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FIRM PATENTING AND TYPES OF INNOVATION IN LEAST DEVELOPED COUNTRIES. AN EMPIRICAL INVESTIGATION ON PATENTING DETERMINANTS

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1. Introduction

The study of innovation and knowledge diffusion have attracted significant attention from scholars in the last three decades. This interest coincides with what is called in the literature the emergence of a ‘pro-patent era’ or an ‘intellectual capitalism era’ (Granstrand,1999; Arundel, 2001; Blind et al., 2006; Barros, 2015). This trend is illustrated by the doubling of the total number of patent applications in the OECD in the 1990s. For Blind et al. (2006) and Arundel (2001) this surge in patenting can be explained by changes in global competition, the rise of new technology fields like biotechnology and ICT, or more generally by improvements in R&D processes. The argument is that IPRs and especially patents provide an effective means of protection for inventions against imitation and thereby influence the propensity to innovate (Mohnen, 2009). Some theoretical studies believed that in general all inventions are patented (Tandon, 1982; Scotchmer, 1991), putting aside the other mechanism of protection. However, this assumption is in contrast to empirical studies[1]. In general results show that patents are not the most prevalent method of appropriation for innovation and invention, but that secrecy and lead time are. Another interesting result is that patents and secrecy, or more generally the informal mechanism of IP protection, are not always mutually exclusive, leaving room for some complementarity (see for example Amara et al., 2008; Howells et al., 2003). This growing field of innovation literature benefits from a diverse approach (Candelin-Palmqvist et al., 2012; Hall et al., 2014). One strand of research aims to investigate the determinant of the use of IPRs at firm level. For Hanel (2008), this use is related to the characteristics of the firm, their activities, and the industry sector where they operate. In their work Hall et al. (2013) explain the choice of the method of appropriation by the type of innovation (product or process), the nature of technology, and the knowledge embodied in the invention. For his part, Arundel (2001) stresses the role of firm size and the advantage that large firms have in patenting over small ones. Most of these studies focus on the developed world (especially North America and European countries), leaving a gap on this issue in developing countries. The small amount of evidence there is suggests that patentable innovation does not contribute to economic growth in developing countries (Kim et al., 2012), and that patents are less useful in regimes with weak appropriability (Keupp et al., 2009; Song et al., 2014; Woo et al., 2015; Barros, 2015).

To fill this gap, we use a dataset of seven developing countries to explore the determinant of patents and, more particularly, how innovation behaviour impacts the engagement of firms in patenting. We think our approach has clear macroeconomic implications. For instance a better highlighting of patent determinants in LDCs enables us to understand what will be the changes on the strength of the technological competition on global markets. In the same vein a lot of studies have shown the consequences of patenting in LDCs on international technology transfer (among others: Mansfield and Mundial, 1994; Reddy and Zhao, 1990).

The remainder of the paper is organised as follows. In the next section we present the literature review, our research questions, and the body of hypotheses that we wish to test. Then, in Section 3, we define the data set and variables. In Section 4, empirical models and econometric strategy are set out. Our results and findings are commented on in Section 5. Finally, Section 6 will conclude the paper by highlighting the main findings and discussing some perspectives for future research.

[1] Large-scale evidence for this was provided in the US by Levin et al., (1987) and Cohen et al. (1998), in Europe by Harabi (1995), Arundel (2001), Gonzalez-Alvarez and Nieto-Antolın (2007), and in Australia by McLennan (1995).

2. Literature review, research question, and hypotheses

Our survey of the literature will concern first the macro determinants of patenting, and then the micro motives (or advantages).

The macro determinants of firm patenting are related to the strengths and weaknesses of the patent system. As a result the patenting behaviour of firms can be derived from institutional environments in which they act as innovator (Owen-Smith and Powell, 2001). In this vein Waguespack et al. (2005) found a positive influence of political stability on patenting in Latin American and Caribbean nations. When a relatively strong protection can be obtained, even if patents are imperfect protection settings, patenting is rational for a series of reasons put forward by the literature: the opportunity to license a new technology, a lever to sue in court, upgrading the firm's intangible capital (important in the perspective of a takeover). Even in underdeveloped or in emerging countries in which the patentor faces a weak appropriability regime (Teece, 2000; Keupp et al., 2012), certain determinants pull (push) the firm to patent a part of its volume of innovations. As an example, the findings presented on Brazilian firms indicate that, despite the weaknesses of the patent system, firms patent in particular those engaged in technological collaborations (Barros, 2015). Moreover, the same study observed that the conduct of domestic and foreign firms is very similar. This finding contrasts in some way with the view of Kim (1997), and of Lall and Albaladejo (2001), arguing that patent protection is valuable to industrial activities only after countries have achieved a threshold level of domestic innovative capacity, with a developed scientific and technological infrastructure.

The literature has long set out the micro rationales behind firms' decisions to patent. In general, the very first studies emphasised several factors, including the prevention of imitation, the opportunity of licensing, and the capacity to reward researchers (Arundel et al., 1995; Duguet and Kabla, 1998). Some later studies pointed to the importance of strategic motives, such as blocking competitors (Blind et al., 2006; Cohen et al., 2000), improving the firm's reputation (Blind et al., 2006; Cohen et al., 2000), and allowing access to foreign markets where entry is conditioned by having a license contract with a domestic firm (Levin et al.,1987; Harabi, 1995). The importance of patenting as a signal for attracting funds has been documented later (de Rassenfosse, 2012). More recently an important motive for patenting has emerged: patenting as a tool for safeguarding its freedom to operate. In effect, through patents inventors tend to exclude other agents from using its own invention. Inventors retain the liberty to operate: innovating today and re-inventing again in the future, licensing, selling the patent (Corbel and Le Bas, 2012). Granstrand (1999) and Holgersson and Granstrand (2017) have shown that this latter motive plays an important role in the decision to patent.

Besides the motives (advantages) of patenting there is also a set of factors that plays an important role in explaining the behaviour of patents. For example, in the business economy, the *size* and the sector matter (Blind et al., 2006). The former is due to the fact that a large firm has enough means to fund a team within the research department in charge of industrial property issues[2]. As far as *sectoral characteristics* are concerned it is now well documented in the industry, in which scientific discoveries push technological innovation, that the new knowledge is very easily codified and that patenting is an effective protection. As a consequence, in chemicals, micro-electronics, and pharmaceuticals, patenting is used a lot as an asset of innovation protection. *Intensity of competition* is acknowledged as a vector of

[2] For example, Albuquerque (2000) finds, as far as firm size is concerned, a U-shaped distribution of patents for DC and LDCs.

patented innovation because fierce competition provides incentives to effectively protect innovation against imitations (Hanel, 2008). Patenting also has the capacity to block competing technological improvements. The importance of qualified employees has often been emphasised. For example, Blind et al. (2006) argue that the higher the share of R&D, the higher the importance of protecting the results of research to maintain firm value at a high level. This result is confirmed by Amara et al. (2008) on data on services from the Canada Innovation Survey. More recently, Holgersson and Granstrand (2017), in accordance with the work of Chesbrough, found in 2003 that patenting motives are strengthened in open innovation and external technology strategies.

There is a huge literature on patent applications and determinants for firms from developed countries (see, for example, for the European patent system the book by Guellec and de la Potterie, 2007). By contrast, LDC firm patenting is described and accounted for much less. The book coordinated by Ahn et al. (2014) sets up a (brilliant) exception. Drawing on the few approaches that deal with these topics, we argue that the propensity to patent a set of innovations is weaker in LDCs (Kim et al., 2012). Nevertheless, the system of patenting provides enough incentives to protect minor, incremental inventions and radical innovation in LDCs, although the international patent system does not fit well with the level of firm technological capabilities on LDCs (Tvedt, 2010). By contrast, the domestic patent system is better, as exemplified by Albuquerque (2000) in the context of Brazil. We also need information and models on the factors pushing innovation activity in LDCs. The work by Rahmouni et al. (2010) on Tunisian firms showed the essential role played by external technical knowledge sources and, by contrast, the limited role of internal R&D. Ayyagari et al. (2011), on a very large panel of firms (19,000) across 47 developing economies, with a broad definition of the innovation process (including activities that promote knowledge transfers and adapt production processes), find that the more innovative firms are large exporting firms with highly educated managers with mid-level managerial experience. The paper by Crespi and Zuniga (2012) studies the determinants of technological innovation across Latin American countries (Argentina, Chile, Colombia, Costa Rica, Panama, and Uruguay) using micro data from innovation surveys. They note that firm-level determinants of innovation investment are much more heterogeneous than in OECD countries, and the weak linkages that characterise national innovation systems in those countries. They confirm the study by Raffo et al. (2008) that put forward the idea that the weakness of firm interaction with national systems is weaker in developing countries. Fagerberg et al. (2010), using data from 28 countries, mostly developing countries, show that national and firm level capabilities interact in the process of development.

Our research question is formulated in this way. At the core of our approach to patenting decisions in LDCs, we place the type of innovative behaviour followed by the firm. We develop this idea in three directions according to innovation taxonomy: innovation intensity (incremental/radical), the kind of innovation (product/process), the complexity of innovation (single/complex).

The body of knowledge in the management of technology has emphasised the crucial importance for firm strategy of the categories of innovation: incremental versus radical. According to Henderson and Clark (1990), there are at least two differences between the two types of innovation: 1) the linkages between the concepts at the core of the technologies are unchanged in the context of incremental innovation, the opposite holds for radical innovation, 2) radical innovation matches a new design (potentially dominant), by contrast incremental innovation tends to refine previous or existing designs. The opposite holds for incremental innovation, this reinforces the competitive position of insiders. As a consequence, it appears that radical innovation has a larger value than incremental innovation. The global novelty requirement related to patenting rules implies that incremental innovations are not in general patentable (see Fagerberg et al., 2010). By contrast, firms that innovate radically are expected to patent their inventions. As a consequence, there are more incentives to patent radical innovation than incremental innovation, all things being equal. Our first hypothesis is as follows:

Hypothesis 1. Firms patent more radical innovations than incremental innovations.

Regarding the definition of product and process innovations we draw on the OSLO manual recommendations which have strongly inspired the numerous Community Innovation Surveys (Mortensen and Bloch, 2005). Product innovation means the market introduction of a new or a significantly improved good or service. When product innovations are new to the enterprise and, at the same time, new to your market, innovation of this kind is considered to be radical innovation. By contrast, process innovation is the implementation of a new or significantly improved production process, distribution method, or support activity for goods or services. This distinction is important because it is linked to different strategies as a way of influencing in a competitive environment. The strategies of process innovation are associated with price competitiveness, while strategies of product innovation are linked to technological competitiveness and technological leadership (Pianta, 2005). With the latter the firm is attentive to the capacities to imitate extended by rivals. As a consequence, patenting is a process that has useful consequences for product innovators to maintain a continuing competitive advantage. By contrast, firms can more easily keep a new process secret. As a result there are fewer incentives to protect an innovation of this kind that is already protected in secret by patent (Arundel, 2001). We assume that these facts also describe the context of innovation in LDCs. As a consequence we retain the following hypothesis:

Hypothesis 2. A firm innovating in its product has a higher probability of a patent than a process innovator.

Very recently a new taxonomy providing richer insights in terms of strategic choices and dynamic implications has been developed. This discriminates between two types of innovator: a single and a complex one (Le Bas and Poussing, 2014; Tavassoli and Karlsson, 2015; Karlsson and Tavassoli, 2016). The first innovates only in one direction: product *or* process, the second in two directions. As a consequence, their technological capacities are not the same. A complex innovator has an advantage over a single innovator as far as creativity and the production of new ideas are concerned, due to synergetic relationships between product improvement and process improvement. There are cross *spillovers* between product and process research projects (Flaig and Stadler, 1994). A large firm has enough resources to carry out research in two directions. Size and technological complexity positively interact. According to Tavassoli and Karlsson (2015), a complex innovator can arrange a competence base that is larger and richer. The gains of complex innovators are twofold (Le Bas and Poussing, 2014): with new products (or improved products) they open new markets (taking a competitive advantage), and with cost-reducing process innovations they can increase the level of demand.

Although there is no study on patenting that takes into account such ‘innovation complexity’, it appears that a complex innovator is more prone to patent than a single innovator. First, because this innovates in the product structure, second, because it carries out more innovations. As a result, we have built the following hypothesis:

Hypothesis 3. A complex innovator receives more incentives to patent an innovation than a single innovator.

3. The data set, building the variables, and first descriptive statistics

3.1. Sample and variables definitions

The data used in this paper are from the World Bank Investment Climate Survey (ICS). The ICS is an important initiative conducted by the World Bank's Enterprise Analysis Unit and its partners over the world to collect harmonised firm level data in developing and least developed countries. The survey questionnaire asks a set of questions on firm performance, behaviour, and their position on financial, labour and sales markets, and contains several questions related to infrastructure, institutional environment, competition, technological and innovation activities. For this study we use the ICS data sets for Algeria, Kazakhstan, Nigeria, Ecuador, Colombia, Mexico and Chile[3]. Due to the uneven quality of the data we could not use the entire data set. We chose a sample of economies that give a relevant picture of LDCs. The sampling is done in such a way as to include two groups of countries: the "rentier" countries whose economies and foreign trade are based on oil products (Algeria, Kazakhstan, and Nigeria), and countries with a diversified economy. For the latter we chose countries from the Central and Latin American zone. As a result, for this study we use the ICS data sets for Algeria, Kazakhstan, Nigeria, Ecuador, Colombia, Mexico and Chile. Some of the rentier economies suffer from resource curse, or more precisely from an institutional resource curse (Amdaoud, 2018).

The firms were randomly selected within each country. The sample was stratified by firm size, branch activities, and geographic location[4]. Our sample includes 3,674 firms belonging to the *manufacturing sector*. Mexico is the largest sample with 1,137 firms and Ecuador is the smallest one with 120 firms (Table 2). We distinguish between two groups, first, "rentier" countries whose economies and foreign trade are based on oil products (Algeria, Kazakhstan, and Nigeria, some of which suffer from the resource curse, or more precisely from an institutional resource curse (Amdaoud, 2018). The second group contains small economies, but which have more diversified resources, such as Ecuador, Colombia, Mexico and Chile.

3.2. Set of variables

We built a set of variables in order to test the relevance of our hypotheses on the basis of innovation (or patenting) determinants literature, on the one hand, and the availability of data, on the other. As far as endogenous variables are concerned, we put the probability to implement incremental innovation (Innoprodincr), radical innovation (Innoprodrad), product innovation (Innoprod), process innovation (Innoproc), single innovator (Innosingl), complex innovator (Innocompl), and patenting (Patent). We also added several control variables that the literature considers as factors that received more attention in the literature, in order to capture both innovation and patenting. Traditional wisdom considers that R&D expenditure provides a good proxy for a firm's capabilities, and, as a consequence, we included the information on whether or not a firm undertakes internal R&D. We also added another less traditional variable for firm capabilities through a variable that measures the level of

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[3] The data were executed respectively in 2007 for Algeria, in 2014 for Nigeria, in 2013 for Kazakhstan, and in 2010 for Ecuador, Colombia, Mexico and Chile.

[4] For more information on the sampling methodology see: http://www.enterprisesurveys.org/methodology.

workforce education (Andersson and Lööf, 2012). A variable indicating whether the firm belongs to a group (Group) was included. According to the paper by Mohnen and Mairesse (2010) belonging to an industrial group positively modifies firm R&D behaviour. We also control whether a foreign entity owns a part of the firm. This variable makes sense to account for the eventual knowledge transfer that LDCs firms could receive from developed economy firms. A variable outlining the occurrence of technological transfers will be put into the models to be estimated. This gives information on the firm's quality of technology management. The incentives for innovating are included through a variable measuring the strength of competition. The variable Multimarket, indicating whether the firm intervenes both on the domestic and the foreign market, would have the same meaning. We add a variable that takes into account whether the firm is in competition with firms from the informal sector. Technological sectoral intensity appears through a dummy. The same for the specific country factors. Table 1 provides a precise empirical definition of each variable.

Table 1. List of variables

Variable	**Definition**
Innoprod	Dummy variable equal to one if the firm introduced new or significantly improved products including those new to the firm's market
Innoproc	Dummy equal to one if the firm introduced new or significantly improved processes
Innoprodincr	Dummy variable equal to one if the firm introduced new or significantly improved products
Innoprodrad	Dummy equal to one if the firm introduced new or significantly improved products which were new to the firm's market
Innosingl	Dummy equal to one if the firm reported a product innovation or a process innovation (only product or only process)
Innocompl	Dummy equal to one if the firm reported a product innovation and a process innovation (both product and process)
Patent	Dummy equal to one if the firm filed for a patent or has patents granted in the previous period
R&D	Dummy being one for firms that invest in R&D
Leffect	Size of the firm, measured by the number of employees in log
Group	Dummy equal to one if the firm is part of a group
Foreigncap	Dummy that takes on the value one if a foreign entity owns a share of the firm
Education	Average number of years of education of permanent production workforce, presented in ordinal form from 1 to 5
Competition	Dummy equal to one if the firm faces strong competition, estimated from the ordinal form of the number of competitors
Techlicen	Dummy being one if the firm uses technology licensed from a foreign-owned company
Informalsec	Dummy that takes the value of one if the firm is competing against the informal sector
Multimarket	Dummy being one for firms serving both domestic and foreign markets
SectFT	Dummy equals one if the firm belongs to a low technology sector

SectMHT	Dummy equal to one if the firm belongs to a medium-high technology sector
DZA	Dummy equal to one if the firm is located in Algeria
CHL	Dummy equal to one if the firm is located in Chile
COL	Dummy equal to one if the firm is located in Colombia
ECU	Dummy equal to one if the firm is located in Ecuador
KAZ	Dummy equal to one if the firm is located in Kazakhstan
MEX	Dummy equal to one if the firm is located in Mexico
NGA	Dummy equal to one if the firm is located in Nigeria

3.3. Descriptive statistics

The descriptive statistics of the variables used in the analysis are reported for the seven countries in Table 2. As expected, structural dissimilarities are observed within developing countries and especially between our two groups. Some of these differences are detailed in the following. When focusing on S&T indicators (R&D, innovation, and patents) the variance is still relevant for the two groups of countries. Only one fifth of the firms in the group of countries dependent on natural resources are engaged in R&D activities, while this ratio reaches half of the population in the group with diversified economies. This gap is also reflected in innovation and patent variables. The classification of innovators by the type of innovations reported (both product and process, only product, only process) helps to understand this heterogeneity. Figure 1 shows that the share of firms that introduce both products and processes is very significant in the case of Chile (38%), Colombia (41%), Ecuador (37%), and Nigeria (46%). In particular, Figure 1 indicates that only product innovators are much more frequent in the diversified group vs the rentier one. This picture is consistent with the distribution of patents across the groups and within countries. SMEs accounted for the majority of the sample, 2,716 firms (74% of the total sample) employed fewer than 100 employees. Large firms are more present in the second group composed of Latin American countries.

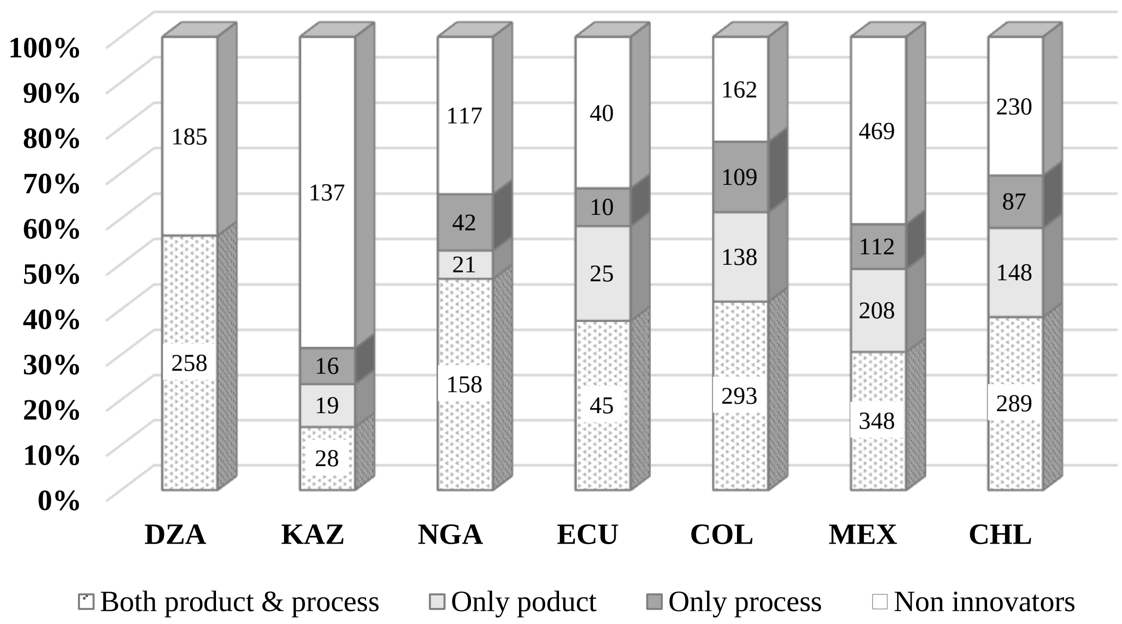
The highest level of firms affiliated to a foreign or domestic group is observed in Chile (23%). Table 2 also shows that foreign participation in the capital of the firms is very heterogenous between our two groups. Only Nigeria in the rentier group seems to have the same proportion of foreign investment as those in the diversified group. Algeria and Kazakhstan face more difficulties to attract international investors. Regarding the acquisition of technology, 15% of the total sample report acquiring licensing technology. This percentage is higher in Latin American countries, in comparison. Similarly, Latin American firms are more likely to cover both domestic and foreign markets (more than one third) than those in the remaining countries (less than a tenth). Furthermore, as expected, Table 2 shows that the majority of firms in the total sample (62%) are operating in a low technology sector (food processing, textiles, garments, nonmetallic and plastic production, and wood and furniture).

Table 2. Summary statistics

Variable	Algeria	Kazakhstan	Nigeria	Ecuador	Colombia	Mexico	Chile
Observations	423	200	338	120	702	1137	754
Innoprod	0.56	0.24	0.53	0.58	0.61	0.49	0.58
Innoproc	-	0.22	0.59	0.46	0.57	0.40	0.50
Innoprodincr	0.52	0.24	0.53	0.58	0.61	0.49	0.58
Innoprodrad	0.28	0.17	0.41	0.32	0.33	0.24	0.32
Innosingl	-	0.17	0.19	0.29	0.35	0.28	0.31
Innocompl	-	0.14	0.47	0.38	0.42	0.31	0.38
Patent	0.11	0.25	0.08	0.71	0.51	0.39	0.58
R&D	0.18	0.06	0.30	0.48	0.62	0.37	0.43
Leffect	3.22	3.49	2.85	3.94	3.63	3.82	3.83
Group	0.09	0.12	0.12	0.14	0.02	0.19	0.23
Foreigncap	0.02	0.07	0.17	0.22	0.10	0.10	0.14
Education	3.14	4.64	2.57	3.88	3.85	3.09	0.14
Competition	0.76	0.59	0.86	0.59	0.64	0.62	0.55
Techlicen	0.13	0.12	0.15	0.14	0.12	0.16	0.18
Informalsec	0.70	0.25	0.41	0.60	0.77	0.66	0.55
Multimarket	0.05	0.13	0.07	0.33	0.46	0.35	0.36
SectFT	0.48	0.56	0.77	0.73	0.62	0.56	0.68
SectMHT	0.43	0.46	0.24	0.28	0.38	0.44	0.33

Notes: Data are from the World Bank Investment Climate Survey (ICS) in each country.

Figure 1. Classification of firms according to their innovative output[5]



[5] Without any precision on process innovation in Algerian survey, we integrate product innovation in the category “both product and process” for this country in this presentation.

4. Models and econometric strategy

Considering the literature review and in order to identify the major determinants of patenting (or registration or patent application) within the firm in LDCs, we can write our model as follows:

$$P_i = \alpha + \beta_1 I_i + \beta_2 L_i + \beta_3 S_j + \beta_4 X_i + \varepsilon_i \quad (1)$$

Where P_i is a binary dependent variable (i =1, …, N. index firms) that takes the value 1 if the firm has a patent granted, and 0 otherwise. I_i is a variable that measures the engagement of the firm in innovation activities, L_i the size of the firm, S_j the technological intensity of the sector (with j = 1,…, J) and X_i a set of control variables. The coefficients β_1, β_2, β_3, β_4 are parameters of interest and ε an error term. Unlike previous studies on innovation, we consider patents not as a measure of innovation but as a proxy of the firm's capacity to effectively protect its invention and value its innovations. Concerning innovation activities, we use six different types or behaviours of innovation (see the previous section): (i) incremental, (ii) radical, (iii) product, (iv) process, (v) single, and (vi) complex. In order to estimate this capacity, it is important to consider the problem of the endogeneity of the variable innovation (I_i) in equation (1). Thus, in order to correct that we consider a system of two equations that relate innovation to patents as follows

$$\begin{cases} I_i = \beta X_i + \varepsilon_i & (2) \\ P_i = \gamma I_i^* + \delta Z_i + u_i & (3) \end{cases}$$

Where I_i and P_i are binary endogenous variables, and where the latent innovation activities, I_i^*, enters as an explanatory variable, X_i and Z_i a vector of variables explaining respectively innovation and patents, β and δ a vector of parameters of interest, and the error term ε_i and u_i which are independent and identically distributed (i.i.d).

Given the qualitative nature of our two dependent variables (innovation and patent), we use a probit model in order to assess the influence of explanatory variables on, respectively, the propensity to innovate (Equation 2) and the probability to patent (Equation 3). The parameters of our recursive system are evaluated with a maximum likelihood estimator. To address the endogeneity of I_i inequation (3) we use the predicted value estimated from equation (2), I_i^*.
To ensure the statistical significance of the global model in the test of the third hypothesis, we have pooled the data set. The set of explanatory variables are the same. Nevertheless, in order to take into account the specificity of each country we add to our system a term that controls for country effects as follows:

$$\begin{cases} I_i = \beta X_i + \varphi D_{ic} + \varepsilon_i & (4) \\ P_i = \gamma I_i^* + \delta Z_i + \varphi D_{ic} + u_i & (5) \end{cases}$$

Where D_{ic} (c = 1,2,…, 6) represents the country dummies variables with Chile as country reference. φ is the coefficient associated with the country dummies.

The pooled data set including firms from seven countries is used to test whether size has the same impact on innovation and patenting behaviour, and more generally to assess the robustness of our findings. We therefore estimate two sub-samples, one for small firms (fewer than 20 employees) and another for large firms (more than 100 employees). We follow for that the specification of the equation (4) and (5). We use the same explanatory variables except size. These equations are estimated using the maximum likelihood technique, estimating the parameter values that make the observed data most probable. In estimation some variables are not added to avoid the problem of multicollinearity. The data used are cross-sectional, which makes it more difficult to solve this type of problems.

5. Estimation, results and main findings

Some checks were carried out to test the robustness of our results. The review of Chi-2 values confirms that all our models are statistically significant. As already said, we have controlled for endogeneity bias by using the predicted values. In addition, we used main determinants, which received more attention in the literature, to capture both innovation and patenting. The econometric results of our system of equation are presented in Tables 3-7.

First, let us comment on the equations related to innovation determinants. The variable R&D is always significantly positive whatever the types of innovation: incremental, radical, product, process, single, complex. There is only one exception: the process innovation equation for Kazakhstan. In some circumstances it is true that firms can innovate in the technologies of process without R & D, properly speaking. In their study, Sung and Carlsson (2007) arrive at the same result in the case of Korea. Technology licensing is the other variable that has a certain effect in terms of explanation. In other words, when a firm uses technology licensed from a foreign-owned company it is a positive factor on the capacity to undertake innovation activity, thus confirming the suggestion of Almeida and Fernandes (2008). Regarding the other variables, a few are positive and significant across regressions. The variable group is among the coefficients positive and significant, in line with the literature indicating that a firm that is part of a group is more innovative. There are exceptions. For Kazakhstan this variable is significantly negative as far as product innovation is concerned. On the other hand, it is a very weak explanation of process innovation (except for Mexico). In contrast with our expectations from Economic Theory, competition never has a power of explanation (with the exception of Nigeria). This result is in line with evidence acquired by Hadhri et al. (2016) in the case of Lebanese firms. Multimarket works well in general for radical innovation and for other types of innovation for two countries (Mexico and Nigeria). The variable indicating the firm level of technological intensity has little effect. In the innovation determinants equation, the size of the firm is seldom significant, with the notable exception of Kazakhstan. It is somewhat surprising since the literature emphasises an effect for firm size on innovation capacity. However, the lack of an effect of economies of scale on the production of knowledge is consistent with studies by Raffo et al. (2008) on Mexico, by Karray and Kriaa (2009) on Tunisia, and Chudnovski et al. (2006) on Argentina. By way of conclusion there are differences across countries as far as innovation determinants are concerned, and even for R & D, the crucial explanative factor, the estimated coefficients range from 1 to 3. This heterogeneity is less important across our two groups of countries (except for Kazakhstan in product innovation and Ecuador in process innovation).

If we now turn our attention to the other equation related to patenting, we find the variable innovation (whatever its type) always has an explanatory power and is very often significant. The only exception is Nigeria for product (incremental and radical) innovation and process innovation (in this latter case the equation for Kazakhstan indicates the same result). As a result, this is evidence that innovating firms in general have a patenting behaviour. Can we obtain differentiated effects across a different variety of innovations? We previously thought that a firm conducting radical innovation should be more of a patentor than a firm carrying out incremental innovation (our Hypothesis 1). This view is mostly verified. The estimated coefficient related to the variable radical innovation is higher than the coefficient related to incremental innovation only for four countries (Algeria, Ecuador, Colombia and Mexico) and is equal (roughly). In this context we can consider our Hypothesis 1 as valid. The comparison between the patenting behaviour for product versus process innovator gives interesting results. The estimated coefficient for innovation is (significantly) larger when innovation concerns the product than it is for process, with only one atypical case of Colombia and Mexico. Nevertheless, for these two countries, the two coefficients are not too different. Miles (2008) explains this by the fact that product innovation comprises a higher degree of knowledge codification and tangibility than process innovations. Hence, this result confirms the literature and enables us to argue that Hypothesis 2 is not rejected.

The final aspect related to single versus complex innovator. As previously mentioned, we ran estimations for the entire sample of firms (see Table 7). The results match our expectations. The variable R&D explains the probability to be a complex innovator (but not a single innovator probability). Second, to be a patentor is a variable explained by the occurrence to be a complex innovator. In other words, to be a single innovator does not affect patenting activity. This result holds with control variables in particular for size effects that are highly significant and positive. As a consequence, our Hypothesis 3 cannot be rejected[6].

Tables 3 to 7 also give other results of patenting determinants of firms in the context of LDCs. We are essentially interested in the effects of variables describing the different types of innovation activity. The main finding in general concerns the role of firm size. The coefficients are more frequently significant and positive. This is evidence of the fact that large firms are more likely to patent their innovations. In effect, large firms tend to have more resources and market power to enforce their property right than small and medium-sized enterprises (SMEs). In his study of six EU countries, Arundel (2001) explains this variation by patent application costs which can be spread across many patents in the case of large firms. The other variable for the firm's patent behaviour is education. The coefficients are positive and significant in all models but not for all countries. It would mean that the more employees have a higher level of education, the more the probability to patent is significant. Barros (2015) found the same result in a Brazilian industrial survey. Finally, being part of a group and acting in both domestic and foreign markets seems relevant only in the case of Nigeria.

[6] We observe a certain asymmetry across the two equations: variables have no explanatory power in the first but they have this in the second, and conversely. More analysis would be required in order to explain this.

Table 3. Probit Model for Incremental Innovation and Patenting

	Algeria	Kazakhstan	Nigeria	Ecuador	Colombia	Mexico	Chile
Incremental innovation							
Leffect	0.0291	0.0597*	-0.0586*	-0.00734	0.0230	0.00549	0.0126
	(0.0305)	(0.0338)	(0.0317)	(0.0468)	(0.0173)	(0.0135)	(0.0189)
R&D	0.204***	0.453***	0.267***	0.388***	0.322***	0.390***	0.298***
	(0.0771)	(0.148)	(0.0688)	(0.116)	(0.0409)	(0.0358)	(0.0432)
Group	0.0929	-0.180	0.152	0.0317	0.354*	0.0921**	0.159***
	(0.0975)	(0.110)	(0.125)	(0.156)	(0.213)	(0.0467)	(0.0524)
Foreigncap	-0.115	-0.0150	0.0256	-0.114	0.0810	-0.0383	0.0639
	(0.192)	(0.164)	(0.115)	(0.158)	(0.0825)	(0.0664)	(0.0719)
Education	0.0164	0.0984	0.00859	0.119	0.0256	-0.0144	0.0161
	(0.0332)	(0.0703)	(0.0216)	(0.0824)	(0.0304)	(0.0242)	(0.0400)
Competition	-0.0850	0.0397	0.144	-0.180	-0.00273	0.00758	0.0131
	(0.0636)	(0.0725)	(0.0916)	(0.114)	(0.0421)	(0.0340)	(0.0406)
Techlicen	0.140*	0.156	0.147	0.417***	0.0883	0.0848*	0.0394
	(0.0813)	(0.107)	(0.103)	(0.158)	(0.0689)	(0.0500)	(0.0600)
Multimarket	0.140	0.132	0.190	0.149	0.0431	0.0284	0.0457
	(0.144)	(0.108)	(0.135)	(0.132)	(0.0462)	(0.0408)	(0.0504)
SectMHT	-0.0938*	-0.0766	-0.00931	0.0191	-0.0870**	0.00434	0.0229
	(0.0541)	(0.0703)	(0.0692)	(0.121)	(0.0415)	(0.0342)	(0.0426)
Patent							
Leffect	-0.0204	0.0764**	-0.00483	0.0523	0.101***	0.116***	0.00362
	(0.0127)	(0.0353)	(0.0120)	(0.0419)	(0.0188)	(0.0138)	(0.0195)
Innoprodincr	0.749***	0.687**	-0.144	0.666**	0.599***	0.396***	0.622***
(predicted)	(0.156)	(0.275)	(0.128)	(0.294)	(0.136)	(0.0916)	(0.155)
Group	0.0363	0.147	0.0932**	-0.0658	-0.176	-0.0179	-0.0673
	(0.0342)	(0.116)	(0.0439)	(0.134)	(0.185)	(0.0438)	(0.0542)
Foreigncap	0.0539	-0.0257	-0.0944*	0.239*	-0.0473	0.0344	-0.0348
	(0.0774)	(0.176)	(0.0519)	(0.138)	(0.0841)	(0.0662)	(0.0671)
Education	-0.00567	0.0206	-0.0106	0.103	0.0608*	0.0653***	-0.0601
	(0.0159)	(0.0712)	(0.00744)	(0.0719)	(0.0330)	(0.0248)	(0.0410)
Competition	0.0575*	-0.0180	0.132***	0.108	0.0359	-0.0377	-0.112***
	(0.0312)	(0.0740)	(0.0511)	(0.115)	(0.0435)	(0.0341)	(0.0405)
Techlicen	-0.0101	-0.112	0.0611	-0.228	0.0742	0.0492	0.0364
	(0.0340)	(0.124)	(0.0390)	(0.157)	(0.0726)	(0.0477)	(0.0570)
Informalsec	0.0214	-0.0139	0.0312	0.0335	0.105**	-0.0155	-0.0766*
	(0.0280)	(0.0786)	(0.0244)	(0.0993)	(0.0508)	(0.0357)	(0.0413)
Multimarket	-0.170***	0.0288	0.124***	0.0508	-0.0374	0.0427	-0.140***
	(0.0654)	(0.116)	(0.0452)	(0.116)	(0.0500)	(0.0386)	(0.0511)
SectMHT	0.0307	-0.0231	-0.112***	-0.131	0.0197	0.0193	-0.00365
	(0.0278)	(0.0709)	(0.0381)	(0.102)	(0.0435)	(0.0334)	(0.0422)
Observations	380	172	270	108	654	1040	679

Notes: $p < 0.01$ (***), $p < 0.05$ (**), $p < 0.1$ (*). Reported are marginal effects at sample means and standard errors in parentheses.

Table 4. Probit Model for Radical Innovation and Patenting

	Algeria	Kazakhstan	Nigeria	Ecuador	Colombia	Mexico	Chile
Radical innovation							
Leffect	0.0196	0.0179	-0.0443	-0.00306	0.00786	-0.00842	-0.00765
	(0.0272)	(0.0283)	(0.0326)	(0.0394)	(0.0158)	(0.0109)	(0.0183)
R&D	0.184***	0.375***	0.189***	0.325***	0.270***	0.212***	0.341***
	(0.0630)	(0.121)	(0.0686)	(0.106)	(0.0408)	(0.0283)	(0.0399)
Group	0.142*	-0.0916	0.197*	0.120	-0.156	0.0696*	0.0833*
	(0.0807)	(0.0893)	(0.119)	(0.146)	(0.176)	(0.0357)	(0.0460)
Foreigncap	-0.0763	-0.0307	-0.0861	0.135	0.0400	-0.0837	0.110*
	(0.177)	(0.151)	(0.110)	(0.129)	(0.0676)	(0.0547)	(0.0625)
Education	-0.0128	-0.00796	-0.0178	0.0788	-0.00576	-0.0224	-0.0990***
	(0.0287)	(0.0596)	(0.0217)	(0.0822)	(0.0306)	(0.0187)	(0.0375)
Competition	-0.0117	-0.0390	0.112	-0.0588	-0.0241	0.0115	-0.00995
	(0.0565)	(0.0603)	(0.0907)	(0.0960)	(0.0388)	(0.0277)	(0.0385)
Techlicen	0.0847	0.100	0.0277	0.267**	0.0894	0.0981***	0.119**
	(0.0681)	(0.0906)	(0.103)	(0.117)	(0.0593)	(0.0375)	(0.0514)
Multimarket	0.197*	-0.0470	0.295**	0.0506	0.0690	0.0444	0.107**
	(0.111)	(0.101)	(0.132)	(0.112)	(0.0432)	(0.0329)	(0.0457)
SectMHT	-0.0674	-0.0177	-0.0575	0.152	-0.0226	-0.0222	0.00466
	(0.0490)	(0.0569)	(0.0731)	(0.104)	(0.0391)	(0.0277)	(0.0404)
Patent							
Leffect	-0.0168	0.103***	-0.00697	0.0431	0.108***	0.123***	0.0140
	(0.0120)	(0.0323)	(0.0121)	(0.0424)	(0.0187)	(0.0135)	(0.0189)
Innoprodrad	0.766***	0.534*	-0.226	0.672*	0.763***	0.666***	0.527***
(predicted)	(0.155)	(0.281)	(0.173)	(0.346)	(0.175)	(0.151)	(0.131)
Group	-0.0198	0.0911	0.119**	-0.118	0.0794	-0.0335	-0.0225
	(0.0390)	(0.115)	(0.0549)	(0.137)	(0.189)	(0.0448)	(0.0510)
Foreigncap	0.0460	-0.0293	-0.114**	0.103	-0.0466	0.0788	-0.0617
	(0.0752)	(0.176)	(0.0560)	(0.128)	(0.0848)	(0.0679)	(0.0682)
Education	0.0148	0.0841	-0.0153*	0.138**	0.0787**	0.0751***	-0.00560
	(0.0151)	(0.0672)	(0.00808)	(0.0680)	(0.0326)	(0.0248)	(0.0414)
Competition	0.0119	0.0242	0.138***	0.0296	0.0508	-0.0426	-0.102**
	(0.0295)	(0.0752)	(0.0516)	(0.0996)	(0.0440)	(0.0342)	(0.0404)
Techlicen	0.0172	-0.0517	0.0505	-0.164	0.0446	0.00975	-0.00719
	(0.0329)	(0.117)	(0.0328)	(0.152)	(0.0749)	(0.0500)	(0.0602)
Informalsec	0.0222	-0.00879	0.0317	0.0376	0.104**	-0.0155	-0.0779*
	(0.0285)	(0.0777)	(0.0241)	(0.0976)	(0.0508)	(0.0357)	(0.0413)
Multimarket	-0.276***	0.146	0.161**	0.129	-0.0643	0.0233	-0.169***
	(0.0791)	(0.113)	(0.0626)	(0.107)	(0.0519)	(0.0394)	(0.0532)
SectMHT	0.0183	-0.0611	-0.123***	-0.209**	-0.00985	0.0352	0.00782
	(0.0270)	(0.0690)	(0.0379)	(0.106)	(0.0428)	(0.0333)	(0.0418)
Observations	380	172	270	108	654	1040	679

Notes: $p < 0.01$ (***), $p < 0.05$ (**), $p < 0.1$ (*). Reported are marginal effects at sample means and standard errors in parentheses.

Table 5. Probit Model for Product Innovation and Patenting

	Algeria	Kazakhstan	Nigeria	Ecuador	Colombia	Mexico	Chile
Product innovation							
Leffect	0.0186	0.0597*	-0.0586*	-0.00734	0.0230	0.00549	0.0126
	(0.0309)	(0.0338)	(0.0317)	(0.0468)	(0.0173)	(0.0135)	(0.0189)
R&D	0.202***	0.453***	0.267***	0.388***	0.322***	0.390***	0.298***
	(0.0762)	(0.148)	(0.0688)	(0.116)	(0.0409)	(0.0358)	(0.0432)
Group	0.0846	-0.180	0.152	0.0317	0.354*	0.0921**	0.159***
	(0.0971)	(0.110)	(0.125)	(0.156)	(0.213)	(0.0467)	(0.0524)
Foreigncap	-0.0350	-0.0150	0.0256	-0.114	0.0810	-0.0383	0.0639
	(0.185)	(0.164)	(0.115)	(0.158)	(0.0825)	(0.0664)	(0.0719)
Education	0.0226	0.0984	0.00859	0.119	0.0256	-0.0144	0.0161
	(0.0327)	(0.0703)	(0.0216)	(0.0824)	(0.0304)	(0.0242)	(0.0400)
Competition	-0.0769	0.0397	0.144	-0.180	-0.00273	0.00758	0.0131
	(0.0642)	(0.0725)	(0.0916)	(0.114)	(0.0421)	(0.0340)	(0.0406)
Techlicen	0.145*	0.156	0.147	0.417***	0.0883	0.0848*	0.0394
	(0.0815)	(0.107)	(0.103)	(0.158)	(0.0689)	(0.0500)	(0.0600)
Multimarket	0.267	0.132	0.190	0.149	0.0431	0.0284	0.0457
	(0.168)	(0.108)	(0.135)	(0.132)	(0.0462)	(0.0408)	(0.0504)
SectMHT	-0.115**	-0.0766	-0.00931	0.0191	-0.0870**	0.00434	0.0229
	(0.0535)	(0.0703)	(0.0692)	(0.121)	(0.0415)	(0.0342)	(0.0426)
Patent							
Leffect	-0.0125	0.0764**	-0.00483	0.0523	0.101***	0.116***	0.00362
	(0.0122)	(0.0353)	(0.0120)	(0.0419)	(0.0188)	(0.0138)	(0.0195)
Innoprod	0.757***	0.687**	-0.144	0.666**	0.599***	0.396***	0.622***
(predicted)	(0.158)	(0.275)	(0.128)	(0.294)	(0.136)	(0.0916)	(0.155)
Group	0.0450	0.147	0.0932**	-0.0658	-0.176	-0.0179	-0.0673
	(0.0339)	(0.116)	(0.0439)	(0.134)	(0.185)	(0.0438)	(0.0542)
Foreigncap	-0.00571	-0.0257	-0.0944*	0.239*	-0.0473	0.0344	-0.0348
	(0.0746)	(0.176)	(0.0519)	(0.138)	(0.0841)	(0.0662)	(0.0671)
Education	-0.0103	0.0206	-0.0106	0.103	0.0608*	0.0653***	-0.0601
	(0.0161)	(0.0712)	(0.00744)	(0.0719)	(0.0330)	(0.0248)	(0.0410)
Competition	0.0514*	-0.0180	0.132***	0.108	0.0359	-0.0377	-0.112***
	(0.0307)	(0.0740)	(0.0511)	(0.115)	(0.0435)	(0.0341)	(0.0405)
Techlicen	-0.0116	-0.112	0.0611	-0.228	0.0742	0.0492	0.0364
	(0.0339)	(0.124)	(0.0390)	(0.157)	(0.0726)	(0.0477)	(0.0570)
Informalsec	0.0216	-0.0139	0.0312	0.0335	0.105**	-0.0155	-0.0766*
	(0.0279)	(0.0786)	(0.0244)	(0.0993)	(0.0508)	(0.0357)	(0.0413)
Multimarket	-0.211***	0.0288	0.124***	0.0508	-0.0374	0.0427	-0.140***
	(0.0702)	(0.116)	(0.0452)	(0.116)	(0.0500)	(0.0386)	(0.0511)
SectMHT	0.0451	-0.0231	-0.112***	-0.131	0.0197	0.0193	-0.00365
	(0.0291)	(0.0709)	(0.0381)	(0.102)	(0.0435)	(0.0334)	(0.0422)
Observations	380	172	270	108	654	1040	679

Notes: $p < 0.01$ (***), $p < 0.05$ (**), $p < 0.1$ (*). Reported are marginal effects at sample means and standard errors in parentheses.

Table 6. Probit Model for Process Innovation and Patenting

	Kazakhstan	**Nigeria**	**Ecuador**	**Colombia**	**Mexico**	**Chile**
Process innovation						
Leffect	0.0744**	-0.0451	0.00430	0.0109	-0.0214	0.0341*
	(0.0296)	(0.0304)	(0.0475)	(0.0168)	(0.0133)	(0.0194)
R&D	0.154	0.188***	0.545***	0.305***	0.323***	0.304***
	(0.126)	(0.0670)	(0.119)	(0.0419)	(0.0342)	(0.0439)
Group	-0.202	0.177	-0.0339	-0.0399	0.0968**	-0.0443
	(0.143)	(0.122)	(0.177)	(0.149)	(0.0442)	(0.0525)
Foreigncap	0.0136	-0.210**	0.129	-0.0224	-0.0411	-0.0778
	(0.144)	(0.102)	(0.166)	(0.0782)	(0.0647)	(0.0737)
Education	0.108	0.000343	-0.0365	-4.81e-05	0.00865	-0.00496
	(0.0700)	(0.0213)	(0.0718)	(0.0312)	(0.0234)	(0.0408)
Competition	0.0196	0.155*	-0.0411	-0.0341	-0.0278	-0.0289
	(0.0683)	(0.0862)	(0.114)	(0.0419)	(0.0331)	(0.0413)
Techlicen	0.239**	0.123	0.116	-0.0365	0.127***	0.176***
	(0.0975)	(0.100)	(0.146)	(0.0668)	(0.0467)	(0.0593)
Multimarket	-0.0387	0.441**	0.0251	0.0255	0.102**	0.0277
	(0.105)	(0.180)	(0.131)	(0.0469)	(0.0397)	(0.0516)
SectMHT	-0.0309	0.0126	0.272**	-0.0290	-0.0875***	0.0357
	(0.0669)	(0.0674)	(0.125)	(0.0419)	(0.0332)	(0.0438)
Patent						
Leffect	0.0379	-0.00306	0.0452	0.107***	0.127***	-0.00785
	(0.0588)	(0.0124)	(0.0423)	(0.0187)	(0.0135)	(0.0207)
Innoproc	1.044	-0.145	0.474**	0.631***	0.464***	0.599***
(predicted)	(0.679)	(0.173)	(0.209)	(0.144)	(0.108)	(0.151)
Group	0.219	0.0929*	-0.0260	0.000384	-0.0275	0.0407
	(0.136)	(0.0498)	(0.136)	(0.191)	(0.0444)	(0.0504)
Foreigncap	-0.0557	-0.125*	0.131	0.00242	0.0392	0.0356
	(0.180)	(0.0678)	(0.128)	(0.0843)	(0.0663)	(0.0678)
Education	-0.0179	-0.0119	0.176***	0.0745**	0.0567**	-0.0485
	(0.0894)	(0.00752)	(0.0609)	(0.0326)	(0.0250)	(0.0407)
Competition	-0.00959	0.135**	0.0216	0.0537	-0.0231	-0.0896**
	(0.0723)	(0.0555)	(0.0977)	(0.0441)	(0.0341)	(0.0404)
Techlicen	-0.300	0.0563	-0.0454	0.137*	0.0239	-0.0345
	(0.226)	(0.0407)	(0.125)	(0.0717)	(0.0490)	(0.0632)
Informalsec	-0.0198	0.0308	0.0366	0.104**	-0.0155	-0.0778*
	(0.0782)	(0.0249)	(0.0978)	(0.0508)	(0.0357)	(0.0413)
Multimarket	0.178	0.146**	0.134	-0.0286	0.00915	-0.130**
	(0.115)	(0.0655)	(0.108)	(0.0496)	(0.0404)	(0.0506)
SectMHT	-0.0386	-0.110***	-0.219**	-0.0106	0.0575*	-0.00933
	(0.0723)	(0.0390)	(0.106)	(0.0428)	(0.0337)	(0.0425)
Observations	172	270	108	654	1040	679

Notes: $p < 0.01$ (***), $p < 0.05$ (**), $p < 0.1$ (*). Reported are marginal effects at sample means and standard errors in parentheses.

Table 7. Probit Model (pooled) for Single Innovation, Complex Innovation, and Patenting

Dependent variable	Single innovation	Complex innovation	Patent	
			1	2
Innosingl (predicted)			0.330	
			(0.694)	
Innocompl (predicted)				0.469***
				(0.0686)
Leffect	-0.00179	0.00678	0.0982***	0.0826***
	(0.00730)	(0.00803)	(0.00856)	(0.00866)
R&D	-0.00353	0.316***		
	(0.0185)	(0.0201)		
Group	-0.0292	0.0741***		-0.0172
	(0.0263)	(0.0284)		(0.0305)
Foreigncap	0.0218	-0.0391	-0.0245	0.00257
	(0.0312)	(0.0339)	(0.0380)	(0.0368)
Education	0.0156	0.00506		0.0255*
	(0.0118)	(0.0123)		(0.0138)
Competition	-0.00353	-0.00531	-0.0271	-0.0220
	(0.0179)	(0.0197)	(0.0206)	(0.0205)
Techlicen	0.0216	0.0809***	0.0798**	0.0319
	(0.0252)	(0.0279)	(0.0321)	(0.0301)
Informalsec			0.0174	0.00821
			(0.0218)	(0.0220)
Multimarket	0.00950	0.0583**	0.0383	0.00108
	(0.0213)	(0.0231)	(0.0258)	(0.0255)
SectMHT	-0.0191	-0.00759	-0.00137	-0.0171
	(0.0178)	(0.0195)	(0.0233)	(0.0202)
COL	0.0391	-0.0203	-0.0703*	-0.0725**
	(0.0253)	(0.0280)	(0.0425)	(0.0296)
ECU	-0.0262	-0.0181	0.147***	0.145***
	(0.0471)	(0.0497)	(0.0571)	(0.0542)
KAZ	-0.177***	-0.135***	-0.241**	-0.218***
	(0.0439)	(0.0487)	(0.110)	(0.0485)
MEX	-0.0129	-0.0710***	-0.195***	-0.146***
	(0.0245)	(0.0270)	(0.0315)	(0.0288)
NGA	-0.103***	0.205***	-0.469***	-0.570***
	(0.0374)	(0.0396)	(0.0887)	(0.0539)
Observations	2923	2923	2923	2923

Notes: $p < 0.01$ (***), $p < 0.05$ (**), $p < 0.1$ (*). Reported are marginal effects at sample means and standard errors in parentheses.

6. Conclusion: discussion and extension

In this paper we explore the main determinants of firm patenting behaviour in LDCs. As a new approach we place the emphasis on the type of innovation implemented and the potential effect of firm size. We use data for seven countries at firm level from the ICS implemented by the World Bank that contains data on formal appropriation (patent) and innovation activity.

Regarding innovation, the main determinants of the empirical analysis suggest that R&D activity does matter in innovation activity, whatever the type of activity. This is in line with the theoretical view and empirical studies (Levin et al.,1987; Amara et al., 2008; Crespi and Zuniga, 2012). The second determinant is the purchase of external or foreign technology which can act as meaning deep learning within the firm. Firm size does not seem relevant for innovation behaviour. We recall that here we estimate the probability to innovate; as a consequence we are concerned neither by the volume of innovation achieved nor by its value.

Our estimations also suggest that the hypotheses we built up are supported for the manufacturing sector in LDCS. First, the radical innovator has a higher probability than the incremental innovator to patent. The degree of innovation novelty was earlier discussed in literature (see for example Knight, 1967; Dosi, 1982). This result reflects that found by Hanel (2008) concerning Canadian manufacturing firms, in which the value of patenting is a function of the originality of innovation. Second, product innovators mainly have a higher probability to patent than process innovators (other things being equal). That is line with the studies by Cohen et al. (2002), Arundel (2001), Harbi (1995) and Hanel (2008), highlight the fact that patents protect product innovation or invention more efficiently than process innovation. Third, the distinction between a complex innovator with respect to a single innovator (a new taxonomy of innovation recently documented in a few papers) is relevant. Obviously, firms that develop product and process innovation have more chance to patent their innovation than firms developing only product or only process innovation.

Furthermore, as far as firm size is concerned, we show that large firms always patent more than small firms, whatever the type of innovation at stake. This result is similar to the results obtained in previous studies (Blind et al., 2006; Arundel, 2001; Hanel, 2008; Barros, 2015; Neuhäusler, 2012). Another key result shows that the structure of ownership does not appear as determinant. This means that firms with foreign participation in their capital are not more inclined to patent than domestic firms. This evidence is consistent with studies conducted by Barros (2015) and Albuquerque (2000) on the Brazilian economy.

We find differences across countries, but we do not note significant differences between the group of national economies based on oil rent and the others. A result deserves particular attention. Our findings indicate technology licensing has a certain explanative power: when a firm uses technology licensed from a foreign-owned company it is a positive factor on its capacity to innovate. Such good evidence tends to indicate management of technology transfer is correlated to firm innovation.

Thus, the main lesson in this paper is the relevance of types of innovation behaviour (originality, type and complexity of innovation) in explaining patenting decisions in developing countries or in weak institutional environments. These considerations link our study to the literature of appropriation in developed countries (Hanel, 2008; Arundel, 2001; Blind et al., 2006).

We now look at relevant extensions of this work.

A first possible extension could be linked to the specificity of the context. In developing countries, the imitation and adaptation of already-created innovations are more important than cutting-edge innovations. Moreover, in small firms, innovation and R&D activity are more sporadic and when the need arises (OECD, 1993). This minor and adaptive aspect of inventions makes patentability an unusual practice. An exception could be small firms pursuing a high technology strategy or innovating at the frontier level. However, this set of firms is very limited in developing countries (Crespi and Zuniga, 2012; Ayyagari et al., 2011). Another extension would concern small firms. Often they are unable to develop their own appropriation strategies satisfactorily, since they rarely have the necessary financial resources, competence and special experience (legal and technical know-how)[7]. The importance of financial constraints on small rather than large firms is largely documented in the works of Canepa and Stoneman (2008) in the UK, Tourigny and Le (2004) in Canada, and Rahmouni (2014) in Tunisia. Thus, small firms grow faster with a financially developed sector. In addition, patent protection could be too expensive for small firms because of the high costs involved in obtaining patents (application costs) and defending them from infringement (Gonzalez-Alvarez and Nieto-Antolın, 2007). All these reasons may increase for small firms the relative value of the other forms of IPRs rather than the use of patent system[8].

At last future research could explore how firms in developing countries, according to their own experience, use different types of IPRs including both the formal mechanism of appropriation (utility models, industrial designs, copyrights, and trademarks) and informal ones (secrecy, lead time, confidentiality agreements, and complexity)[9].

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[7] See Arundel (2001), Harbi (1995), and Tager and von Witzleben (1991).

[8] Public policies can here play a crucial role by supporting small firms or by enhancing the business climate (e.g. IP protection or patent law), and to tackle hampering factors that limit innovation activity and appropriation.

[9] Knowing that studies show differences in the choice of appropriability method across the manufacturing and service sector (Amara et al., 2008; Blind et al., 2003; Hanel, 2008) and within the manufacturing sector (Arundel, 2001; Blind et al., 2006; Neuhäusler, 2012; Barros, 2015).

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