Innovation and Productivity: Evidence from Six Latin American Countries

Gustavo Crespi, Pluvia Zuniga

Institutions: University of Chile, Organisation for Economic Co-operation and Development

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Crespi, Gustavo; Zuniga, Pluvia

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Gustavo Crespi
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Abstract[1]

This study examines the determinants of technological innovation and its impact on firm labor productivity across six Latin American countries (Argentina, Chile, Colombia, Costa Rica, Panama, and Uruguay) using micro data from innovation surveys. In line with the literature, in all countries firms that invest in knowledge are more able to introduce new technological advances, and those that innovate have greater labor productivity than those that do not. Yet firm-level determinants of innovation investment are much more heterogeneous than in OECD countries. Cooperation, foreign ownership, and exporting increase the propensity to invest in innovation activities and encourage innovation investment in only half of the countries studied. Scientific and market sources of information have little or no impact on firm innovation efforts, which illustrates the weak linkages that characterize national innovation systems in those countries. The results in terms of productivity, however, highlight the importance of innovation in enabling firms to improve economic performance and catch up.

JEL classifications: O12, O14, O31, O33, O40

Key words: Innovation, Productivity, Developing countries, Latin America, Innovation surveys

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1. Introduction

In order for developing countries to catch up—and reach per capita income levels similar to those of the richest economies—productivity is crucial. Improving productivity is the most important challenge for Latin American and Caribbean countries. As evidenced in recent studies (Daude and Fernández-Arias, 2010; IDB, 2010a; IDB, 2010b), low productivity growth is the root cause of the region's poor economic performance in the last four decades. Innovation is essential for increasing productivity.

The evidence shows that applying technological advances leads to a more effective use of productive resources, and the transformation of new ideas into new economic solutions (new products, processes, and services) is the basis of sustainable competitive advantages for firms. Furthermore, several cross-country studies demonstrate a virtuous circle in which R&D spending, innovation, productivity, and per capita income mutually reinforce each other and lead countries to long-term sustained growth rates (Hall and Jones, 1999; Rouvinen, 2002). At the firm level, there is convincing evidence for industrialized countries showing the positive links between R&D, innovation, and productivity (Griffith et al., 2004; Griffith et al., 2006; Mairesse and Monhen, 2010; OECD, 2009).

For Latin American firms, however, these relationships are not as well established. Some of the shortcomings are due to differences in survey and sampling methodologies.[2] From a theoretical standpoint, it has long been emphasized that, as in other developing countries, the roles of imitation and technology acquisition are more important than R&D and innovation as preconditions for learning and catching up (Katz, 1986; Bell and Pavitt, 1993). Accordingly, innovation becomes valuable as firms develop technological skills and internal knowledge capacity. Despite this, much of the previous research in the region has simply replicated the developed country agenda, focusing on R&D investments as the sole source of innovation and productivity growth. It is thus not surprising that the findings on the relationships between R&D and productivity are mixed.

This study intends to fill these gaps in the literature. Through the estimation of a compatible and harmonized economic model, this paper examines the determinants of

[2] In developed countries, particularly in the EU, comparative research in this area has greatly benefited from the methodological support of the OECD and the harmonization work of Eurostat, which led to the production of several versions of the so-called Community Innovation Survey (CIS).

technological innovation and its impact on firm labor productivity across six Latin American countries (Argentina, Chile, Colombia, Costa Rica, Panama, and Uruguay) using micro-data from innovation surveys. Following the seminal papers of Griliches and Pakes (1980) and Crepon, Duguet, and Mairesse (1998), we use a structural recursive model that formalizes: (i) the decision of firms to invest in innovation (rather than just R&D) and its determinants; (ii) the knowledge production function, or how much knowledge output is generated from innovation investment; and (iii) the output production function in which innovation, together with other inputs, is related to labor productivity. Our empirical model is similar to Griffith et al. (2006) and properly customized to the specificities of innovation surveys in Latin America. As differences in questionnaires are important, variables across surveys have been harmonized to come up with a valid common model denominator. We provide guidelines for this harmonization at the end of the paper for future studies.

Our study produced interesting results. In line with the literature, we found strong evidence of the importance of knowledge for innovation and a very strong association between innovation and productivity. In all countries, firms that invest in knowledge are more able to introduce new technological advances, and those that innovate have higher labor productivity than firms that do not innovate. Yet the determinants of investment in innovation activities in the Latin American countries studied are much more heterogeneous than in OECD countries. For example, cooperation, foreign ownership, and exporting increase the propensity to invest in innovation and encourage innovation investment in only half of the countries studied. Scientific and market sources of information have little or no impact on firm innovation efforts.

These results highlight the importance of innovation for firms to catch up as well as the difficulties facing firms that invest in innovation. In particular, our results show the weakness of firms' links with the national innovation system and their inability to integrate scientific and technological resources into their innovation strategies. Lastly, this study calls for further harmonization of methodologies and sampling and coverage, and highlights the urgent need for a LAC core questionnaire. Advance comparability and use of internationally comparable micro data are necessary steps to advance our understanding of innovation systems in Latin America and to facilitate policy design and evaluation.

The outline of the paper is as follows. Section 2 provides a brief overview of the literature on the productivity effects of R&D and more general innovative activities. Section 3 describes the model and data sets used for the empirical analysis and the variables employed. The econometric results are presented in Section 4. Section 5 concludes.

2. Literature Review

The analysis and measurement of the productivity effects of innovation activities has been one the most challenging and controversial tasks in empirical economics. Following the seminal work of Griliches (1979) and Griliches and Pakes (1980), a widely accepted approach is to model the relationship between innovation and its determinants in a knowledge production function and the contribution of innovation to productivity in an output production function. The knowledge production function approach (Griliches, 1979) assumes that the production of new knowledge depends on current and past investment in new knowledge (e.g., current and past R&D expenditures) and on other factors such as knowledge flows from outside the firm.

Taking advantage of the innovation surveys (OECD and Eurostat, 2005) and the broader set of indicators available, 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) in an 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 labor. In accordance with previous studies, they also show that a firm's decision to invest in innovation (R&D) increases with its size, market share and diversification, and with demand pull and technology push forces.

Building on the CDM model, a new wave of studies based on innovation surveys emerged and reported similar results for other industrialized countries. Using different indicators of economic performance such as firms' labor productivity, multifactor productivity, sales, profit margins and market value, studies in this vein have recurrently shown that technological innovation (product or process) leads to superior firm economic performance in European firms (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 in explaining innovation activities and their effects on firm performance and must be controlled for in empirical estimations (Hall and Mairesse, 2006; Mairesse and Monhen, 2010). 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 the manufacturing sector than in the services sector (OECD, 2009). With respect to the impact of R&D on innovation outcomes, these studies consistently confirm a positive association. Firms that invest more intensively in R&D are more likely to develop innovations—products, process innovation or patents—once corrected for endogeneity and controlling for firm characteristics such as size, affiliation with a group, or type of innovation strategies (i.e., externalization, collaboration in R&D, etc.).

In contrast, evidence with regard to the ability of firms in developing economies to transform R&D into innovation is much more mixed than in the case of firms in industrialized countries. Satisfactory results showing a positive association between R&D, innovation, and productivity have been found for newly industrialized 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), which began investing in R&D and human capital a few decades ago. There is evidence that higher levels of investment in innovation (notably in R&D) lead to a higher propensity to introduce technological innovation in firms from Argentina (Chudnovski et al., 2006, Arza and López, 2010), Brazil (Correa et al., 2005; Raffo et al., 2008), and Bulgaria (Stoevsky, 2005). On the other hand, results from Chile (Benavente, 2006; Benavente and Bravo, 2009) and Mexico (Pérez et al., 2005) do not support this finding.

The results regarding the impact of innovation on labor productivity are equally inconclusive for Latin American firms. Raffo et al. (2008) found a significant impact of product innovation for Brazil and Mexico but not for Argentina. In contrast, 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 Mexican firms, respectively. Hall and Mairesse (2006) suggested that the lack of significance of innovation in productivity equations in several developing countries may be a reflection of the different circumstances surrounding innovation in developing economies as compared to Western Europe and stressed the need to evaluate effects over longer periods of time (for evidence on Chile, see Benavente, 2010).[3]

The failure of R&D to correlate significantly with innovation outcomes and productivity in developing countries could be explained by the fact that firms in developing countries are too

[3] 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-term relationships.

far from the technological frontier and incentives to invest in innovation are weak or absent (Acemoglu et al., 2006). In many Latin American economies, firms' innovations consist basically of incremental changes with little or no impact on international markets, and are mostly based on imitation and technology transfer, e.g., acquisition of machinery and equipment and disembodied technology purchasing (Anlló and Suárez, 2009; Navarro et al., 2010). R&D investment is many cases prohibitive (both in terms of financial costs and human capital needed) and, due to its cumulative effects, it could require longer time horizons to demonstrate results (Navarro et al., 2010).[4] The lack of significance of innovation for productivity is not unique to Latin American economies. Using the PICS (Productivity and Investment Climate Survey) data from the World Bank for a large group of developing countries, Goedhuys (2007a, 2007b) and Goedhuys et al. (2008) failed to confirm any significant effect.[5]

This literature review is far from exhaustive, and many other studies have evaluated the CDM model or similar models to explain technological innovation and its impact on productivity.[6] Other studies in emerging economies include: Roud (2007) for Russia, Masso and Vather (2008) for Estonia, and Lee and Kang (2007) for Korea. (For a review of studies see Fagerberg et al., 2008, and Bogliacino, 2009.)

3. Model and Data

3.1 The Model

In this paper we apply a structural model based on Crepon, Duget, and Mairesse (1998), also called the CDM model, to estimate the determinants of innovation and its impact on labor productivity. The CDM model consists of four stages: (i) firms decide to invest in innovation activities; ii) firms decide on the amount to invest; (iii) knowledge (technology) is produced as a result of this investment (the "knowledge production" function, e.g., Griliches, 1979 and Pakes and Griliches, 1984); and (iv), 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 labor productivity. In addition to firm

[4] Albeit, the international evidence demonstrates that having an internal R&D capacity is necessary for absorption and for taking full advantage of external technology acquisition, which in turn facilitates the path towards more innovative stages (Griffith et al., 2004).

[5] For a concise table of studies in this vein and main results, see Fagerberg et al. (2009).

[6] An important limitation of this literature is that panel data in most cases do not exist. This caveat makes it hard not only to resolve causality issues but also to track dynamics in a satisfactory manner (Fagerberg et al., 2009).

characteristics, the model also includes external forces acting concurrently on the innovation decisions of firms. These are traditionally indicators of demand-driven innovation (i.e., environmental, health and safety regulation), technological push (i.e., scientific opportunities), innovation policy (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^**:*

$$IE_i^* = zi'\beta + e_i \qquad (1)$$

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 innovation 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 in innovation and equal to one for firms investing in innovation activities; ID_i^* is a corresponding latent variable such that firms decide to invest in (and/or report) innovation if it is above a certain threshold level *c*, and where w is a vector of variables explaining the innovation investment decision, *a*, α a vector of parameters of interest, and ε an error term. Conditional on firm *i* engaging in innovation activities, we can observe the amount of resources invested in innovation (IE) activities, and write:

[7] The problem of selectivity is that in each time period, only of handful of firms report positive investment in innovation activities. Deleting firms with zero activity will bias the sample.

[8] Innovation indicators from innovation surveys are noisy (in part because they are subjective measures) and need to be fine-tuned to correct for errors in variable measurement. Hence, factors that are not observed and that affect the probability of innovation may lead companies to invest more in 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).

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

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 generalized Tobit model by maximum likelihood.

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

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

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 labor productivity. Firms produce output using constant returns to scale Cobb-Douglas technology with labor, capital, and knowledge inputs as follows,

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

where output y_i is labor 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 an 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 SIC code dummies. We also control for firm size in all equations but the innovation investment equation (equation (2)), innovation 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 generalized 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 rather

[9] It is worth noting that the significance of product and process innovation on labor productivity is a debatable effect, especially when it is measured by sales per worker. 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, 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 a dependent variable. Yet, this is not always the case in other countries (e.g., Griffith et al. (2006) for Germany, Spain and the United Kingdom; for Ireland see Roper et al. (2008).

than reporting innovation efforts, correcting for potential endogeneity in the 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).

As in other studies using innovation survey data, our estimation of the CDM model suffers from several measurement shortcomings. First, the original Griliches (1979) and CDM models (Crepon et al., 1998) use patent data as indicators of technological innovation. However, patent information is almost irrelevant in developing countries, where only a very small set of firms actually innovate at the frontier level. We use innovation survey data, which is qualitative information and much noisier than patent statistics. It is frequently argued that innovation data 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 innovation may not necessarily be considered as such by 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 only have cross-sectional information, we can use the investment in knowledge in the previous year(s), inducing a measurement error in the knowledge capital.[10] These are typical limitations when analyzing R&D or innovation activities with innovation survey data, and many previous studies share these restrictions.

We differ with Griffith et al. (2006) in the use of main explanatory variables. We use investment in innovation activities as a measure of knowledge investment rather than R&D investment.[11] Our variable is more comprehensive than the commonly used R&D (see also Loof and Heshmati, 2006; Criscuolo, 2010; OECD, 2009).[12] We include under the heading of innovation activities any action taken by a firm which aims to implement any concepts, ideas, or methods necessary for acquiring, assimilating, and incorporating new knowledge. It includes R&D expenditures and other innovation expenditures such as design, installation of new

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

[11] R&D investment in Latin American firms is extremely low: it represents less than 1 percent in average relative to turnover (Navarro et al., 2010; IDB, 2010).

[12] Such a broad perspective of innovation should not distract from the fact 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). For firms, internal R&D (Cohen and Levinthal, 1989, 1990) presents several distinctive advantages: without such infrastructure, the use, identification, assimilation, adaptation, and exploitation of external knowhow—such as licenses, acquired patents, or other types of technology transfer—are less than optimal, which diminishes the impact of innovation on productivity.

machinery (machinery and equipment linked to the implementation of innovations), industrial engineering and embodied and disembodied technology (capital and machinery, patents, patent and trademark licensing, disclosures of know-how, and computer and other technical services), and design, marketing, and training.

We also diverge from previous studies in the use of technological innovation (process or product innovation) in equation (4), estimating process and product innovation separately. The reason for doing this is that there is high collinearity between these two variables in Latin American surveys. Most of the firms that introduce product innovation are the same ones that introduced process innovation. As a result, it is hard to separate empirically product from process innovation, which leads to problems with identification when putting the two variables together in the productivity equation. We prefer to be more conservative and work with a combined explanatory variable.

Lastly, as distinct from most previous studies (e.g., OECD, 2009) but in line with Griffith et al. (2006) we estimate the CDM model not only for innovative firms, but for all firms. That is, we estimate steps (i), (ii) and (ii) based on reported innovation investment activities and use predicted values for all firms to proxy innovation effort in the knowledge production function. In turn, equation (3)—technological innovation—is estimated for all firms, and equation (4)—productivity is run for all firms. We include in the latter the predicted value of technological innovation. The reason for using this estimation strategy is twofold. First, most Latin American surveys do not have a filter and most of the questions are asked of all firms (Chile is an exception). 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 produces knowledge, and we can then have an estimate of innovation efforts for all firms.[13] 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 rather that actual ones, we need to correct for the standard errors in equations (3) and (4). This is done by bootstrapping.

As a robustness check, we also estimate the productivity equation using the predicted value of innovation expenditure intensity (IE) instead of predicted technological innovation. As

[13] 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.

before, we run the regression on the total sample of firms (including both innovators and non-innovators). This procedure allows us to evaluate the elasticity of productivity to innovation investment directly.

3.2 Empirical Implementation and Explanatory Variables

The model is run for six countries. The analysis focuses on the manufacturing industry. Innovation surveys used were: Argentina (1998-2001), Chile (2004-2005), Colombia (2004), Uruguay (2006) and Costa Rica (2008). (See Table 1 at the end for further details.) Table 2 displays the definition of variables and their means. We have established a team of researchers from these countries with access to micro data who implemented the empirical common model. A series of national studies have been conducted in parallel to fully exploit the richness of each individual survey by local researchers.[14]

Tables A.1 and A.2 in the Annex depict in gridlines the harmonization of variables. One of the strengths of this study is that great care has been taken to make data compatible so that variables could be fully comparable across the six countries. We have undertaken a substantial review of questionnaires and, given the limitations both in data comparability and availability, we have come up with a structural model simpler than that of Griffith et al. (2006).[15] One interesting advantage of innovation surveys in Latin America is that the rate of response is much higher than their European counterparts, as surveys are obligatory. In Colombia, the survey actually covers the entire population of firms (as the Economic Census).[16]

When interpreting the results, we need to take into account several aspects of innovation surveys in Latin America and the way that firms perceive innovation in these countries. First, innovation is a broader concept and firms consider only minor changes in products and services

[14] See Arza and López (2010), Cassoni and Ramada (2010), Arbeláez (2009), and Benavente and Bravo (2009).

[15] For a more detailed description of the datasets and their comparability across countries, see Crespi and Peirano (2007) and Boglicino et al. (2009).

[16] In spite of progress made with the Bogota Manual (RICYT et al., 2001), divergences across surveys in Latin America still persist both in terms of methodology (sampling method and coverage) and questionnaires (see Lugones, 2006; Crespi and Peirano, 2007). Questionnaires in Chile and Brazil are close to the Oslo Manual (OECD and Eurostat, 2002) whereas those of Colombia and Uruguay follow the Bogota Manual. Further, several questions such as cooperation and sources of information are not fully compatible across countries. Uruguay, Costa Rica, and Argentina (survey 1998-2001) have a question on collaboration in design or R&D, which is broken down by type of partner. In contrast, Colombia does not include this question but asks firms to rate the degree of satisfaction with services received from other agents in the national innovation system (Chapter V) broken down by type of innovation activity. In this case we considered a firm to be engaged in collaboration if there was at least one answer in this section in the column on design and R&D (regardless of the level of satisfaction).

to be innovation. Often, innovation refers to adoption of external technology developed by other firms. Not surprisingly, then, innovation rates are much higher than those found in OECD countries.[17] The technological backwardness of LAC firms is evidenced in the indicators regarding the nature of innovation (IDB, 2010b; Navarro et al., 2010). Process innovation is more frequent than product innovation, and this seems to be related to the preponderance of capital goods and machinery in total innovation investment (see Figure 1 and Figure 2). Latin American firms seem to devote substantial resources to innovation (relative to turnover) although the part devoted to R&D is significantly low. Yet, when looking at the nature of innovation outcomes, technological innovation is mostly concentrated in innovations of the adaptive and incremental type. Indeed, for firms that are far from the technological frontier, imitation and technology acquisition are deemed the main channels for learning and catching up. These necessities, in combination with a fragile business climate for innovation (e.g., unstable macro and micro conditions, limited market size and growth, and weak regulatory and policy frameworks), make firms perceive innovation as beyond their means (and objectives) and explain in part the lack of R&D investment in Latin American countries (IDB, 2010b).

Second, when comparing results across countries, we need to bear in mind that business, economic, and policy environments in Latin America differ between countries and generally diverge from OECD countries. Innovation policy work has made greater strides in the last decade in Argentina, Chile, and Uruguay than in other countries of the region. Finally, the reader should keep in mind that this is an analysis of the manufacturing industry, which represents a small share of the total economy in some countries (IDB, 2010b). The results apply only to this industry. We acknowledge, however, that innovation is relatively more important in manufacturing and services industries where value added originates and knowledge skills are more valued.

In each of the four equations of the model, the choice of explanatory variables was dictated mostly by the need to find a minimum common denominator for all countries while adhering at the same time as closely as possible to the literature. In what follows, and before laying out the results, we describe the specification of the four equations.

[17] For instance, Costa Rica, Colombia, and Argentina report percentages above 40 percent for technological innovation (percent of firms introducing process or product innovation in total firms); whereas countries such as France, Norway, and Japan report less than that. For Costa Rica, we define technological innovation as product or process innovation that is new to the market. Otherwise the innovation rates are too high.

3.3 The Determinants of Innovation Investment (equations (2) and (3))

We will briefly discuss the determinants of firm innovation investment. The *size* of the firm 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, it is important to differentiate between the effects of size on the decision to invest from the impacts of size on investment expenditures. Here, 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 generalized Tobit: we assume that the size of the firm affects the decision to invest in innovation, but it does not affect the intensity of that investment once 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 countries (e.g., Benavente, 2006; Crespi and Peirano, 2007). Yet, the results regarding the innovation intensity equation, mostly done with R&D intensity, indicate that those larger firms are not necessarily the ones that invest the most (for Colombia see Alvarado, 2000; for Brazil, De Negri et al., 2007). Thus, 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 (LEM), but that this variable does not affect the intensity of innovation investments.

Other control variables included in both the decision to invest and innovation intensity are exports (EX) and foreign ownership (FO). Regarding exports, the "competition" and "learning" effects of exporting are expected to enhance innovation efforts by firms, notably when local firms have a 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). The impact of foreign ownership on innovation investment is

[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).

less clear. In principle, the economic superiority of multinational firms can be associated with more sophisticated knowledge assets (Girma, and Gorg, 2007) and easier access to finance and human capital (Kumar and Agarwal, 2000). In particular, foreign ownership should have a positive effect on R&D investment when the size and growth of markets are substantial.[19] Furthermore, we include in both the decision and investment intensity equation a dummy if the firm has filed for a patent or obtained patents granted in the past (PA). We take this variable 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) the strength (and usefulness) the intellectual property institutional regime within which the firm is actually embodied. Although potentially interesting, unfortunately we do not have enough information to untangle these two effects. We make the strong assumption that PA is exogenous to the decision and level of investment in innovation. Surveys in Argentina and Costa Rica ask whether the firm obtained patents granted in the previous period. As the process of examination is quite long in patent offices (it usually takes around two years), patents that are granted in the period of inquiry in surveys are probably associated with inventions that occurred much earlier (at least two years before the date surveyed for knowledge investment in questionnaires).

With regard to the variables that only affect the innovation intensity we have: collaboration (COL), public funding (FUN) and information sources (INFO1-INFO3). Collaboration has in principle ambiguous effects on innovation investment. Indeed, by allowing firms to share costs and internalize spillovers, collaboration enhances the 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 access to effective R&D (internal plus external), but perhaps saving costs on internal innovation activities (Klenow et al., 1996).

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

[19] This is the case for Chinese and Malaysian manufacturing firms (Jefferson et al., 2006; Hegde and Shapira, 2007). The opposite has been reported for Brazil (Correa et al., 2005).

firms, public support for R&D investment is essential (Navarro et al., 2010; Anlló and Suárez, 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 to innovation perceived by firms in Latin America. Although in this paper we do not aim to conduct a full impact evaluation of public funding, we think that this is an important control variable that somehow captures the costs of financing and as such should be included in the analysis.[20]

Finally, we also include in the investment decision function three variables indicating the intensity of use in the following information sources: an indicators reflecting the importance given by the firm to market sources of information (from clients, competitors, suppliers, consulting firms and experts-INFO1), an indicator that measures the intensity of importance of scientific information sources (INFO2), and a variable that indicates the importance given by firms to public sources of information such as the Internet, journals, magazines, patents, publications, expositions, or meetings (INFO3). These indicators have values between 0 and 100 percent.[21]

There is no theoretical reason why COL, FUN, and INFO1-INFO3 variables should be included only in the investment intensity equation. Indeed, the same variables could also have some effect on innovation decisions. The rationale for this specification is mainly data driven, as some of the surveys include a filter in the questionnaire by which information on this variable is only collected for firms with positive innovation spending.

We opted for not including variables in any of the equations indicating the importance of obstacles for innovation activities in the propensity equation. This set of questions, although for the most part harmonized across surveys, does not always refer to all firms. For instance, Colombia and Panama ask about the importance of obstacles to innovating firms whereas the rest of countries ask this question to all firms. Furthermore, the interpretation of these variables is awkward, according to previous studies. The information regarding demand-pull and push drivers along the lines of Griffith et al. (2006), again, differs across countries (notably the

[20] 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 is mostly done, compare the difference in innovation performance between matched pairs of supported and non-supported firms (give each treated firm a counterfactual).

[21] These three variables are calculated as an index: it is the sum of values in a Likert scale (0 indicating that the firms consider such a source as having no importance and 3 or 4 very important, depending on the survey) over the sum of maximum possible values.

question regarding innovation driven by environmental regulation).[22] Notice, however, that our variables INFO1 and INFO2 capture in some way push (scientific sources of information) and pull forces (market information sources) that influence innovation investment decisions.

We have not included human capital in the first two equations (Leiponen, 2003). There are two reasons for this. First, not all surveys include comparable indicators of human capital and second, as discussed by Janz et al. (2004), the introduction of human capital, which includes researchers and other personnel in R&D, may introduce endogeneity problems due to the overlap with the R&D expenditure variable. Indeed, skill level is correlated with the labor cost of innovation activities, notably in R&D activities.

4. Results

4.1 The Decision to Invest in Innovation and the Intensity of Innovation Expenditure

Table 5 presents the estimated results for equations (2) and (3), which specify the determinants of the likelihood to engage in innovation activities within the firm and the intensity of this expenditure (log of innovation expenditure per worker) for each country in the sample. As discussed previously, we consider all firms engaging in innovative activity, but only some of them are engaging in a sufficient amount for it to be reported. Estimates reported are marginal effects generalized Tobit that correct for sample selection.

The results vary sharply across countries, making it hard to generalize lessons. This divergence in results illustrates, however, the heterogeneity of innovation investment behavior across Latin American countries and the corresponding innovation systems. Overall, the results differ from those reported for European countries (Griffith et al., 2006; Raffo et al., 2006; Criscuolo, 2009; OECD, 2009) where countries coincide closely in the determinants of innovation activities. It should be mentioned, though, that consistency in major European countries is in large part explained by the fact that they have broadly comparable innovation processes and regulatory environments (Griffith et al., 2006), which is not the case in Latin American countries and other developing economies.

Consider the coefficients on firm size (LEM). In all regressions, larger firms are more likely to engage in innovation activities. The coefficients are remarkably similar between

[22] In previous studies, demand pull indicators often turn out to have a significant positive coefficient in the innovation intensity equation; technology push is also positive but less often significant (e.g., Griffith et al., 2006).

countries: the marginal effect is about 0.10 for Argentina, Chile, Colombia, and Costa Rica and is 0.08 in Panama. The largest effect is reported for Uruguay (0.17). Likewise, exporting firms (EXP) are more likely to engage in innovation activities in Argentina, Chile, and Colombia. Firms that export have a 7 percent higher probability of investing in innovation in Colombia, 11 percent higher in Chile, and 15 percent in Argentina compared to firms that only target domestic markets. However, in the innovation intensity equation, exporting is significant only in the case of Argentina and Colombia. This result should be interpreted with care, as the lack of significance of exporting in Chile, Uruguay, and Panama may be due to the economic structure and export orientation of these countries (weakly intensive in technology and less associated with innovation).[23]

Firms that have foreign ownership (greater than 10 percent of capital) show a higher propensity to invest in innovation in Argentina, Panama, and Uruguay (with probability increases between 0.11 (Argentina) and 0.16 (Panama) compared to domestic firms). In terms of the intensity of innovation expenditure, multinational companies have a significantly higher level of investment in Argentina, Colombia, and Panama.[24] In Chile and Costa Rica, there is no distinct innovation investment by multinational firms.[25] Hence, multinational firms are not, in all cases, significantly different from domestic firms with respect to the propensity to innovate or innovation intensity. 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 no specific national academic attractiveness (Raffo et al., 2008).[26] It could also be the case that multinational firms do not invest in innovation in Latin America at all given that their activity is more focused on the exploitation of comparative advantages in terms of, for instance, access to natural resources, distribution costs or labor savings, and use of technological assets from headquarters

[23] A second possible cause could be that the effects are hidden and that the impact would derive from differences in the geographic destination (it is not the same to export to Mercosur as to the United States or Europe). A better understanding of this complex relationship is needed.

[24] The result for Argentina contrasts with Chudnovski et al. (2006), who previously did not find any distinctive behavior on the part of multinational firms in Argentina. This partial evidence of a multi-nationality effect on innovation efforts differs as well from results reported by studies conducted on Chinese and Malaysian firms, which consistently report a positive association (Jefferson et al., 2006; Hegde and Shapira, 2007).

[25] One should mention though that the lack of significance of multi-nationality in Costa Rica is perhaps due to the overrepresentation of multinational firms in the sample.

[26] Some recent exemptions are China, India, and some Southeast Asian countries, where technology hotspots are emerging and increasingly attracting R&D investment and new labs by foreign firms.

(Navarro et al., 2010). And if they do conduct some kind of technological activity, they focus more frequently on adaptation and tailoring products to local markets (with low needs for R&D investment).

A more consistent result across countries concerns patent protection (PA). Firms that have patents have a higher propensity to invest in innovation activities in all countries but Argentina, although they are not necessarily investing more. In the innovation intensity equation, the coefficient is only significant in the case of Costa Rica. The probably of investing in innovation increases by 10 percent in Colombia, 17 percent in Costa Rica, 23 percent in Chile, 29 percent in Uruguay, and 33 percent in Panama, compared to firms that do not patent. This finding suggests that formal means of appropriation of knowledge strengthen firms' incentives to continue investing in innovation (as these firms were already engaged in some kind of inventive activity in order to have a patentable product or process).

Firms that received public financing for innovation invest significantly more than those who did not. This is the case for firms in Chile, Colombia, and Costa Rica. In Chile and Colombia, firms that received government support invest about 80 percent more than the rest of firms. The impact of public support is almost the same in Chile and Colombia (0.79 and 0.81). The largest effect is reported in Costa Rica, where firms who benefit from this policy invest twice as much as their counterparts. This finding suggests the huge impact that innovation policy can have on firms' innovation efforts and illustrates the importance of access to financing for those who, as innovators, get engaged in activities that are characterized by high uncertainty, high fixed costs, and considerable economic risk, such as R&D. The lack of significance of public support for Argentina has been reported in previous studies (for evidence on Mexico and Argentina, see Raffo et al. (2008).[27]

Cooperation in innovation (R&D or design) is complementary to innovation investment in three countries (Colombia, Panama, and Uruguay). This partial evidence for Latin American firms differs from that of industrialized countries that repeatedly show that R&D collaboration is associated with higher R&D efforts (e.g., Veugelers and Cassiman, 1999; OECD, 2009). It illustrates more broadly, to some extent, the absence or weak development of innovation networks. In the case of Chile, the lack of significance can be explained simply by the very low

[27] It should be noticed that the marginal effect of governmental funding will differ across countries owing to differences in funding systems as well as to potential differences in firm behavior.

share of firms involved in this activity (fewer than 3 percent). One should take into account that collaboration could be a costly process requiring longer time horizons in developing economies.

The results of the three variables concerning “sources of information” differ markedly across countries. Market sources of information (INFO1) are significantly associated with higher levels of innovation investment only in the case of Colombia. Scientific information sources (INFO2) are only significant in Costa Rica. Lastly, public sources of information—INFO3 (patents, journals, databases, expositions, and business associations)—show complementarities with firms’ innovation efforts in Argentina and Colombia but have no effect on the rest of countries. In general, the lack of significance of information sources reflects the limited knowledge exchange among actors in the innovation systems and may also reflect the limited capacity of firms to take advantage of available knowledge (due to weak internal R&D capacity, irrelevancy of public research for business, or both).

4.2 The Impact of Innovation Investment on the Probability of Technological Innovation

We next consider the estimates of the knowledge production functions (equation (4)) in Table 6. Marginal effects are reported for equation (4): the probability of introducing technological innovation (product or process). As expected, the marginal effects for innovation intensity are both statistically and economically very significant in all countries. They show clearly that greater innovation effort per employee leads to a higher probability of having at least one process or product innovation. Marginal effects vary substantially across countries: between 0.18 for Costa Rica and 1.16 for Chile. Argentina and Panama have a similar coefficient with an effect of about 0.30. In average, the effect of innovation investment is about 0.5, which is significantly higher than the average of 0.3 reported by Griffith et al. (2006) for R&D investment on product innovation for France, Germany, Spain and UK; and Raffo et al. (2006) for Brazil, Argentina, and Mexico.[28]

As in the case of the innovation investment (stage 1 and 2), company size matters for technological innovation. Larger firms tend to innovate more frequently, and this effect may be due to the development of economies of scale and scope in the production of knowledge. With respect to foreign ownership and exporting, the results diverge sharply across countries.

[28] As we use a broader knowledge investment indicator, which encompasses R&D, it is not surprising to have a larger impact. Recall that investments in other forms of technological (other than R&D) and non-technological infrastructure are considered.

Exporting is only significant and has a positive impact in Costa Rica (it increases chances of innovating by 4 percent) while it shows a negative and significant coefficient in Chile and Colombia (being an exporting firm decreases chances of innovating by 15 and 14 percent, respectively). As we previously explained, this result should be considered with care, as further refinement of this indicator is needed (by geographic destination or R&D intensity of goods). Last, foreign firms in Argentina and Colombia display a lower (and significant) probability of developing technological innovation (by 16 and 44 percent respectively), whereas in Chile they are more able to innovate (0.22 more likely).

4.3 The Impact of Innovation on Productivity

Finally, we discuss the results of the productivity equation shown in Table 7. The coefficients reported in this table are elasticities or semi-elasticities, since the dependent variable is the log of sales per employee. Consistent with prior studies for industrialized countries, the evidence confirms a positive impact of technological innovation on productivity for all countries, except for Costa Rica, where the coefficient is positive but very imprecisely estimated. Notice that in these regressions we control for firm size and introduction of non-technological innovation. The latter is a dummy indicating whether the firm has introduced organizational or marketing innovation in the previous year.

The innovation coefficients, however, appear quite different across countries. The semi-elasticity of output with respect to innovation outcomes ranks between 0.24 (Argentina) and 1.95 (Colombia has an average close to 1 (0.95). That is, on average, introducing technological innovation is associated with increases above 100 percent in labor productivity. This result is well above the elasticity reported for industrialized countries (studies on Spain report the highest, with an elasticity of about 0.18).

With respect to the other variables, non-technological innovation leads to higher productivity in Argentina and Colombia. In the rest of the countries, this variable has no significant impact. A positive association with company size is reported for Colombia, Chile, and Uruguay (the latter two only in the case of the regression using predicted innovation investment). A negative relationship is found for firms in Costa Rica and a non-significant effect for firms in Argentina. Recall that the adoption of new organizational and marketing practices may induce deep adjustments that may be costly to the firm in the short run. Size is not related to productivity in the LAC countries chosen for this study. It is not significant in Argentina, Chile, Panama, or Uruguay and has a negative significant association with productivity in Costa Rica.

For the purpose of checking the robustness of results, the same model was tested using the predicted innovation investment intensity. Again, results are significant in all countries except Costa Rica and, as in the case of regressions with innovation outcome (IT), marginal effects vary considerably across countries. The average impact of innovation investment is 0.41. The highest elasticity is reported by Panama (0.70) and the lowest by Chile (0.20).

5. Conclusion

This paper has presented an international econometric comparison using micro-level data. We investigated the drivers of technological innovation and how this one feeds into productivity at the firm level for six countries 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. Consistent with the literature, in all countries firms that invest in knowledge are more able to introduce new technological advances and those who innovate have higher labor productivity than the rest of firms. The consistency in these two results provides solid evidence for Latin American countries, and we hope thereby to help fill some of the gaps in the literature and reduce the inconclusiveness of previous studies.

Our findings have important repercussions. As firms who invest in knowledge are those who innovate and are more productive, these results underscore the need for more effective policy action to alleviate the obstacles that dissuade firms from investing in innovation and provide better market and business conditions for innovation to flourish. Furthermore, the impact of innovation is far beyond those reported previously for firms in industrialized countries, which indicates that innovation is the answer for catching up for Latin American economies.

Yet the determinants of innovation are not the same across countries. The analysis also shows the diversity of innovative behavior across countries in Latin America. Consequently, the policy and business strategies designed to target innovation should pay attention to the specificities of national innovation systems and firm innovative behavior and should customize strategies accordingly. At least two indicators seem reasonably important given their magnitude of their impact and importance as policy and regulatory instruments. One is public support, which has proven to encourage innovation efforts in Chile, Colombia, and Costa Rica. The other is the role of intellectual property rights systems in firms' decisions to invest in innovation. For both instruments, policy challenges include increasing their use and impact, notably within small and medium size firms (as these firms are less likely to invest in innovation), and making instruments more affordable (in the case of patents) and effective. Transparency, regulatory quality, and enforcement are obviously necessary for these purposes.

We recognize that the model is limited to the typical caveats related mostly to the proper instrumentation of variables and the absence of panel data. Extensions are needed with further harmonization of variables and data access. Advancing comparability and accessibility to innovation surveys micro-data are necessary steps to advance our understanding of innovation behavior and innovation systems in Latin America. Progress in these lines of work would enable us to have a richer set of explanatory variables, more properly evaluate dynamic relationships, and more robustly assess the impact of innovation on economic performance. These are topics for further research.

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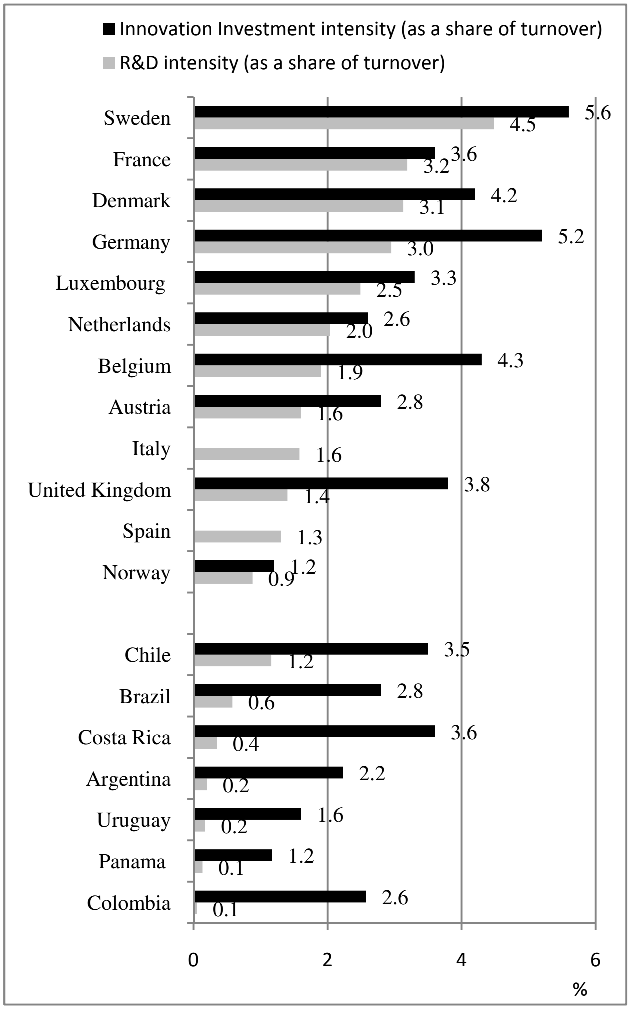
ANNEX

Table 1. Innovation Surveys

	Argentina	Chile	Colombia	Costa Rica	Panama	Uruguay
Innovation Survey	1998-2001	2003-2004	2003-2004	2008	2008	2004-2006
Source	SECYT-INDEC	INE	DANE-DNP-Colciencias	MICIT-CINPE/UNA	SENACYT	ANII
Sample Size	1192	1154	5934	352	481	759
Minimum firm size	10 employees	10 employees	10 employees	10 employees	10 employees	5 employees

Note: The innovation surveys used are: Argentina: Encuesta Nacional a Empresas Sobre Innovación, I+D y TICs,- 2002-2004 (SECYT-INDEC); Chile: Cuarta Encuesta de Innovación Tecnológica 2005, Instituto Nacional de Estadísticas, INE; Colombia: Segunda Encuesta de Desarrollo e Innovación tecnológica 2005, DANE-DNP-Colciencias; Costa Rica: Encuesta Nacional de Ciencia, Tecnología e Innovación a Empresas. Costa Rica, 2008, MICIT-CINPE/UNA; Panamá: Encuesta de investigación, desarrollo e innovación al sector privado, 2008, SENACYT; and Uruguay: III Encuesta de Actividades de Innovación en la industria uruguaya (2004-2006). Agencia Nacional de Investigación e Innovación,. Uruguay.

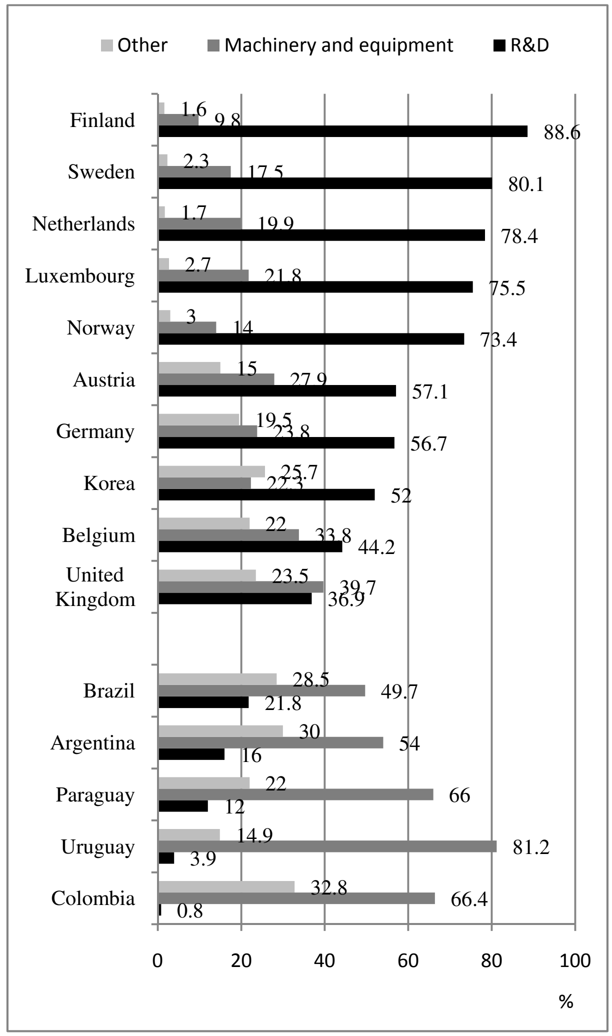
Figure 1. Investment in R&D and Investment in Innovation Activities



Sources: Innovation Surveys (Argentina: 1998-2001; Brazil: 2005; Chile: 2004- 2005; Colombia: 2003-2004; Costa Rica: 2008; Panama: 2008; Uruguay: 2005-2006). Data for OECD countries are from OECD (2009) except for Spain and Italy (Eurostat).

Note: Indicators refer to the Manufacturing Industry. Weighted shares are reported only in the case of OECD countries and Brazil. The indicators reported are averages in the total sample of companies (except for Chile, Spain, and Italy, whose averages correspond to shares of the total number of innovating companies).

Figure 2. Distribution of Innovation Expenditures



Sources: Innovation Surveys (Argentina: 1998-2001; Brazil: 2005; Colombia: 2003-2004; 2008; Uruguay: 2005-2006; Paraguay: 2004-2006). Data for OECD countries are from OECD (2009).

Note: Indicators refer to the Manufacturing Industry. Indicators are weighted except for Uruguay, Argentina, and Colombia.

Table 2. Definition of Variable and Means per Country

Variables and Definition		Argentina	Chile	Colombia	Costa Rica	Panama	Uruguay
Explained Variables and Definition							
Technological Innovation (dummy equal to one if the firm introduced product or process innovation)	**TI**	0.58	0.38	0.61	0.85	0.38	0.37
Expenditures on innovation activities per employee (local currency)	**IE**	2843.78	1129.61	3033.86	1417.94	3191.492	25927
Productivity : sales per employee (local currency)	**Y**	127471.6	371021.8	117999.5	39906.16	397070.9	1614967
Explanatory Variables and Definition							
Firm size (number of employees)	**EM**	214.49	91.27	90.4	120.31	145.56	117.59
Export dummy (equal to one if the firm exports)	**EX**	0.49	0.25	0.32	0.26	0.16	0.43
Non-technological innovation (dummy equal to one if the firm introduced marketing or organizational innovation)	**NTI**	0.45	0.29	0.46	0.64	0.31	0.24
Foreign ownership (equal to one if foreign capital ownership is above 10%)	**FO**	0.19	0.07	0.013	0.11	0.25	0.13
Patent protection (dummy equal to one if the firm filed for a patent or has patents granted in the previous period)	**PA**	0.06	0.06	0.02	0.11	0.03	0.23
Co-operation (dummy equal to one if the firm is engaged in collaboration for innovation)	**CO**	0.24	0.04	0.03	0.34	0.06	0.16
Public Finance (dummy equal to one if the firm received public support to finance innovation)	**FIN**	0.05	0.08	0.05	0.01	0.03	0.01
Sources of information for innovation:							
Importance of market sources of information (suppliers, clients, competitors, consulting firms and experts) is considered very important*	**INFO1**	0.29	0.41	0.12	0.80	0.11	0.47
Importance of scientific sources of information (universities, public research center, technological institutions) is considered very important*	**INFO2**	0.19	0.19	0.03	0.61	0.04	0.28
Importance of public sources of information (journals, patents, magazines, expositions, associations, databases, Internet) is considered very important*	**INFO3**	0.28	0.28	0.09	0.70	0.03	0.42
Capital per employee (stocks are only available for Uruguay and Colombia; values are in local currency))	**INV**	11045.23	NA	41893.7	NA	2510838	NA

Note: The variable used to proxy for physical capital is investment made during the period considered for Argentina, Chile, and Panama. Uruguay and Colombia use the stock of physical capital. Statistics are unweighted for all countries but Chile.
* : The variables INFO1, INFO2 and INFO3 are calculated as an index (it has a value between 0 and 100): it is the sum of values in a Likert scale across the different sources (0 indicating that the firms consider such a source as having no importance and 3 or 4 very important, depending on the survey) over the sum of maximum possible values.

Table 3. Definition of Dependent Variables per Country (in Spanish)

Definition	Argentina Encuesta 1998-2001	Chile Encuesta 2004	Colombia Encuesta 2005	Uruguay Encuesta 2006	Costa Rica Encuesta 2008
Gasto en I+D por empleo (RD). R+D incluye R+D interna y externa	Pregunta 402. 1 (I+D interna) + 2 (I+D externa) / empleo Valor del 1998 Monto en Ar$	Pregunta 10.1.A a la 10.1.C mas 10.2 + 10.3 / empleo Valor del 2003 Monto en Miles de Ch$	Capitulo I, Numeral 4, item 73 /empleo Valor del Monto invertido 2003 (Moneda ¿??)	Pregunta B.1.1 (I+D interna) + Pregunta B.1.2, columna del medio / empleo Valor del 2006, Monto en miles de Uy$	Pregunta (402) 1 (I+D interna) + (402) 2 (I+D externa) / empleo Valor del 2006 (Moneda ¿??)
Gasto en Innovación por trabajador (IE) **El gasto en Actividades de Innovación incluye: I+D, non I+D, maquinarias y equipos, training, etc) por trabajador.**	Pregunta 402, total / empleo Valor de 1998 Monto en Ar$	RD (como arriba) + 9.2.1+9.2.2+9.2.3+ 9.2.4.+9.2.5/empleo Valor del 2003 Monto en Miles de Ch$	Capitulo I, item 75 / empleo Monto invertido 2003 (Moneda ¿??)	Pregunta B.1.1 a la B.1.9 /empleo Valor del 2006, Monto en miles de Uy$	Pregunta (402) total /empleo Valor del 2006 (Moneda ¿??)
Innovación de Producto (IPRD). Dummy igual a uno si introdujo innovación de producto e independientemente del grado de novedad (cualquier tipo de novedad)	Pregunta 901.1	Parte II Pregunta 1.1.1 al 1.1.4	Capítulo III numeral 1 La variable tomará el valor de 1 si la firma reporta obtener output en alguna de estas categorías (1-3) y donde el estado de avance=O	Pregunta E .1.1 (SI o NO)	Pregunta 901.1 o 2
Innovación de Producto nuevo para el mercado (NEWPRDMKT). Dummy igual a uno si introdujo producto nuevo para el mercado local y/o internacional	Pregunta 901.1.2a o 1.2c	Parte II Pregunta 1.1.3 al 1.1.4	Capítulo III numeral 1 La variable tomará el valor de 1 si la firma reporta obtener output en alguna de estas categorías (2-3) y donde el estado de avance=O	Pregunta E.1.1 (Local o Internacional)	Pregunta 901 RU 2.o.3
Innovación de Proceso (IPRC). Dummy igual a uno si introdujo innovación de proceso independientemente del grado de novedad (cualquier tipo de novedad)	Pregunta 901.2	Parte II Pregunta 1.3.1 al 1.3.4	Capítulo III numeral 1 La variable tomará el valor de 1 si la firma reporta obtener output en alguna de estas categorías (4-5) y donde el estado de avance=O	Pregunta E.1.2 (SI o NO)	Pregunta 902.1 o 2
Innovación de Proceso nuevo para el mercado (NEWPRCMKT). Dummy igual a uno si introdujo proceso nuevo para el mercado local y/o internacional	Pregunta 901. 2.2.a o 2.2.c	Parte II Pregunta 1.3.3 al 1.3.4	NA	Pregunta E.1.2 (Local o Internacional)	Pregunta 901 RU 2 o 3

Definition	Argentina Encuesta 1998-2001	Chile Encuesta 2004	Colombia Encuesta 2005	Uruguay Encuesta 2006	Costa Rica Encuesta 2008
Innovación tecnológica (TI) (Innovación de producto y/o de proceso)	IPRC y/o IPRD	IPRC y/o IPRD	IPRC y/o IPRD	IPRC y/o IPRD	IPRC y/o IPRD
Productividad Laboral (Y)	201.c / 301.d Valor del 2001 Monto en Ar$	Parte I Pregunta 1.1 / Pregunta 1.3 valor 2004 Monto en Miles $CH	Valor para 2004 Se obtiene de la encuesta industrial Por favor indicar Monto	Pregunta 5.5.1 sección información general de la empresa / Pregunta 4.1 sección información general de la empresa. Valor para 2006 l Miles $ Uy	Pregunta 201.c / Pregunta 301.d valor del 2007 Por favor indicar monto Se entiende que varias observaciones se pierden por la mala calidad de los datos de ventas

Nota 1: (*) Para expresar en términos reales el cambio, se recomienda utilizar el deflactor de precios de la industria manufacturera o el Índice de precios mayoritarios. En el caso de Chile se pueden usar los deflactores a 3 dígitos CIIU para las ventas tal como lo sugiere el equipo de ese país.

Table 4. Definition of Explanatory Variables per Country (in Spanish)

Definition	Argentina Encuesta 98-2001	Chile Encuesta 2004	Colombia Encuesta 2005	Uruguay Encuesta 2006	Costa Rica Encuesta 2008
Size (EMP)	Pregunta 301.d	Parte I Pregunta 1.3	Capitulo II, Numeral 1 total (1a+1b+2a+2b) columan total (suma hombres y mujeres)	Información General de la empresa Pregunta 4.1	Pregunta 3.1 D (permanentes y temporales suma hombres y mujeres)
Exports Dummy (EX)	Sección B, pregunta 202	Part I 1.2	Encuesta industrial – EAM	Información General de la empresa Pregunta 5.3	Sección B pregunta 202
Foreign Ownership Dummy (FO) (*)	Sección A pregunta 105	(véase datos de identificación de empresa proprietaria o bien se obtiene de ENIA)	Encuesta industrial – EAM	Información General De la empresa Pregunta 3.2	Sección A pregunta 105)
Patent protection (PA) Dummy (**)	Sección I, pregunta 904)… (ha obtenido la empresa patentes en el país y/o en el exterior…,). Igual a uno si hay patentes obtenidas independientemente del origen geográfico	Sección 5, pregunta 5.2: Número total de derechos de propiedad intelectual **solicitados** por su establecimiento..	Capitulo VI, numeral 1, 1): *Cuantas patentes ha solicitado en el periodo...* Independientemente del status	Preguntas E.4.1) –solicitudes-	Pregunta 904.1 (patentes **obtenidas** en el país o extranjero)
Cooperation Dummy (***) (CO)	Sección K, 1.102. solo columnas sobre Diseño y/o I+D Es decir, dummy igual a uno si hubo al menos una respuesta en 1.102 que concierna solamente en los ítems I+D y/o diseño. Exceptuar empresas del mismo grupo (relacionadas) y Casa Matriz	La variable se construirá como sigue: Dummy igual a uno, si en la Sección 3, en la pregunta 3.2 es igual a SI, y enseguida, si en la pregunta 3.3 hay alguna respuesta en 3.3.2-3.3.7 (independientemente de la procedencia geográfica). Nótese que se excluye 3.3.1 (cooperación con empresas afiliadas y matriz).	Utilizar capitulo V de la encuesta en la pregunta *"califique el grado de satisfacción de la relación de acuerdo con el servicio recibido*". NA (no aplica) seria =0. El foco debe ser la respuesta a las preguntas (4) y (5) (I+D y/o Diseño). Dummy igual a uno si hubo una relación involucrando ya sea I+D y/o Diseño. Excluir relaciones con casa matriz.	Pregunta H.1. (1-13) si hubo alguna vinculación, aplicable sólo en ítems Diseño y/o I+D Dummy igual a uno si hubo al menos una vinculación en cualquiera de esas dos actividades y exceptuar empresas del mismo grupo (relacionadas) y Casa Matriz	Pregunta 1102 Aplicable solo a objetivos Diseño y/o I+D Dummy igual a uno si hubo cooperación con cualquier agente salvo: Empresas del mismo grupo Casa Matriz
Public financial support Dummy (FIN)	Utilizar pregunta en sección K, 1.103) Dummy igual a uno si recibió fondos de alguno de estos programas públicos (FONCYT, Ley de Fomento a la Innovación Tecnológica y Programa de apoyo a Pymes..)	Combinar: 9.3.2 Recursos externos públicos 10.1.A.1. (fondos gobierno para investigación básica) 10.1.B.1. (fondos gobierno para investigación aplicada) 10.1.C.1. (fondos gobierno para desarrollo experimental) 10.2.1 Fondos Gobiernos subcontratados (universidades, centros de investigación y otras empresas) y 10.3.1	Capitulo IV de la encuesta, si se recibió algún financiamiento del sector público –ya sea como co-financiación o acceso al crédito-, en 2003 y/0 en 2004	YES Sección D, pregunta D.1, ítem 7)	YES Sección F Pregunta 601 ítem j)

Definition	Argentina Encuesta 98-2001	Chile Encuesta 2004	Colombia Encuesta 2005	Uruguay Encuesta 2006	Costa Rica Encuesta 2008
Information sources (***). **Three variables:** **1. Market sources (INOF1):** **suppliers, clients, competitors, consulting firms and experts.** **2. Scientific sources (INFO2):** **universities, public research center, technological institutions,..** **3. Other sources (INFO3):** **journals, patents, magazines, expositions, associations, databases, Internet**	Sección G, preguntas (701. 1-12 En caso de Otras fuentes incluir sólo: Ferias, Conferencias, Exposiciones; Revistas y Catálogos; Bases de Datos; Internet.	Sección 3, usar preguntas 3.1.2-3.1.4, columna A Es decir: Fuentes de mercado=3.1.2 Fuentes científicas=3.1.3 y Otras fuentes=3.1.4	Usar el capitulo III – Numeral 2 de la encuesta en 2003 y 2004). Fuentes de mercado: preguntas 10, 11 y 12 y 17 (consultores y expertos) Fuentes científicas: preguntas 15 y 16. Otras fuentes: preguntas 13, 14, 18-25.	Sección F, Preguntas F.1, 1-12 Fuentes de mercado: 2.3.5.7 Fuentes científicas: 6 Otras Fuentes: 8,9,10,11	Sección F Pregunta 701) Fuentes de mercado : 4.5.6.8 Fuentes científicas: 7 Otras fuentes: 9.10.11.12
Non Technological innovation (NTI) **Non technological innovation (dummy equal to one if the firm introduced marketing or organizational innovation) (regardless of the degree of novelty).**	Sección I, 901) combinación de ítems 3 y 4	Se utilizará las preguntas de Sección 2, ítem 1.4, 1.5 y 1.6. Dummy igual a uno si introdujo alguna de estas innovaciones. Para innovación de 1.6, se tomará en cuenta cualquier tipo (1.6.1, 1.6.2 y 1.6.3).	Capitulo III, numeral 1, si Estado de Avance=O (obtenido. Ítems 6 y 7	Sección E, Combinar preguntas E.1.3 y E.1.4 (organizacional/ comercialización)	Sección I Pregunta 901 Combinar preguntas 3) y 4) organizacional/ de mercadeo)
Capital per employee (CAP). If capital is not available use physical investment per employee (INV).	Encuestas complementarias	Encuestas complementarias	Encuestas complementarias	Capital físico/empleo e Inversión/empleo (se usara una u otra dependiendo de que la ecuación sea en nivel o crecimiento)	No disponible en Costa Rica. No se recomienda no utilizar la proxy que se propone a nivel sector, ya que esta seria correlacionada con las dummies de sectores (y por lo tanto no daría un efecto significativo). El modelo en este caso se estima si sin esta variable.

Nota 1: (*) En las encuestas que preguntan solo por porcentaje de participación, la dummy será igual a uno si la propiedad extranjera es superior al 10%.

Nota 2: (**) Dummy igual a uno si se uso o intenta usar protección de la propiedad intelectual por medios formales.

Nota 3: (***) Dummy igual a uno si hubo algún tipo de cooperación en actividades de innovación.

Exceptuar relaciones con casa matriz y empresas afiliadas. La definición se adapta a cada encuesta (en Argentina, Colombia y Uruguay solo aplica si la cooperación implicó actividades en I+D y diseño).

Nota 4: (****) La variable para cada tipo de fuentes se calculará como un índice: la suma de valores sobre el valor máximo del bloque. Por ejemplo si se usa una Likert scale en la escala (0,1,2,3) y la empresa contesto 1 (clientes. 2 (proveedores) y 3 (competidores. el índice seria: (1+2+3)/(3+3+3) o sea 2/3. El índice siempre está entre 0-1. Es decir, se construirá el índice como la suma de valores sobre el valor máximo del bloque usando lo siguiente: “No importante” o ¨Irrelevante¨ es igual a cero, “Poco Importante” es uno, “Importante” es dos, y “Muy Importante” es tres. Téngase en cuenta que hay que atribuir el valor de cero a la categoría ¨irrelevante ¨o similar, cuando ésta reporta un valor superior al de ¨alta importancia¨. Téngase en cuenta que en esta tipología se excluyen *otras empresas relacionadas, casa matriz y fuentes internas a la empresa.*

Table 5. Probability of Investing in Innovation (ID) and Intensity of Innovation Expenditure per Employee (IE)

	Argentina	Chile	Colombia	Costa Rica	Panama	Uruguay
ID (Probability of investing in innovation IE>0)						
Exporting	0.15	0.11	0.07	-0.03	0.03	0.42
	(0.03)***	(0.08)***	(0.01)***	(0.16)	(0.17)	(0.43)
Foreign Ownership	0.11	-0.01	0.02	0.04	0.16	0.14
	(0.04)***	(0.11)	(0.03)	(0.24)	(0.14)***	(0.06)**
Patent Protection	0.06	0.23	0.10	0.17	0.33	0.29
	(0.06)	(0.16)***	(0.03)***	(0.28)***	(0.37)**	(0.14)**
Size	0.10	0.10	0.11	0.11	0.08	0.17
	(0.01)***	(0.03)***	(0.01)***	(0.05)***	(0.04)***	(0.02)***
IE (Log Innovation expenditure per employee)						
Exporting	0.031	0.07	0.29	-0.07	0.12	0.21
	(0.16)**	(0.18)	(0.07)***	(0.24)	(0.42)	(0.20)
Foreign Ownership	0.59	-0.20	0.88	0.01	0.64	0.33
	(0.17)***	(0.25)	(0.09)***	(0.36)	(0.38)***	(0.25)
Patent Protection	0.22	0.07	0.2	0.52	-0.24	0.05
	(0.24)	(0.23)	(0.15)	(0.29)***	(0.75)	(0.21)
Co-operation in R&D	0.19	0.33	0.24	0.18	1.34	0.57
	(0.15)	(0.23)	(0.1)**	(0.18)	(0.42)***	(0.2)***
Public Financial Support	0.39	0.79	0.81	1.94	-0.16	0.62
	(0.24)	(0.21)***	(0.08)***	(0.84)**	(0.62)	(0.49)
Market information sources (INFO1)	-0.18	-0.16	0.55	0.11	0.41	0.6
	(0.35)	(0.29)	(0.14)***	(0.36)	(0.42)	(0.43)
Scientific Sources (INFO2)	-0.16	-0.01	-0.08	0.39	0.23	-0.15
	(0.24)	(0.31)	(0.17)	(0.22)*	(0.57)	(0.32)
Other Spillovers (INFO3)	0.59	0.44	1.22	-0.17	-1.47	-0.33
	(0.36)*	(0.29)	(0.22)***	(0.32)	(0.74)**	(0.42)
Observations	1192	1151	5934	352	481	813
Wald χ2	44.77***	75.92***	620.63***	33.05***	29.82**	43.40***
Log Pseudo Likelihood	-1927.83	-1732.29	-11976.11	-656.65	-753.69	-1168.62
Wald test of Independence (ρ=0)	5.48**	26.18***	9.23***	38.32***	25.02***	0.1

Notes: Coefficients reported are marginal effects. * 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.

Table 6. Probability of Technological Innovation
(TI: Introduction of Product or Process Innovation)

	Argentina	Chile	Colombia	Costa Rica	Panama	Uruguay
IE_p (predicted Innovation expenditure per employee)	0.26	1.16	0. 43	0.18	0.36	0.52
	(0.04)***	(0.18)***	(0.03)***	(0.06)***	(0.08)***	(0.09)***
Size	0.10	0.09	0.07	0.08	0.06	0.16
	(0.01)***	(0.01)***	(0.01)***	(0.02)***	(0.015)***	(0.02)***
Exporting	0.01	-0.18	-0.04	0.15	-0.06	-0.05
	(0.04)	(0.07)**	(0.02)**	(0.06)**	(0.07)	(0.05)
Foreign Ownership	-0.16	0.22	-0.44	0.11	-0.29	-0.03
	(0.05)***	(0.05)***	(0.04)**	(0.09)	(0.08)***	(0.06)
Observations	1192	1151	5934	352	481	813
Wald $\chi 2$	175.45***	169.47***	466.44****	36.85***	64.49***	188.68***
Log Pseudo Likelihood	-699.76	-592.92	-3361.15	-223.3	-276.49	-422.46
Pseudo R^2	0.14	0.26	0.13	0.08	0.13	0.21
Observed probability	0.58	0.50	0.64	0.47	0.38	0.37
Predicted probability (values at means)	0.59	0.56	0.67	0.47	0.38	0.35

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.

Table 7. The Impact of Innovation on Labor Productivity (Y: Log Sales per Employee)

	Argentina		Chile		Colombia		Costa Rica		Panama		Uruguay	
Technological Innovation (TI_p)	0.24		0.60		1.92		0.63		1.65		0.8	
	(0.14)*		(0.25)**		(0.32)***		(0.76)		(0.55)***		(0.24)***	
IE_p (predicted Innovation expenditure per employee)		0.41		0.20		0.61		0.07		0.69		0.45
		(0.05)***		(0.13)**		(0.07)***		(0.19)		(0.12)***		(0.11)***
Size	0.02	-0.01	0.03	0.06	0.18	0.27	-0.35	-0.29	0.05	0.08	-0.001	0.09
	(0.04)	(0.03)	(0.04)	(0.03)**	(0.04)***	(0.04)***	(0.092)***	(0.06)***	(0.07)	(0.06)	(0.05)	(0.05)*
Non Technological Innovation	0.09	0.06	-0.08	-0.22	0.3	0.31	-0.17	-0.16	0.05	-0.01	-0.09	-0.09
	(0.05)*	(0.05)	(0.10)	(0.08)	(0.09)***	(0.08)***	(0.15)	(0.16)	(0.16)	(0.15)	(0.08)	(0.08)
Capital per employee	0.09	0.08	0.04	-0.02	0.28	0.27			0.03	0.03	0.31	0.30
	(0.01)***	(0.01)***	(0.19)	(0.21)	(0.03)***	(0.03)***			0.01**	0.01**	0.02***	0.02***
Obs.	1192	1192	1151	1151	5934	5934	352	352	481	481	759	759
Fisher	28.84***	36.88***	12.36***	11.94***	39.54***	42.92***	4.67***	4.43	10.23***	12.47***	32.04***	30.49***
R^2	0.17	0.21	0.13	0.14	0.17	0.17	0.1	0.1	0.015	0.2	0.40	0.40

Note: Bootstrapped standard errors in parentheses (100 replications). The variable used to proxy for physical capital is investment made during the period considered for Argentina, Chile, and Panama. Uruguay and Colombia use the stock of physical capital.
* 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.