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INNOVATION DYNAMICS AND PRODUCTIVITY: EVIDENCE FOR LATIN AMERICA[1]

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Abstract

Innovation is fundamental for economic catching-up and raising living standards. Evidence demonstrate a virtuous circle in which R&D spending, innovation, productivity, and per capita income mutually reinforce each other and lead to long-term, sustained growth rates and may foster job creation. Previous evidence highlights that Latin America and the Caribbean (LAC) has great potential to benefit from investment and policies that foster innovation. However, one important limitation of previous research on innovation in LAC is the absence of harmonised and comparable indicators across the different countries. This seriously limits the possibility to infer policy conclusions that are not affected by country specificities with respect to data quality and coverage. Also, most of this research is focused on estimating firm level correlations without attempting to identify market failures or other limitations which harm innovation investment or which could guide policy. In this paper, a wide range of innovation indicators are analysed in order to describe the innovation behaviour of manufacturing firms in LAC using the Enterprise Survey (ES) database. Our objective is to understand the main characteristics of innovative firms in LAC and to gather new evidence with regard to the nature of the innovation process in the region**.** In this paper we apply a structural model based on Crepon, Duget and Mairesse (1998), to estimate the determinants of innovation (R&D) and its impact on total factor productivity. We pay special attention to whether there is heterogeneity in the effects of investments in innovation on productivity and whether there is any evidence of spillovers that could guide policy design. We found strong evidence concerning the relationships between innovation input and output, and innovation output and productivity. We found that private returns to innovation depend on the type of innovation, being larger for product than process innovation. Furthermore, we found some evidence that spillovers are stronger in the case of product than process innovation. It was also found that innovation returns are higher for the most productive firms. This increasing relationship between returns and productivity is not consistent with an interpretation that financial constraints cause more harm to low productivity firms. However, it is consistent with alternative interpretations about the lack of innovation opportunities in the case of low productivity firms or that low private returns are the results of poor appropriability.

Key words: Innovation, productivity, developing countries,
Latin America, innovation surveys

JEL-codes: O12, O14, O31, O33, 040.

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1) Introduction

Although GDP per capita of most Latin American and Caribbean (LAC) countries has been growing rapidly during the last decade, it still lags significantly behind industrialised countries levels. Further, productivity, the main-driver of long-run economic growth, has been growing at a lower rate than the world technological frontier growth rate (IDB 2010a). Thus, improving productivity constitutes the main challenge for LAC. But what is behind productivity growth? Economies are becoming more knowledge-based, where innovation is a key driver of national competitiveness, development, and long-term economic growth. At the firm level, innovation— the transformation of ideas into new products, services, and production processes — leads to a more efficient use of resources, creating sustainable competitive advantages. At the same time, innovation leads to the appearance of completely new sectors, where new firms start operating and new production routines are generated. Change in the production structure is what increases specialisation and productivity growth (Katz, 2006) as well as the gradual expansion of more knowledge-intensive production activities. Hence, innovation is essential to spur economic growth and to raise living standards.[2] At the macro level, research and development (R&D) spending, innovation, productivity, and per capita income reinforce each other and lead to sustained long-term growth (Hall and Jones, 1999; Rouvinen, 2002).

Evidence on the relationship between R&D, innovation, and productivity has been found in studies of industrialised countries (Griffith *et al.*, 2004; Griffith *et al.*, 2006; OECD, 2009a; Mairesse and Mohnen, 2010). Investing in innovation can have substantial economic payoffs: firms that invest in innovation are better equipped to introduce technological advances and tend to have higher labour productivity than those that do not. Crespi and Zuñiga (2012) report that productivity gaps in the manufacturing sector between innovative and non-innovative firms are much higher in LAC than in industrialised countries. For the typical EU country, the productivity gap is 20 percent, while for the typical LAC country it is 70 percent. Thus, LAC has great potential to benefit from investment and policies that foster innovation.

[2] Hall (2011) presents a short discussion on the topic of how the results for individual firms' productivity, aggregate to the economy as a whole.

One of the most important limitations of previous research on innovation in LAC is the absence of harmonised and comparable indicators across the different countries. This seriously limits the possibility to infer policy conclusions that are not affected by country specificities with respect to data quality and coverage.[3] Also, most of this research is focused on estimating firm level correlations without attempting to identify market failures or other limitations that harm innovation investment and could as guide policy. In this paper, a wide range of innovation indicators are analysed in order to describe the innovation behaviour of manufacturing firms in LAC using the Enterprise Survey (ES) database.[4] Our objective is to understand the main characteristics of innovative firms in LAC and to gather new evidence with regard to the nature of the innovation process in the region. Section 2 of the paper reviews the main findings in the literature on the determinants of innovation in both industrialised and developing countries. Section 3 presents statistics about the level of innovation performance of LAC firms using different types of indicators. The ways that innovation relates to firm characteristics in the LAC context are explored, using a structural model approach to untangle the determinants of innovation investment and performance, and productivity at the firm level. Section 4 extends the model to gather some evidence regarding the prevalence of spillovers and the extent to which there is an important heterogeneity regarding innovation returns. Section 5 concludes.

2) **Literature Background**

Innovation is fundamental for economic catching-up and raising living standards. Evidence demonstrate a virtuous circle in which R&D spending, innovation, productivity, and per capita income mutually reinforce each other and lead to long-term, sustained growth rates (Hall and Jones, 1999; Rouvinen, 2002; Guloglu and Tekin, 2012) and may foster job creation (Vivarelli,

[3] In this respect, the Inter-American Development Bank together with regional agencies such as RICYT have emphasised the need to develop comparable innovation surveys and have developed suggestions for sample design, data collection and harmonization of questionnaires based on the existing manuals. Anlló *et al* (2014) summarises these recommendations.

[4] ES define innovation rates as the share of firms introducing product or process innovations. In this paper, the term "*product innovation*" refers strictly to firms that introduced a new or significantly improved product that is new to the firm or the establishment's market in the last 3 years. "*Process innovation*" refers strictly to firms that introduced new or significantly improved processes that are new to the firm or to the industry in the last 3 years. Mohnen and Hall (2013) presents in detail the notions of different types of innovation and discuss the way they are measured.

2013).[5] R&D is a source of direct and indirect advantages for firms. There is convincing evidence for industrialised countries showing the positive linkages between R&D, innovation, and productivity at the firm level (Griffith *et al.*, 2004; Griffith *et al.*, 2006; OECD, 2009a; Mairesse and Mohnen, 2010; Mohnen and Hall, 2013). In addition, R&D also contributes to firms' absorptive capacity, a fundamental prerequisite for "learning by doing". Internal R&D allows for better identification of the value of external technology, its assimilation and use, while expanding firms' stock of knowledge (Cohen and Levinthal, 1989; Griffith *et al.*, 2004). Hence, strengthening in-house technological capabilities induces knowledge spillovers through acquisition of machinery, equipment, and interaction with other firms.

It should be noted that an important strand of the received literature deals with country level or sector level information. However, and taking into consideration that innovation results from the investment decisions taken by individual firms, the microeconomic analysis has the potential to enlighten on the foundations of the correlations found at the macro level. Taking advantage of the innovation surveys, Crépon, Duguet and Mairesse (1998) (henceforth CDM) were the first to integrate empirically these relationships in a recursive model allowing for the estimation of innovation inputs (R&D investment) investment function. Their findings for France corroborate that firm productivity correlates positively with a higher innovation output, even when controlling for the skill composition of labour. They also confirm that firm decision to invest in innovation (R&D) increases with its size, market share and diversification and with the demand-pull and technology push forces.

Building on the CDM model, a new wave of studies exploiting innovation surveys emerged and reported similar results for other industrialised countries. Using different indicators of economic performance such as firms' labour productivity, multifactor productivity, sales, profit margins and market value, studies have recurrently shown that technological innovation (product or process) lead to superior firm economic performance (e.g. see Loof and Heshmati, 2002; Loof *et al*, 2003; Janz *et al*, 2004; Van Leeuwen and Klomp, 2006 or Monhen *et al*, 2006). This literature also highlights that firm heterogeneity is important to explain innovation activities and

[5] Crespi and Tacsir (2013) present empirical evidence of the impact of process and product innovation on employment growth and composition in a sample of Latin American countries.

their effects on firm performance and must be controlled for in empirical estimations (Hall and Mairesse, 2006; Mairesse and Monhen, 2010, and the introductory chapter in this volume). Further, the correlation between product innovation and productivity is often higher for larger firms (Griffith *et al,* 2006; OECD, 2009), and as expected, in most countries the productivity effect of product innovation is larger in manufacturing than in services (OECD, 2009). In addition, a positive association is consistently confirmed between of R&D and innovation outcomes. Firms that invest more intensively in R&D are more likely to develop innovations — once corrected for endogeneity and controlling for firms characteristics such as size, affiliation to group, or the type of innovation strategies.

In contrast, evidence with regard to the ability of firms in developing economies to transform R&D into innovation is not as conclusive. This heterogeneity could be explained by the fact that firms in developing countries are too far from the technological frontier and incentives to invest in innovation are weak or absent (Acemoglu *et al.,* 2006). In this vein, a positive association between R&D, innovation and productivity have been found for new industrialised countries such as South Korea (Lee and Kang, 2007), Malaysia (Hegde and Shapira, 2007), Taiwan (Yan Aw *et al*, 2008) and China (Jefferson *et al*, 2006), who by investing in R&D and human capital managed to narrow their distance to the best practices. Differently, in many LAC economies, firms' innovations consist in incremental changes with few or no impact on international markets, and mostly based on imitation and technology transfer, -e.g. acquisition of machinery and equipment and disembodied technology (Anlló and Suarez, 2009; Navarro *et al*, 2010). R&D is in many cases prohibitive (both in terms of financial costs and human capital needed) and it could demand perhaps longer time horizons to be manifested (Navarro *et al*, 2010).

There is evidence that higher levels of investment in innovation (notably in R&D) lead to higher propensity to introduce technological innovation in firms from Argentina (Chudnovsky *et al*, 2006) and Brazil (Correa *et al,* 2005; Raffo *et al*, 2008), but research does not support this relation for Chile (Benavente, 2006) or Mexico (Perez *et al*, 2005). The results regarding the impact of innovation on labour productivity are equally inconclusive for Latin American firms. Raffo *et al* (2008) find a significant impact of product innovation for Brazil and Mexico but not for Argentina but Perez *et al* (2005), Chudnovsky *et al* (2006) and Benavente (2006) failed to find any significant effect of innovation on firms' productivity (measured as sales per employee) in Argentinean and Chilean firms, respectively. Hall and Mairesse (2006) suggest that the lack of significance of innovation in productivity in developing countries may perhaps be a reflection of the very differing circumstances surrounding innovation in these economies as compared to Western Europe and they suggest to evaluate effects over longer periods of time (for evidence for Chile see Benavente, 2010).[6]

One important pitfall of previous research, acting as a potential underlying factor behind the heterogeneity just mentioned, has to do with the lack of homogenous and comparable data across the different countries in the region. Differences in sampling methodologies, questionnaire design and data processing of the existing innovation surveys seriously affect the comparability of the results. Crespi and Zuñiga (2012), was the first comparative study in LAC that examines the determinants of technological innovation and its impact on firm labour productivity in manufacturing, across Latin American countries (Argentina, Chile, Colombia, Costa Rica, Panama and Uruguay), using micro data from innovation surveys but the same specification and identification strategy. This comparable exercise shows more consistent results. Specifically, firms that invest in knowledge are more able to introduce technological advances and those that innovate exhibit superior labour productivity than those that don't. Yet, firm level determinants of innovation investment are still more heterogeneous than in OECD countries. Co-operation, foreign ownership and exporting, increase the propensity to invest in innovation and its size only in half of the countries. At the same time, the inconsistency of the impacts of firm's cooperation linkages, and the fact that the use of several sources (both scientific and market) of information for innovation activities have little or no impact on innovation efforts, illustrates the weak articulation that characterises national innovation systems in the region. The results regarding productivity however highlight the importance of innovation for firms to improve economic performance and catch-up.

Taking these efforts a bit further, our contributions is twofold. Firstly, we make a use of a homogenous questionnaire and dataset allowing us to make the conclusion more easily generalisable. Secondly, most of the previous research on the micro-determinants of innovation

[6] Accordingly, if adjustment costs emerging from weaker innovation systems are higher in developing countries, it may be more important to specific dynamic linkages than in western economies, for which it is more likely that the cross sectional estimates of the CDM type model can reflect long-run relations.

and their impacts of productivity deal with structural determinants and although these results are useful for policy design, they are insufficient in that they are not directly linked to market failures. This research extends the inherited analyses by looking at the impacts spillovers regarding the determinants of innovation investments.

3) Research Questions and Conceptual Framework

This paper aims at gathering new evidence regarding the determinants of innovation investments – in particular R&D – in LAC and their impacts on productivity at the firm level. More specifically, we address the following research questions: (a) what are the determinants of innovation investments in LAC?; (b) what are the innovation returns of innovation investments; (c) what are the impacts of innovation outputs on productivity?; (d) is there heterogeneity in the effects of investments in innovation on productivity?; (e) is there any evidence of spillovers that could guide policy design and analysis?

In this paper we apply a structural model based on Crepon, Duget and Mairesse (1998), to estimate the determinants of innovation (R&D) and its impact on total factor productivity. The CDM model consists of three stages: *i)* first firms decide whether or not to invest in R&D activities and how much to invest; *ii)* knowledge (technology) is produced as a result of this investment ("knowledge production" function, e.g. Griliches, 1979 and Pakes and Griliches, 1984); and lastly *iii),* output is produced using new knowledge (technological innovation) along with other inputs. Thus knowledge is assumed to have a direct impact on firm economic performance, generally expressed by total factor productivity. In addition to firm characteristics, the model also includes external forces acting concurrently on the innovation decisions of firms, and indicators of demand-driven innovation (i.e. environmental, health and safety regulation), technological push (i.e. scientific opportunities), financing (i.e. R&D subsidies) and spillovers.

The CDM model intends to deal with the problem of selectivity bias[7] and endogeneity in the functions of innovation and productivity.[8] The model can be written as follows. Let *i=1,…., N.* index firms. The first equation accounts for firms' innovative effort IE_i^*:

$$IE_i^* = z_i{}'\beta + e_i \qquad (1)$$

Where we consider IE_i^* as an unobserved latent variable, and where z_i is a vector of determinants of innovation effort, β is a vector of parameters of interest, and e_i an error term. We can proxy firms' innovative effort IE_i^* by their (log) expenditures on R&D activities per worker denoted by IE_i only if firms make (and report) such expenditures, and thus could only directly estimate equation (1) at the risk of selection equation (Griffith *et al*, 2006). Instead, we assume the following selection equation describing whether the firm decides to do (and/or report) innovation investment or not:

$$ID_i = \begin{cases} 1 \; if \; ID_i^* = w_i'\alpha + \varepsilon_i > c, \\ 0 \; if \; ID_i^* = w_i'\alpha + \varepsilon_i \leq c \end{cases} \qquad (2)$$

Where ID_i is an innovation decision binary endogenous variable equal to zero for firms that do not invest on innovation and one for firms investing in innovation activities; ID_i^* is a corresponding latent variable such that firms decide to do (and/or report) innovation investment if it is above a certain threshold level c, and where w is a vector of variables explaining the innovation investment decision, a, α vector of parameters of interest, and ε an error term. Conditional on firm *i* doing innovation activities, we can observe the amount of resources invested in innovation (IE) activities, and write:

$$IE_i = \begin{cases} IE_i^* = z_i'\beta + \varepsilon_i \; if \; ID_i = 1 \\ \quad 0 \; if \; D_i = 0 \end{cases} \qquad (3)$$

Assuming that the error terms e_i and ε_i are bivariate normal with zero mean, variances $\sigma_\varepsilon^2=1$ and σ_e^2 and correlation coefficient $\rho_{\varepsilon e}$, we estimate the system of equations (2) and (3) as a generalised Tobit model by maximum likelihood.

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[7] The problem of selectivity is due to fact that in each time, only a handful of firms report positive investment in R&D. Deleting firms with zero activity will bias the sample.

[8] Innovation indicators are noisy (in part because they are subjective measures) and need to be instrumented to correct for errors in variable measurement. Hence, non-observable factors that affect the probability of innovation may lead companies to invest more on innovation activities. Likewise, there are unobservable factors that explain productivity that may also affect the choice of inputs (which implies correlation between the error in the productivity equation and explanatory variables).

The next equation in the model is the knowledge or innovation production function:

$$TI_i = IE_i^* \gamma + x_i' \delta + u_i \qquad (4)$$

where TI_i is knowledge outputs by technological innovation (introduction of a new product or process at the firm level), and where the latent innovation effort, IE_i^*, enters as explanatory variable, x_i is a vector of other determinants of knowledge production, and (γ, δ) are vectors of parameters of interest, and u_i an error term. The last equation relates innovation to total factor productivity. Firms produce output using constant returns to scale Cobb-Douglas technology with labour, capital, and knowledge inputs as follows,

$$y_i = \pi_i \, k_i + \pi_2 TI_i \;\; + v_i \qquad (5)$$

where output y_i is labour productivity (log of sales per worker), k_i is the log of physical capital per worker (proxied by physical investment per worker), and TI_i enters as explanatory variable and refers to the impact of technological innovation on productivity levels.[9]

In all equations we control for unobserved industry characteristics by including a full set of two digit ISIC code dummies. We control for idiosyncratic characteristics of each national innovation system by including a full set of country dummies. We also control for firm size in all equations but the R&D investment equation (equation 2), R&D investment intensity being already implicitly scaled for size. As this recursive model does not allow for feedback effects between equations, we implement a three-step estimation routine. First, we estimate the generalised Tobit model (equations 2 and 3). In a second step, we estimate the innovation function as a probit equation using the predicted value of (log) innovation expenditure as the main explanatory variable instead of reported innovation efforts, so correcting for potential endogeneity in knowledge production equation. In the last step, we estimate the productivity equation using the predicted values from the second step to take care of the endogeneity of TI_i in equation 5).

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[9] It is worth mention that the relative significance of product and process innovation on total factor productivity is debatable, especially when sales per worker is used as a proxy. To the extent that product innovation may imply superior quality in production systems and more inputs, we may not see any change in productivity levels. In contrast, we would expect process innovation to affect directly the average cost of production and indirectly impacting output and profit margins. For France, Mairesse *et al.,* (2006) find that process innovation yields higher returns than product innovation, using total factor productivity as dependent variable. Yet, this is not always the case in other countries (e.g. Griffith *et al.,* (2006) for Germany, Spain and the UK; for Ireland see Roper *et al.,* (2008).

As in other studies using innovation survey data, our estimation of the CDM model suffers from several measurement shortcomings. First, both Griliches (1979) and Crepon *et al* (1998), use patent data as indicators of technological innovation, however patent information is almost irrelevant in developing countries where just a very small set of firms actually innovate at the frontier level. Instead, we use a self-reported innovation output variable, which is qualitative information and much noisier than patent statistics. It is frequently argued that this type of innovation measurement is very subjective as firms are asked to declare whether they innovated or not (introduced a product or a process) and what one firm considers as an innovation may not necessarily coincide with other firms. And second, the original knowledge production models relate knowledge production to "knowledge capital", that is, the stock of R&D (or innovation investment). As we have cross-sectional information we can only use the investment in knowledge in the previous year(s), inducing a measurement error in the knowledge capital.[10] These are typical limitations though when analysing R&D or innovation activities with innovation survey data and many previous studies share these restrictions.

Consistently with the developed countries evidence we also used R&D as the main dependent variable in equations (2) and (3). This decision is mostly data driven. According to Crespi and Zuñiga (2012) a better dependent variable could have been total innovation investment, which includes also training and investment in know-how and technology transfer. Unfortunately, the data is not enough detailed as to produce information on these additional sources of investment in innovation. However, having R&D as main dependent variable has the strength that internal R&D efforts preserve a privileged role as part of the mechanism that leads to the creation, adaptation and absorption of new ideas and technological applications (Griffith *et al*, 2004) and enables a better identification, assimilation, adaptation and exploitation of external know how (Cohen and Levinthal, 1989, 1990) augmenting the impact of innovation on productivity. From a policy perspective, R&D consists of an intangible investment and as such, the most likely to be affected by market failures such as externalities or coordination failures.

[10] For further discussion on the use of innovation surveys for economic analysis of innovation see Hall (2006) and Mairesse and Monhen (2010).

In line with previous studies we not only use as a dependent variable technological innovation but also estimate separated versions of equation 4, for each type of innovation output (product to process). This would allow us to explore whether there are different returns for each different class of innovation investment. Lastly, in line with Griffith *et al* (2006) and Crespi and Zuñiga (2012), we estimate the CDM model not only for innovative firms but for all firms. Accordingly, we estimate steps *i)* and *ii)* based on reported innovation investment activities. Then, we use the relationship found between observable characteristics and innovation spending to predict the likeliness to invest for all firms, to proxy innovation effort in the knowledge production function. In turn, equation 3 (technological innovation) and 4 (productivity), are estimated for all firms. We include in the latter the predicted value of technological innovation. The reason to use this estimation strategy is twofold. First, the survey does not have a filter and most of the questions are asked to all firms. Second, the model assumes that all firms exert some kind of innovative effort, but not all firms report this activity. The output of these efforts produce knowledge and we can have then an estimate of innovation efforts for all firms.[11] Of course, this strategy is debatable as this approach assumes that the process describing innovation efforts and innovation output for firms that do not report innovation activities is the same as for reporting firms. Given that we are using estimated independent variables we need to correct for the standard errors in equations (3) and (4). This is done by bootstrapping.

4) Dataset and Empirical Implementation

This paper makes use of the Enterprise Survey, a firm-level survey of a representative sample of an economy's private sector. The World Bank has been conducting these surveys since 2000 for key manufacturing and service sectors in every region of the world. In each country, businesses in the cities/regions of major economic activities are interviewed. ES is aimed to formal (registered) companies with 5 or more employees, however firms with 100% government ownership are not considered. The sampling methodology for ES is stratified random sampling, where firm size, business sector, and geographic region within a country are used as strata. Typically 1200-1800 interviews are conducted in larger economies, 360 interviews are conducted in medium-sized economies and for smaller economies, 150 interviews are conducted.

[11] As explained by Griffith *et al* (2006), workers in firms engage in innovation related tasks not officially recorded as innovation activity (below a certain threshold activities are not recorded) to improve efficiency in production systems or to develop new products.

The data we are using corresponds to the innovation module of the 2010 ES. This module excludes the service sector; as a result, the analysis only covers manufacturing firms and we focus on the 17 Latin American countries.[12] The surveys are include, in addition to descriptive and performance variables, data on a range of innovation activities, such as the development of technological products, processes, and non-technological innovation (such as managerial, organisation, and marketing practices). Firms are considered innovators if they have introduced either a product innovation or a process innovation in the previous three years. These innovations could be either new to the firm or to the market.

Following Mohnen et al. (2006), we eliminate all firms with sales growth over 250% and lower than -60% in the period 2007-2009, and also firms that report a ratio of R&D spending over sales higher than 50%. To maintain consistency with the sample design of the survey, we drop firms that report less than 5 employees, and we only consider sectors in countries that have at least 5 firms surveyed. After applying the data cleaning procedure, we made sure that we have enough observations by country, setting a threshold of at least 50 observations (a third of the minimum sample size) each.

Table 1 summarises the main dependent variables definitions and it also introduces the main control variables. Overall, 70% of the firms in our dataset are innovators, and product innovators are more pervasive than process innovators (57% vs. 50%). However, successful product innovations are quite limited as they represent only 14% of total sales of the company. On the other hand 26% of the firms report having filed for an IPR application. This is significantly less than the percentage of firms that have innovated. If an IPR application is a signal of novelty, then more than a half of the innovators either do not protect their innovations or they mostly use and adopt already protected technology. With regards to innovation efforts, the R&D investment by a typical Latin American firm is about US$386 per employee.[13] This small amount of investment would only allow the hiring of a few engineers for a short period of time. Something that is consistent with the adaptive nature of R&D, rather than with activities of a high level of novelty.

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[12] We do not include Brazil in the analysis, because innovation variables are not available for this group of firms.
[13] Only 43% of the firms report some investment in R&D.

With regards to the main determinants of innovation, they have been grouped in four groups: internal capabilities, access to external knowledge, demand pull and access to finance. With regards to the internal capabilities the most obvious one is firm age which is supposed to capture tacit knowledge accumulated at the firm level through process such as learning-by-doing (Arrow, 1962). The average firm in the sample is almost 30 years old. The second variable related to capabilities is human capital, which captures the degree of cognitive skills needed to absorb new knowledge and to develop new technologies (Acemoglu et al., 2006). Whether the company is part of an economic group or subsidiary of a multinational corporation is also an indicator of internal capabilities. In principle, the economic superiority of multinational firms can be associated with more sophisticated knowledge assets (Girma, and Gorg, 2007) and easier access to human capital (Kumar and Agarwal, 2005).

Sales diversification is also an indicator of the scope of the productive capabilities of the firm. It gives some idea about to what extent the knowledge base of the firm is specialised in narrowly defined sectors or it can be used in different sectors. It is expected that a diversified knowledge base would allow the firm to jump more easily to other sectors so improving the expected returns of its R&D investments. The final two indicators of internal capabilities are manager experience and previous knowledge stock. Managerial experience is approximated by the year of experience of the manager in the same sector. Previous research (Barker et al, 2002; Balsmeier and Czarnitzki, 2014; Galasso and Simcoe, 2011), identifies a robust positive relationship between industry-specific experience of the top-manager and the decision to innovate as well as the share of new-product related sales. These effects are particularly pronounced for small firms in countries with relatively weaker institutions. Results suggest that managerial experience affects firm innovations predominately indirectly, for example, by reducing uncertainty about future returns on innovations (Balsmeier and Czarnitzki, 2014).

Table 1. Main Variables used in the analysis

Variable	Definition	Obs.	Mean	Min.	Max.
Innovation					
Innovation	(0/1) if firm introduced a product or process innovation	4376	0.70	0	1
Product Innovation	(0/1) if firm introduced a product innovation	4376	0.57	0	1
Process Innovation	(0/1) if firm introduced a process innovation	4376	0.50	0	1
Innovative sales	(%) Sales of innovated products on total sales	4376	14.22	0	100
IPRs	(0/1) if firm has filed for a IPR application	4376	0.26	0	1
Performance					
Labour Productivity	(US$ of 2009) Sales per worker	4376	166373	151	437,000,000
R&D per worker	(US$ of 2009) R&D expenditures per worker	4376	386	0	40,700
R&D Dummy	(0/1) if firm has invested in R&D	4376	0.43	0	1
Fixed Investment	(US$ of 2009) Fixed investment per worker	4376	2,510	0	780,556
Employment	(headcount) Full time employment	4376	158	5	21955
Capabilities					
Age	(years) Firm's age	4376	28.73	2	183
Human Capital	(%) Workers with bachelor degree on total workers	4376	0.14	0	1
Group	(0/1) if firm is part of a large group	4376	0.16	0	1
FDI	(0/1) if firm has 10% or more of foreign ownership	4376	0.12	0	1
Diversification	(%) Diversification Index (100 - % of sales of main product)	4376	32.77	0	99
Manager Experience	(years) Experience of the manager in the sector of the firm	4376	24.63	1	70
Knowledge Stock	(0/1) if firm has any patents abroad	4376	0.11	0	1
External Knowledge					
Cooperation	(%) firms that cooperate for innovation activities in same sector and country	4376	0.20	0	0.55
Large City	(0/1) if firm is located in a city with more than 1 million population	4376	0.76	0	1
Licenses	(0/1) if firm use technology licensed from a foreign owned company	4376	0.15	0	1
Internet	(0/1) if firm has broadband access	4376	0.90	0	1
Demand Pull					
Competitors 1	(0/1) if firm face 0 competitors in main market	4376	0.03	0	1
Competitors 2	(0/1) if firm face 1 competitor in main market	4376	0.03	0	1
Competitors 3	(0/1) if firm face between 2 to 5competitors in main market	4376	0.32	0	1
Competitors 4	(0/1) if firm face more than 5 competitors in main market	4376	0.62	0	1
International market	(%) firms which main market for main product is international in same sector and country	4376	0.09	0	0.60
Financing					
Public Support	(%) firms that receive public support for innovation activities in same sector and country	4376	0.12	0	0.50

With regard to knowledge stock, we use a variable measuring if the firm has any patents abroad as an indicator of two things, both of them positively correlated with innovation efforts: (a) the capacity of the firm to manage intellectual property in order to protect innovation investments results and (b) a measurement of the degree of novelty of their innovations. Although potentially interesting, unfortunately, we do not have enough information to untangle these two effects. We make the assumption that having these patents is exogenous to the decision and level of investment in innovation. As the process of examination is quite long in patent offices (it usually takes around two years in average) patents that are granted in the period of inquiry in surveys probably concern inventions that occurred much earlier in time (at least two years before the date surveyed for knowledge investment in questionnaires).

Access to external knowledge is normally an important determinant of innovation decisions. We explore this issue by using several variables. First, we used an indicator firms are collaborating with others in innovation activities. In principle, collaboration has ambiguous effects on innovation investment. Indeed, by allowing firms to share costs and internalise spillovers, collaboration enhances productivity of internal innovation activities which stimulates further innovation investment (Kamien, *et al.*, 1992). On the other hand, collaboration might allow for the pooling of research resources, increasing the access to effective R&D (internal plus external), while perhaps saving costs on internal innovation activities (Klenow *et al.*, 1996). In order to deal with a potential endogeneity problem, instead of collaboration activities reported by the firm, we use the average of firms, in the same sector, in the same country, collaborating with other organisations pursuing innovation activities. The second variable measures whether the firm is located in a large city. Previous research has pointed out to the importance of agglomeration economies as key determinants of innovation investments. Agglomeration allows the firm to get access to a pool of specialised resources (mostly human capital) and service providers (Moretti, 2004). Also knowledge spillovers are normally geographically bounded due to the limits of tacit knowledge (Jaffe, Trajtenberg and Henderson, 1993). So, in principle agglomeration economies increase the expected returns to R&D and so innovation related investments. Third, the acquisition of technology through licenses is a potentially important means of accelerating productivity growth, especially in ‘‘late starter’’ developing countries in the throes of ‘‘catch-up.’’ Yet the literature has tended to focus on the potential benefits to the seller, overlooking those to the purchaser. Alvarez, Crespi and Ramos (2002), find that expenditures on licensing showed exceptionally high rates of return, on the order of twice those for investment in physical capital. This investment significantly improved firms' performance and productivity in Chilean industry during the 1990s. So, we expect that licensing could be a powerful complementary asset to endogenously generated knowledge, in particular when talking about catching-up economies. Fourth, the ICT revolution has allowed for an exponential growth in the volume and circulation of information. Indeed, given that ICTs allow for a substantial decrease in the costs of information storage and transmission, their diffusion across the economy reduces the uncertainty and costs associated with economic interactions. This, in turn, leads to an increase in the volume of transactions, generating higher levels of production for the same set of inputs. In other words, ICTs become a trigger for higher productivity (Chen and Dahlman, 2005). Furthermore, ICTs increase organisational capabilities to codify knowledge that otherwise would have remained tacit, accelerating learning processes and productivity growth (Foray, 2007), so increasing the returns to innovation investment.[14]

Innovation investments are not only the results of internal capabilities or the access to external knowledge. Innovation investments are also the results of incentives that firms. One long-standing issue concerning innovation is on the relationship between innovation and competition. It has been argued that innovation is at odds with competition because the need to generate innovation rents to reward the innovators normally implies accepting some sort of market distortion (for example, through the granting of intellectual property rights) as the price to pay to get more innovation. Recent research on this subject has re-evaluated this view, finding that the relationship between these two variables is more complex than previously thought. Aghion and others (2010) argue that the firm decision to invest in innovation will depend on the degree of competition among firms: the more competitive the sector is, the more these firms will be encouraged to innovate in order to *escape competition*. In other words, competition is a key trigger for this demand. As a measurement of competition faced by the firm, we use a self-reported categorical variable indicating the number of competitors in the main market of the

[14] In this respect, this paper considers broadband connectivity as a factor behind the decision to invest and the likelihood of obtaining innovation outputs from which productivity effects might be derived.

main product.[15] An additional key component of the demand pull is the exposure to international markets. Regarding to exports, the "competition" and "learning" effects from exporting are expected to enhance innovation efforts by firms, notably when local firms have certain level of technological skills. Braga and Willmore (1991) and Alvarez (2001), respectively, report for Brazilian and Chilean firms that exporting firms invest more in innovation (R&D in their case). In this case rather than specific firm exposure we use the average exposure of the sector and country.[16]

A key variable is the extent to which the firm has access to public support programs for innovation. Public financial support has been frequently found to be a booster of R&D investment. Most studies conclude that government R&D support leads to additional private R&D, innovation expenditures or innovation outputs and not to crowding-out of private R&D by public financial support (Mairesse and Monhen, 2010, Hall and Maffioli, 2008). For Latin American firms, public support for R&D investment is essential (Navarro *et al,* 2010; Anlló and Suarez, 2009). Constraints in securing financing for innovation (high costs of innovation and risks) and the inability by firms to wait for long periods of time (rates of return) are among the most important obstacles for innovation perceived by firms in LAC. Although we do not aim to do a full impact evaluation of public funding, we think that this is an important control variable that captures the costs of financing and as such it should be included in the analysis[17]. Again as before in order to somehow get rid of the problem of reverse causality regarding this variable, we use the proportion of firms that claim getting support from government in sector and country as the explanatory variable rather than if a particular firm has access as well. We think that this average captures better the generosity of the public support system, which is likely to be more exogenous than the alternative of using a dummy variable for whether the firm has used a particular innovation instrument.

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[15] This variable presented a relatively high number of missing data across countries. In order to not decrease the number of observations in the sample, we imputed missing values with the median of the competitors reported by the firms with the same main market, in the same sector and country.

[16] Before calculating sector-country averages, for firms that didn't report their main market in the survey, we assumed that they were focused in local/national markets if they reported exports equals to zero.

[17] To properly correct for this selection and evaluate the impact of public support, we would need to model the determinants of public support, or, as it is mostly done, by comparing the difference in innovation performance between matched pairs of supported and non supported firms (give each treated firm a contra-factual).

Finally, in all our regressions we control for the *size* of the firm as this constitutes a proven significant determinant of innovation-related activities. The claimed advantages of large-size firms are numerous: a larger spread of R&D fixed costs over greater output (e.g. Cohen and Levin, 1989), economies of scope relating to R&D production and R&D diversification as well as a better appropriation of external knowledge spillovers.[18] However here is important to differentiate between the effects of size of the decision to invest from the impacts of size of investment expenditures. The inherited empirical evidence suggests that there is a positive and rather proportional relationship between R&D investment and size of the firm. That is, large firms invest more in R&D in level but not proportionally more, once the decision to invest has been taken (Cohen and Klepper, 2006). Based on this finding, we make the following identification assumption for the generalised Tobit: the size of the firm affect the decision to invest in innovation, but it does not affect the intensity of that investment when the decision to invest has been taken. For Latin American firms, a positive association between size and propensity to invest has been systematically reported for most of the countries (e.g. Benavente, 2006; Crespi and Peirano, 2007, Crespi and Zuñiga, 2012). Yet, the results regarding the innovation intensity equation, mostly done with R&D intensity, point out that those larger firms are not necessarily the ones who invest the most (for Colombia see Alvarado, 2000; and for Brazil, De Negri *et al*, 2007), so we are confident with our identification assumption. Furthermore, this is the same identification assumption maintained by many of the previous empirical implementations of the CDM model reviewed above. In summary, we assume that the decision to invest depends on the size of the firm, measured by the (log) employment but that this variable does not affect the intensity of innovation investments.

5) The results

5.1) The decision to invest in innovation and the intensity of innovation expenditure

Table 2 summarises the findings regarding R&D investment. In general the decision to invest in R&D is strongly correlated with the size of the firm. Larger firms are more likely to invest in R&D. On top of this several variables related to firm capabilities are positively influencing this

[18] Yet is also argued that small firms have more flexibility and adaptability (and less complex organizational structures) which favor innovation and the development of new projects (e.g. Acs and Audretsch, 1988).

decision: the firm level of knowledge stock, human capital and diversification. Age, on the other hand is negatively correlated with firm decision to invest in R&D, suggesting that new firms rather than old firms are more likely to invest. With regards to the access to external knowledge, this seems to be very relevant as the acquisition of licenses and broadband access are very positively related with the decision to invest. Differently, firms that operate in sectors with higher levels of cooperation for innovation do not show a higher propensity to invest in R&D. Neither the intensity of the competition faced by the firm or the degree of exposure to international markets of the sector where the firm operates, are relevant for the decision to invest. On other hand, firms in sectors that have relatively greater public support for innovation are more likely to engage in R&D activities.

With regards to the determinants of the intensity of this investment, we found that again firm internal capabilities are very relevant, and in particular the presence of qualified workers and previous knowledge stock. With regards to the access to external knowledge, licensing and connectivity are important and positive determinants of R&D investment, although this does not seem to be the case for cooperation, suggesting that the ambiguity of the effect noted above it is also present in Latin American firms. Competition and international markets exposure remains not significant. Finally, firms in a sector and country with generous public support system for innovation positive influence the intensity of R&D expenditures.

Being in a large city and being a foreign controlled firm produce two unexpected results. Absence of significance for city size suggests that there are no relevant agglomeration economies. FDI presents negative sign with respect to the decision to invest in R&D as with regards its size, but only significant on the decision to invest. These results, as in Crespi and Zuñiga (2012), confirm that the FDI that the region has managed to attract does not develop technology locally. One plausible interpretation of this result is that, generally speaking, in technologically lagging countries multinational firms rarely invest in local R&D units if the market size is not sufficiently large to justify fixed costs for R&D, or if there is not a specific national academic attractiveness (Raffo *et al,* 2008).[19] It could also be the case that multinational firms do not invest in innovation in LAC at all given that their activity is more focused on the

[19] A recent exemption are China, India and some South East Asian countries where technology hotspots are emerging and increasingly attracting R&D investment and new labs by foreign firms.

exploitation of comparative advantages in terms of, for instance, access to natural resources, distribution costs or labour savings, and use technological assets from headquarters (Navarro *et al*, 2010). If they conduct some kind of technological activities, these are frequently focused on adaptation and tailoring products to local markets (with low needs for R&D investment).

Table 2. The determinants of R&D investment

	R&D per Worker	Decision to Invest
Age	-0.0034	-0.0049***
	(0.0017)	(0.0011)
Human Capital	1.7087***	0.5291***
	(0.2078)	(0.1239)
Group	0.0595	-0.0145
	(0.0945)	(0.0585)
FDI	-0.1336	-0.3300***
	(0.1134)	(0.0707)
Diversification	-0.0002	0.0026***
	(0.0013)	(0.0008)
Manager Experience	-0.0008	0.0014
	(0.0029)	(0.0017)
Knowledge Stock	0.3960***	0.1984***
	(0.1077)	(0.0685)
Cooperation	-0.1231	0.0187
	(0.4864)	(0.2955)
Large City	0.1253	-0.0674
	(0.0964)	(0.0533)
License	0.2385***	0.1832***
	(0.0914)	(0.0589)
Broadband	0.4003***	0.4952***
	(0.1561)	(0.0783)
Competitor 2	0.3323	0.0251
	(0.3012)	(0.1685)
Competitors 3	-0.0013	0.0226
	(0.2333)	(0.1246)
Competitors 4	-0.1134	-0.0755
	(0.2296)	(0.1225)
International Markets	-0.1231	-0.0201
	(0.4864)	(0.3007)
Public Support	1.7068***	1.4029***
	(0.7340)	(0.4257)
Employment		0.2121***
		(0.0157)
N	4376	
ll	-5797.2963	
chi2	556.1525	
p	0.0000	
rho	0.7530	
chi2_c	149.7066	

Notes: Coefficients reported are marginal effects, i.e. they predict the likelihood of introducing product or process innovation. Standard errors in parentheses. * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

5.2) From innovation effort to innovation outputs

We next consider the estimates of the knowledge production functions (equation 4) in Table 3, where the reported coefficients are marginal effects. Five different outputs are considered: innovation (product or process), product innovation, process innovation, innovative sales, filing for IPRs, and product innovation new to the market. The results for innovation suggest that there is a positive and significant correlation between R&D investment and the firm likelihood to innovate. Indeed, a 10% increase in R&D spending translates into 1.7% increase in the probability to innovate. According to the results reported in this table, this is mostly due to the impacts of R&D spending on product rather than process innovation. Furthermore, R&D spending increases the likelihood that a firm applies for IPR's, and it has a positive impact on innovative sales (an increase of 10% on R&D spending translates into an increase of 1.3% on innovative sales).

With regards to the remaining control variables, some firm internal capabilities are important determinants of innovation outputs beyond their influence through R&D. Indeed, highly diversified firms are more likely to introduce any type of innovation. However, and quite surprisingly, human capital is negatively correlated with the capability of the firms to innovate, mainly driven by the effect in product innovation. This may be capturing that the type of product innovation that the majority of LAC firms develops is less complex, without necessarily requiring highly skilled workforce. In the same line, the stock of knowledge of the firm is not significantly correlated with product innovation (and only slightly with process innovation), but it has a strong effect on the likeliness of the firm of applying for IPRs protection.

Being part of a group correlates positively with the probability of introducing a product innovation. On the other hand, multinationals are less likely to introduce innovations, particularly in process innovation and IPRs. This result could be capturing the sector orientation of most of the subsidiaries in the region, which tend to operate in non-innovation driven sectors.

External knowledge is also an important determinant of innovation results. In particular, licensing is an important channel to acquire technological knowledge for product and process innovations, but this effect is not significant for new IPRs applications. On the other hand, band is a significant variable for product innovation and the share of sales coming from innovative products. Size of the firm and level of fixed investments, as expected, are important factors conditioning innovation results and for all classes of innovation, particularly for the introduction of IPRs, in the case of size, and process innovation, in the case of fixed investments.

Table 3. The determinants of Innovation Outputs

	(1) Innovation	(2) Product	(3) Process	(4) Innov. Sales	(5) IPRs
R&D per Worker	0.1677***	0.1481***	0.1029	0.1579***	0.1305**
	(0.0625)	(0.0676)	(0.0673)	(0.0477)	(0.0567)
Age	-0.0000	0.0001	-0.0003	-0.0005	0.0013***
	(0.0004)	(0.0005)	(0.0005)	(0.0003)	(0.0004)
Human Capital	-0.1958*	-0.2068*	-0.0758	-0.2709***	-0.1255
	(0.1170)	(0.1255)	(0.1246)	(0.0880)	(0.1048)
Group	0.0206	0.0543**	0.0091	0.0192	-0.0174
	(0.0214)	(0.0231)	(0.0237)	(0.0150)	(0.0191)
FDI	-0.0441	-0.0141	-0.0919***	-0.0186	-0.0967***
	(0.0280)	(0.0291)	(0.0283)	(0.0178)	(0.0193)
Diversification	0.0021***	0.0031***	0.0006**	0.0009***	0.0006**
	(0.0003)	(0.0003)	(0.0003)	(0.0002)	(0.0003)
Manager Experience	-0.0003	0.0001	-0.0000	0.0007	-0.0010*
	(0.0006)	(0.0007)	(0.0007)	(0.0005)	(0.0006)
Knowledge Stock	0.0471	0.0128	0.0663*	-0.0164	0.2395***
	(0.0335)	(0.0384)	(0.0372)	(0.0250)	(0.0388)
Cooperation	0.0939	0.0750	0.1179	-0.0263	0.1420
	(0.0992)	(0.1085)	(0.1080)	(0.0757)	(0.0934)
Large City	-0.0042	-0.0080	-0.0135	-0.0142	-0.0047
	(0.0203)	(0.0223)	(0.0225)	(0.0159)	(0.0197)
License	0.0613***	0.0667***	0.0496**	0.0318	0.0258
	(0.0251)	(0.0280)	(0.0281)	(0.0196)	(0.0243)
Broadband	0.0362	0.0964**	0.0351	0.0631**	0.0369
	(0.0359)	(0.0394)	(0.0385)	(0.0302)	(0.0325)
Fixed Investment	0.0174***	0.0156***	0.0244***	0.0107***	0.0120***
	(0.0021)	(0.0023)	(0.0023)	(0.0016)	(0.0020)
Employment	0.0229***	0.0179***	0.0247***	-0.0022	0.0497***
	(0.0064)	(0.0070)	(0.0070)	(0.0048)	(0.0058)
N	4376	4376	4376	4376	4376
Ll	-2394.0886	-2718.2569	-2818.4319	-2197.7553	- 2116.7052
chi2	500.2333	488.6863	403.7300	.	653.9383
P	0.0000	0.0000	0.0000	0.0000	0.0000

Notes: Coefficients reported are marginal effects, i.e. they predict the likelihood of introducing product or process innovation. Standard errors in parentheses. * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

5.3) From innovation outputs to productivity

Given that firm capabilities, connectivity and innovation efforts have some result on innovation results, the next step is to explore the extent to which these changes translate into higher productivity levels. This is done by estimating equation (5), which is a traditional Cobb-Douglas production function augmented by predicted innovation results. The findings summarised in table 4 suggests that innovation has a strong impact on labour productivity, even when controlling for intermediate inputs, capital stock, employment and human capital. The coefficients reported in this table are elasticities or semi-elasticities, since the dependent variable is the log of sales per employee. Consistently with evidence for industrialised countries, our results confirm a positive impact of technological innovation on productivity. The coefficients are large, indeed. An innovative firm has a productivity 50% higher than a non-innovative firm (column 1). In column (2) innovation is split among product and process innovation. Productivity impacts of product innovation seem to be higher, and more significant, than process innovation (36% vs. 19%). These results remain when using innovative sales rather than the product innovation categorical dummy (column (3)). Finally, firms that managed to file for a patent application indeed had a strong productivity increase (35% as showed in column (4))

Table 4. The Impacts of Innovation on Productivity

	(1) Ln(Q/L)	(2) Ln(Q/L)	(3) Ln(Q/L)	(4) Ln(Q/L)
Materials	0.5025***	0.5028***	0.5028***	0.5070***
	(0.0180)	(0.0180)	(0.0181)	(0.0179)
Capital	0.0919***	0.0914***	0.0918***	0.0903***
	(0.0077)	(0.0077)	(0.0077)	(0.0077)
Human Capital	0.4821***	0.4915***	0.5170***	0.4957***
	(0.0574)	(0.0577)	(0.0591)	(0.0589)
Employment	0.0777***	0.0783***	0.0909***	0.0766***
	(0.0097)	(0.0097)	(0.0101)	(0.0107)
Manager Experience	-0.0003	-0.0005	-0.0007	-0.0004
	(0.0007)	(0.0007)	(0.0007)	(0.0007)
Innovation	0.5543***			
	(0.0916)			
Product Innovation		0.3635***		
		(0.1127)		
Process Innovation		0.1860	0.0636	
		(0.1282)	(0.1840)	
Innovative Sales			0.5225***	
			(0.2083)	
IPRs				0.3477***
				(0.0777)
New to market				
N	4376	4376	4376	4376
Ll	-3596.6234	-3596.8416	-3597.4046	-3596.9762

Notes: Coefficients reported are marginal effects, i.e. they predict the likelihood of introducing product or process innovation. Standard errors in parentheses. * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

5.4) From innovation spillovers to productivity

Although in general is very tricky to assess for the presence of spillovers in the context of cross sectional data only, it is worth a preliminary exploration. Since the seminal works by Nelson (1959) and Arrow (1962), knowledge has been regarded as a non-rival[20] and non-excludable[21] good. If knowledge does indeed have these properties, then a firm's rivals may be able to free-ride on its investments. These spillovers may create a wedge between private and social returns

[20] Once produced, new knowledge can be used simultaneously by many different firms because the new "blueprints" are not normally associated with physical constraints. This characteristic is an extreme form of decreasing marginal costs as the scale of use increases: although the costs of the first use of new knowledge may be large, in that it includes the costs of its generation, further use can be done at negligible small incremental costs (Aghion, David, and Foray, 2009).

[21] The non-excludable nature of knowledge refers to the difficulty and cost of trying to retain exclusive possession of it while, at the same time, putting it to use.

and a disincentive against private investment in knowledge production. However, spillovers are not automatic and should not be taken for granted in every circumstance, as not all knowledge enjoys the properties of a public good with the same intensity. Certainly, the “public good” rationale of knowledge applies more strongly to *generic* or *scientific* knowledge than *technological* knowledge, which is more applicable and specific to the firm.[22] Furthermore, in order for the public good rationale to be valid, there should be some possibility of free-riding. If the originator can protect the results of the knowledge generated (through entry barriers or the use of strategic mechanisms, for example), then the potential for market failure declines. On the other hand, knowledge generated through collaboration among different parties might be more difficult to protect and therefore more prone to spillovers than knowledge generated by individual entities. So in principle not all types of innovation could lead to the same degree of spillovers and hence be the focus of innovation policy with the same degree of intensity.

In order to explore for this issue we will assume that a firm will benefit from spillovers if its productivity increase as a result of the innovations introduced by the other firms. In this extent we computed the innovation by the other firms as the average of the innovation propensities at sector and country levels (in other words we are assuming that spillovers when occur are mostly the results of within sector and country knowledge flows). In summary, the standard Cobb-Douglas production function is expanded to include these sector level indicators of innovation intensity. The results are summarised in Table 5. In general, within the limitations of the dataset, it is possible to say that there are spillovers of technological innovation, and these are more related to product than process innovation. Indeed, when looking at column (2) the coefficient of sector product innovation is positive and strongly significant, while is negative and far from significant for sector process innovation. The findings remain when using IPRs as proxy for innovation (column (4)). However, when using sector innovative sales as measure of product innovation the positive correlation remains but is not significant (column (3)).

[22] Technological knowledge is also more likely to be protected by intellectual property rights (IPRs). IPRs provide innovating firms the right to temporarily exclude others from using a new idea commercially so the originators can appropriate the rents of their investments in innovation. In exchange for this, the owner must disclose the invention so anyone can improve upon it. However, IPRs can also generate unintended consequences, as they cause a static market distortion in the form of monopoly power and slower technology diffusion for producers that must pay a higher cost to transfer protected technology. In other words, IPRs also create market distortions that might or might not be compensated by the increased incentives to innovate (De Ferranti et al., 2003).

Table 5. The Impacts of Innovation on Productivity: The search for spillovers

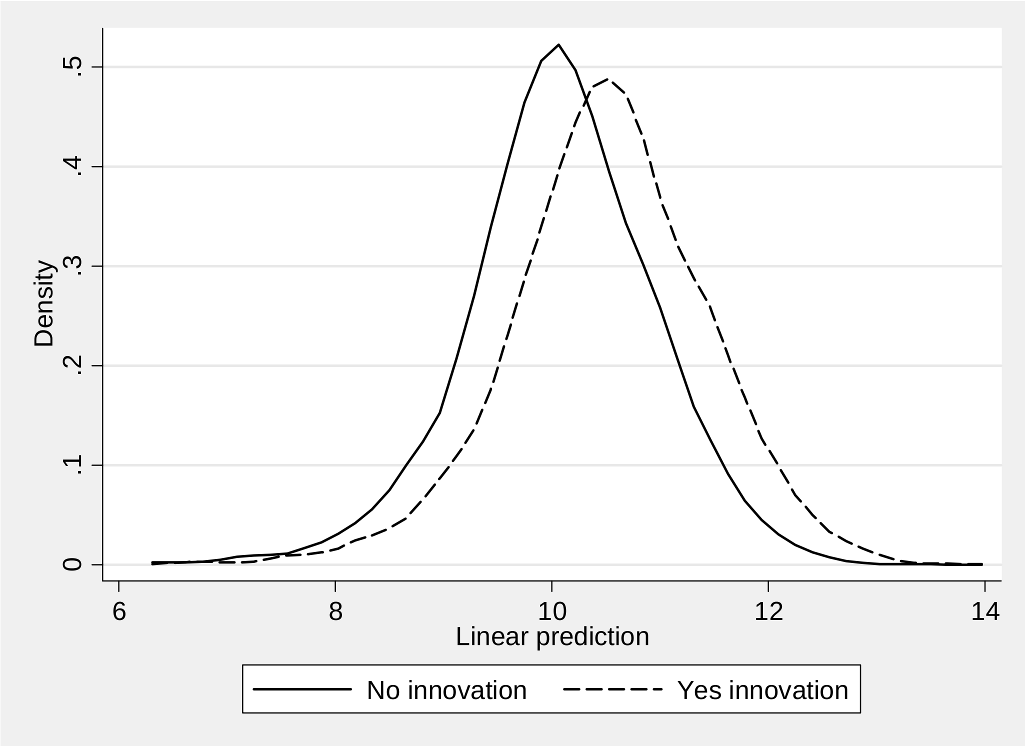
	(1) Ln(Q/L)	(2) Ln(Q/L)	(3) Ln(Q/L)	(4) Ln(Q/L)
Material	0.5020***	0.5021***	0.5026***	0.5067***
	(0.0180)	(0.0180)	(0.0181)	(0.0179)
Capital	0.0922***	0.0916***	0.0920***	0.0902***
	(0.0077)	(0.0077)	(0.0077)	(0.0077)
Human Capital	0.4874***	0.4927***	0.5205***	0.4977***
	(0.0575)	(0.0576)	(0.0591)	(0.0590)
Employment	0.0781***	0.0785***	0.0912***	0.0767***
	(0.0097)	(0.0097)	(0.0101)	(0.0107)
Manager Experience	-0.0003	-0.0005	-0.0007	-0.0004
	(0.0007)	(0.0007)	(0.0007)	(0.0007)
Innovation	0.4999***			
	(0.0916)			
Innovation Spillovers	0.9817***			
	(0.2660)			
Product Innovation		0.3242***		
		(0.1120)		
Product Spillovers		1.1456***		
		(0.4099)		
Process Innovation		0.1854	0.0389	
		(0.1293)	(0.1889)	
Process Spillovers		-0.2052	0.4450	
		(0.3512)	(0.3468)	
Innovative Sales			0.5099***	
			(0.2141)	
Spillovers Sales			0.1687	
			(0.5001)	
IPRs				0.3269***
				(0.0782)
Spillovers IPRs				0.5050**
				(0.2533)
N	4376	4376	4376	4376
Ll	-3589.6525	-3590.1052	-3595.0157	-3605.6452
chi2				
P	0.0000	0.0000	0.0000	0.0000

Notes: Coefficients reported are marginal effects, i.e. they predict the likelihood of introducing product or process innovation. Standard errors in parentheses. * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

5.5) *Not all are the same: exploring the heterogeneous impacts of innovation*

To some extent all the previous results refer to the typical or representative LAC firm, which is somehow at odds with the tremendous heterogeneity that exists in the region in terms of productivity (IDB, 2010). One way of assessing whether these impacts are heterogeneous is by simulating the productivity distribution in two scenarios: with and without innovation. This exercise is summarised in the Figure I, where two results can be inferred. First, the whole distribution of productivity is shifted to the right when innovation occurs, which is consistent with the presence of a positive average impact. Second, the spread of the distribution is higher in the presence of innovation suggesting that the productivity impacts of innovation are not uniform across firms but that they vary according to where the firm is located in the productivity distribution.

Figure I: The heterogeneous impacts of innovation of productivity



In order to further explore this issue, a regression quartile approach was used to estimate the impacts of innovation of productivity according to the productivity levels of the firm. The results of this exercise can be explored in table 6. In general it is observed that the returns to innovation indeed depend on the position of the firm in the productivity distribution. For companies at the bottom of the distribution private returns are not higher than 35%, however these returns increase to more than 65% for companies at the top of the distribution. It is also worth noting that private returns to innovation are not that different between the first three quartiles of the productivity distribution (between 30% and 40%). The big leap is observed between this group and the top 10% of firms. Interestingly the gap between the bottom and the top of the distribution is also observed in the human capital premium. In fact while this premium is 17% for companies at the bottom end of the distribution, it grows to almost the 77% for companies at the top.

Although these results require further exploration, the same one could have important consequences for policy design. For example, if low productivity is due to firms that cannot innovate due to financial constraints, one should observe that returns at bottom of the distribution should be higher than the returns at the top of the distribution. However, given the fact that the opposite is true (i.e., firms at the bottom of the distribution face lower private returns to innovation than firms at the top), suggests that there are constraints that affect the real side of the firm either because the lack of complementary assets (which lead to low both private and social returns) or the lack of appropriability (which lead to low private but not necessarily social return). Untangling which of these two situations dominates is important because if it is the lack opportunities it does not seem reasonable focusing innovation policy on low productivity firms, if – on the other hand – this is due to appropriability conditions it does. Identifying which constraints dominate is the focus of a future research agenda.

Table 6. The heterogeneous impacts of innovation

	(1) Q10	(2) Q25	(3) Q50	(4) Q75	(5) Q90
Innovation	0.3328*** (0.0724)	0.2980*** (0.0546)	0.3005*** (0.0559)	0.3845*** (0.0964)	0.6559*** (0.1981)
Materials	0.7445*** (0.0106)	0.7010*** (0.0076)	0.6429*** (0.0087)	0.5415*** (0.0129)	0.4229*** (0.0169)
Capital	0.0562*** (0.0053)	0.0631*** (0.0045)	0.0667*** (0.0049)	0.0804*** (0.0075)	0.1020*** (0.0114)
Human Capital	0.1708*** (0.0445)	0.2500*** (0.0399)	0.3970*** (0.0494)	0.6177*** (0.0740)	0.7661*** (0.1107)
Employment	0.0305*** (0.0062)	0.0400*** (0.0042)	0.0436*** (0.0061)	0.0535*** (0.0087)	0.0768*** (0.0184)
Manager Experience	0.0003 (0.0006)	0.0004 (0.0004)	-0.0001 (0.0005)	-0.0011 (0.0008)	-0.0027* (0.0015)
N	4376	4376	4376	4376	4376

Notes: Coefficients reported are marginal effects, i.e. they predict the likelihood of introducing product or process innovation. Standard errors in parentheses. * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

6) Conclusion

This paper has presented an econometric comparison using micro level data. We have investigated the drivers of technological innovation and how this one feeds into productivity at the regional level in Latin America. We estimated a common structural model that describes the relationships between knowledge investment, innovation outputs and productivity by firms.

We found strong evidence concerning the relationships between innovation input and output, and innovation output and productivity. In line with the literature, firms that invest in knowledge are more able to introduce new technological advances and those who innovate have superior labour productivity than the rest of firms. The consistency in these two results provides solid evidence for Latin American countries and we hope thereby to contribute to fill some of the gaps in the literature, and alleviate notably the inconclusiveness from previous studies.

Our findings have important repercussions. Firms who invest in knowledge combine internal capacities with innovations. However, internal capacities are not enough, requiring the absorption of technology from abroad. On the other hand, we found that the typical multinational firm operating in Latin America is both less prone to invest locally in R&D and also less likely to innovate. These results contradict previous positive effects found in Argentina, Panama and Uruguay (Crespi and Zuñiga, 2012) where some particular market conditions or policies to attract FDI could be driving those results. Here, public support for innovation is revealed as a key factor for facilitating investments in innovation by LAC manufacturing firms, different from Crespi and Zuñiga (2012) who showed no consistent positive impact of governmental support.

We also found that the private returns to innovation depend on the type of innovation, being larger for product than for process innovation. Furthermore, we found some evidence that spillovers are stronger in the case of product than process innovation suggesting that the wedge between private and social returns could be higher in the case of product innovation, something that could guide policy focus on these sorts of innovations. On the other hand it was also found that the returns to innovation are higher for the most productive firms. This increasing relationship between returns and productivity is not consistent with an interpretation that financial constraints cause more harm to low productivity firms. However, it is consistent with alternative interpretations about the lack of innovation opportunities in the case of low productivity firms or that low private returns are the results of poor appropriability, in which case there could still be some hope for policy intervention in these sorts of firms. These weaknesses seem common among firms at the first three quartiles of the productivity distribution. Clearly this is an important topic for further research.

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