzulli, 2010; Savignac, 2008). These studies point out that there is an endogeneity of the perception of obstacles, and the innovativeness degree of the firms.[3] Another group, analyses the relation between obstacles and innovation output of the firms, assuming obstacles as failures, insufficiencies or lack of public policy (Mohnen and Röller, 2005; Strube and Resende, 2009). We will follow this last perspective, and 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.

Innovation surveys, based on the innovation studies, have typically been concentrated in four kinds of obstacles to innovation:

- *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.
- *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 organisational structure of the firm.
- *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.

- *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.

These obstacles could appear jointly or separately, and could be more important in some instances of the innovation process than in others. The policy could be focused on jointly or separately removing a group of obstacles. That is why it is important to analyse the complementarities that could arise between diverse innovation policies.

The framework developed by Mohnen and Röller (2005) allows to identify complementarities in innovation policies using discrete data through the innovation function.[4] It is assumed that innovation in a firm is characterised by an innovation function $I_i(a, b)$, where the government could choose a set J of policy variables denoted by $a = (a_1, a_2, \ldots, a_J)$, and there is a set β of other firm-specific factors affecting innovation: competences, linkages and innovative efforts as long structural aspects, 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 offer exhaustive data about 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 and Röller, 2005). Defining the obstacles as $C = -a$, we can identify complementarities between policies, testing if $I\,(C, \beta)$ is submodular 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.[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 and Roberts, 1990; Topkis, 1998).

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 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 simultaneously, and the supermodularity in innovation obstacles means submodularity in innovation policy actions.

In innovation economics, two important works that applied supermodularity tests to data about European firms were Miravete and Pernias (2006), that analysed complementarities between product and process innovation, and Cassiman and Veugelers (2006), that analysed the complementarity between in-house R&D activities and the external purchase of technology. Mohnen and Röller (2005) applied this methodology to test the complementarity relations between obstacles to innovation in European manufacturing firms during the nineties. 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.

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 frontier. However, the main findings are only concentrated in developed countries and the studies in emergent economies are incipient or inconclusive.[7] On the other hand, in general, there are no studies focused on the services sector, even less in KIBS sectors. The objective of this paper is to contribute to fill these gaps in the literature, evaluating the complementarities between policy innovation actions in a KIBS sector from an emerging economy: Argentina's software firms.

3 Research design and methods

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 (1), where I represents the intensity of innovation.

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

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 ($k = 2$). 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, and the firm's structural aspects (size, origin of capital and exports).

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. With an innovation function defined by (1) and the states of dummy variables, it is possible to define the following series of inequalities for each pair of obstacles:

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_l's. With these estimations, it will be possible to state the hypothesis for the comparison. For example, 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:

$$(S\tilde{\gamma} - S\hat{\gamma})' \left[S \operatorname{cov}(\hat{\gamma}) S' \right]^{-1} (S\tilde{\gamma} - S\hat{\gamma}) \tag{2}$$

where $\hat{\gamma}$ is a consistent estimator of γ, S represents a matrix that summarises the imposed restrictions for the defined inequalities, and $\tilde{\gamma}$ is the vector that minimises the expression (2) below H_0.

In equation (1), 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:

$$PI_i = \sum_{l=0}^{2^k-1} \lambda_l s_{il} + \sum_{j=1}^{p} \omega X_{ij} + \upsilon_i \tag{3}$$

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 and Röller, 2005), thus, we performed maximum likelihood estimation of a generalised Tobit to obtain consistent estimates of the parameters in (1) and (3) (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. While it could be used generalised non-linear 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.

3.2 Data source and indicators

We used a primary data source based on a technological survey[8] done over 2011 to 257 software and related services producer firms from Argentina, covering the period 2008 to 2010. The survey 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 (organisation of the work process, quality management, training structure, etc.); appropriability issues and the impact of public policies. Data were used to construct a series of indicators to run the pertinent regressions required to test the supermodularity and submodularity between obstacles.

As dependent variables we use two indicators of Innovation, one for each stage of the innovation process. For testing complementarities between obstacles on the propensity to innovate, a dummy indicator (*innovation*) was calculated, assuming 1 if the firm introduced a new product or service in the period considered, or 0 otherwise. 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, organisational changes, or developed new commercial channels; all weighted according to the novelty degree of the innovation: assuming 1 if the innovation was new only for the firm, and 3 if the innovation was new also for the market. Following the descriptive statistics of innovation in the sample, we can see that 64% of the sample firms innovate and std. dev. 4.72, as for the intensity of innovation the observed mean is 7.13 and std. dev. 0.48, while the median is 7.00.[9]

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, 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, labelled '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. 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). 16 C_j dummy indicators of obstacles to innovation were constructed, representing the presence of these four types of obstacles. We define C_j as a string of K binary digits, which represent each obstacle. 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: Adopts 1 if the firm does not face the obstacles to innovation considered), (0001: Adopts 1 if the firm face only the obstacle 4) … (1111: Adopts all the obstacles to innovation considered). The importance of obstacles was answered on a Likert scale in the survey. To convert to dummy variables, we consider the average value of each variable as a cut-off point, so that if the response of a particular firm is less than the average it takes the value 0, otherwise 1. Averages are 3.37 for obstacle 1, 4.05 for obstacle 2, 2.42 for obstacle 3, and 2.20 for obstacle 4. 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} non-trivial inequalities for each. Particularly, with four obstacles (K = 4), the 4 non-trivial inequality restrictions for obstacles 1 and 2 to be complementary in innovation, as defined above, can written as:

$$I(10XX, \beta) + (01XX, \beta) \leq I(00XX, \beta) + I(11XX, \beta) \tag{4}$$

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 (…, β) 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 and 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 51.6% and 50.8% of the firms respectively, while lack of skilled personnel and weakness of appropriability were identified as important by 38.3% and 37.9% of the firms respectively.

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 a continuous indicator considered by the number of employees in 2010
- *export profile* is another continuous variable that considers the percentage of sales coming from exports in 2010
- *origin of capital* is a dummy variable, adopting the value 1 if the firm has more than 50% in foreign capital ownership and 0 otherwise.

As the main determinants of innovation:

- An ordinal indicator of *internal competences* was calculated taking into account the sum of three ordinal sub indicators:
  a *qualification of the personnel*, based on a ad hoc index: assumes 1 when the index is below 20%, 2 when the index is between 19% and 23%, and 3 when the index is between 22% and 50%
  b *quality certification*: assumes 1 when a firm does not certify any norm and does less than seven 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 six kinds of quality activities besides having quality certifications; assumes 3 when a firm has CMM3 or higher certification or ISO and does more than eight kinds of quality activities
  c *R&D structure*: assumes 3 when a firm has a formal team for R&D activities conformed at least by eight workers or at least by three 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 eight workers or at least by three workers when a firm has 30 or less employees; assumes 1 when a firm has an informal team, and when a firm does not have a team at all.
- Another ordinal indicator of *external linkages* that 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 (assumes 3 if the firm interacts with other agents for the three kinds of interactions, 2 if the firms interacts for two of the three types, and 1 otherwise).
- An ordinal indicator of *innovative efforts*, that takes into account 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 programmes, 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: assumes 1 when the firm has done less than four types of activities, 2 when the firm has done between 4 and 6 activities, and 3 when the firm has done more than six innovative activities.

4 Empirical findings and implications

4.1 Propensity to innovate and the intensity of innovation

Table 1 shows the maximum likelihood estimates of the models, both the propensity to innovate model (Probit) and the intensity of innovation model (Tobit). 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 1 Maximum likelihood estimates of the models

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		

Notes: (1)St. err. 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 2. There are the Wald statistics of each pair of obstacles, both for complementarity test (supermodularity) and substitutability tests (submodularity). Each test is accepted at 10% of significance if the statistic is below 1,642 and is rejected if is above 7,094 (Kodde and Palm, 1986).

Table 2 Complementarity and substitutability tests

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

Notes: Propensity to innovate.
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 obstacles 2 and 3, rejecting also substitutability between these obstacles, and complementarity between obstacles 1 and 2, and between obstacles 1 and 4. Regarding the submodularity tests, substitutability was found between obstacles 1 and 3, between obstacles 2 and 4 that also rejects complementarity, and finally, between obstacle 3 and 4.

Table 3 Complementarity and substitutability tests

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

Notes: Intensity of innovation.
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.

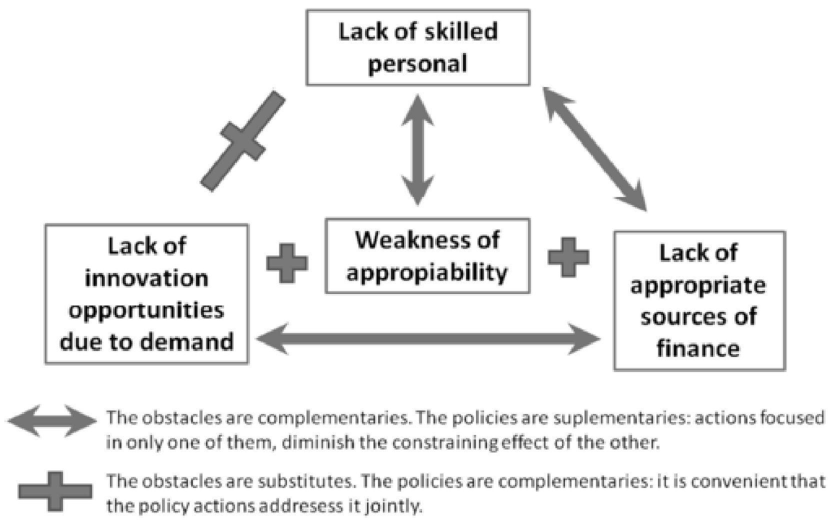
Regarding the intensity of innovation, as Table 3 shows, the supermodularity and submodularity tests found complementarity and rejects susbstitutability between obstacles 1 and 2; and 2 and 3. Between obstacles 1 and 4, the tests only found complementarity. On the other hand, substitutability was found between obstacles 2 and 4, and between obstacles 3 and 4.

4.3 Implications for policy makers

The relations found in 4.2 have particular policy implications. On the one hand, when two obstacles are complementary, policies to remove them are supplementary. In this case, actions focused in only one of them, diminish the constraining effect of the other. On the other hand, by contrary, when the obstacles are substitutes, the policies are complementary and it is convenient that the policy actions address it jointly. When the relations found are considered as a whole, it allow to compare the potential benefits of alternative policy packages, and to take into account the feedback effects between the joint attack of diverse barriers to innovation.

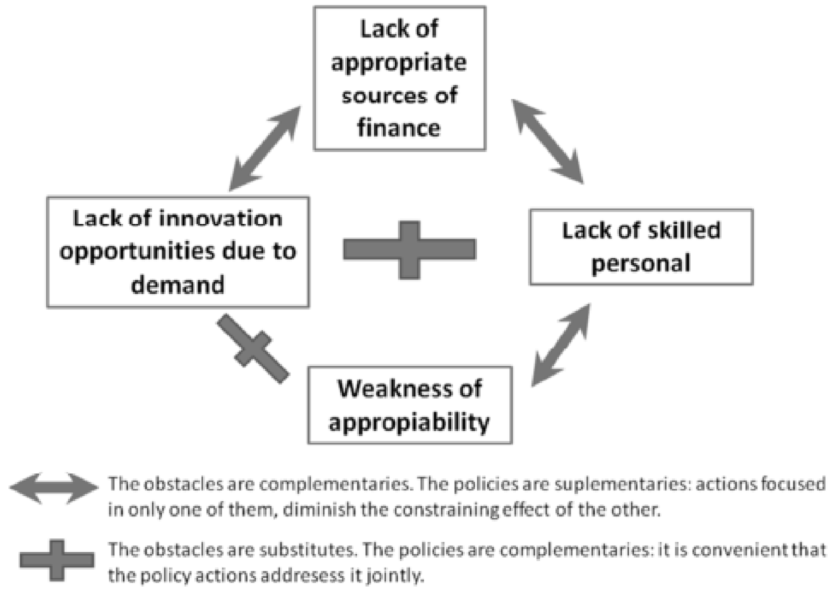
Figures 1 and 2 illustrate as a whole the existence of relations of complementarity and substitutability found in the previous section between policies in two stages of the innovation process of firms: first, to become an innovator and, secondly, to increase the intensity of the innovation. An additional issue relevant to policy makers is if it necessary, either convenient, to design specific policy instruments to different stages of the innovation process. That is, if should be designed different policy packages according the objective to create innovators, or according the objective to increase the innovativeness in already innovator firms.

Figure 1 Complementarity and substitutability between policy actions to create



It can be seen that in both stages of the innovation process three pairs of obstacles restrict innovation in a complementary way (lack of appropriate sources of finance and lack of skilled personnel; lack of appropriate sources of finance and lack of innovation opportunities due to demand; and lack of skilled personnel and weakness of appropriability), and two pairs of obstacles acts over innovation as substitutes (lack of skilled personnel and lack of innovation opportunities due to demand; and between weakness of appropriability and lack of innovation opportunities due to demand).

Figure 2 Complementarity and substitutability between policy actions to increase innovation



Our findings show small discrepancies in the two stages of the innovation process. The main difference is that the obstacles lack of appropriate sources of finance and weakness of appropriability are substitutes over the propensity to innovate and not for the intensity of innovation. These results differ from those obtained in previous studies (Mohnen and Röller, 2005; Strube and Resende, 2009), in which the differences between the two stages are more important. This suggests that could arise specific differences related to KIBS sectors in emerging economies related to this issue, and that is the main contribution to the literature. In addition, for policy makers, our results point out that in the particular case of the Argentinean software sector, policy innovation actions aimed to create innovators are also useful to increase the level of innovation of firms that have already introduced innovations.

Aside the analysis presented, it should be recognised that it do not allow the identification of such thing as a set of 'optimal' actions, nor determine a superior or necessarily more efficient policy package respect to the others. Instead, the results of the presented analysis can serve as justification for alternative policy packages. Ultimately, the innovation policy making must take into account not only the existence of the complementarity and substitutability relations between policies, but also other related aspects as, for example, 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, and the time needed in order for the policy to take effect.

5 Conclusions

The available empirical literature that applies the methodology developed by Mohnen and Röller (2005) to evaluate the existence of relations of complementarity or supplementarity between distinct innovation policies is scarce and has been focused on manufacturing sectors in developed countries. In this sense, this paper advances in the application of that methodology to a KIBS sector in an emerging economy.

This paper also contributes with practical implications to the innovation policy making in the software sector in Argentina arising from the complementarities found between obstacles. 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 neutralised, the obstacle that remains loses importance.

Contrary to the existing previous studies in manufacturing sectors, our main finding show that in the Argentinean software sector the relations between complementarity and substitutability in obstacles to innovation tend to be very similar, regardless if the firm is in the stage of turning non-innovative firms into innovators, or if in the stage of increasing (or decreasing) the intensify of its innovation activity. This reinforces the idea that KIBS has proper particularities on innovation issues and, in that sense, which requires a specific sectoral policy.

Acknowledgements

The authors are extremely grateful for all the careful suggestions and enriching comments received from two anonymous referees of the journal and from the editors, and especially from Dr. Gustavo Crespi to early versions of this manuscript. The authors gratefully acknowledge financial support in data collection to Carolina Foundation (Spain), and Science and Technological Secretary (Secyt) from Universidad Nacional de Córdoba (UNC, Argentina). The findings and conclusions of the paper are the sole responsibility of the authors.

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Notes

1 This, has motivated a number of scholars to investigate the sector on emerging economies, as Arora et al. (2001), Athreye (2005), Chudnovsky and López (2005), Rizk (2012), Uriona et al. (2013), Hajela and Akbar (2013), as many others.

2 A revision and a systematization of the literature regarding barriers to innovation also could be consulted in Madrid-Guijarro et al. (2009).

3 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.

4 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 and Röller, 2005).

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 et al. (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 and Roberts, 1990; Topkis, 1998).

7 A particular *CESIfo 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 manufacturing 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.

8 'Capacity of Absorption and Production Systems Connectivity and Local Innovation'. Carolina Foundation (id. 386317).

9 Propensity assumes values between 0 and 18.