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The finance of innovation in Latin America

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ABSTRACT

This study contributes to the extant literature on innovation by examining how private companies fund innovation activities and R&D in Latin America. Specifically, this study seeks to identify whether innovative companies exhibit financing patterns different from those of non-innovative ones. In addition, this study aims at gauging the association between innovation and firm features, such as age, bank financing, female participation in ownership, financial constraints, and foreign ownership, among others.

Based on information for Argentina, Colombia, Chile, Mexico, and Peru for 2010, firm size, firm age, financial constraints, and funding sources appear as the main drivers of innovation in Latin American countries. The figures also show that over 60% of the sampled firms displayed a very low or non-existent innovation level. A pending strategic task in Latin America is to increase both the R&D expenditure/GDP ratio and patent activities, and to attract highly-qualified researchers to industry.

1. Introduction

Economic theory has shown that firms operating in competitive markets tend to achieve suboptimal levels of research and development (R&D) investment (Arrow, 1962, chap. 23; Hall, 2002; Hall & Lerner, 2010, chap. 14). The main argument is that the knowledge of producing new products and processes, which is the primary output of R&D, is non-rival. Indeed, to the extent that knowledge cannot be kept secret, the benefits will not be fully appropriated by the firm carrying out the investment. This will lead to an R&D underinvestment, despite the fact that imitation is costly.

On the other hand, R&D differentiates from ordinary investment (Hall, 2002; Hall & Lerner, 2010, chap. 14). First, a very high percentage of R&D investment involves wages and salaries of highly-qualified human capital. Due to its intangible nature, human capital is very different from investment in physical assets, such as inventory goods or plant and equipment, in the sense that it may be partially lost as some highly-trained employees leave or are fired from the firm. Second, R&D investment is associated with a high degree of uncertainty regarding its final outcome and economic retribution. This state of uncertainty tends to be particularly severe at early stages of an investment project, so that traditional valuation methods render inappropriate to assess its profitability.

Alternatives ways to mitigate the underinvestment problem are an intellectual property system, government support of R&D, tax incentives, and encouragement of research partnerships. Such interventions are usually justified by the fact that the social return to R&D exceeds its private level. However, when the innovator and financier are different entities, there is an additional gap: the discrepancy between the private return and the cost of capital. Regarding this funding gap, Hall (2002) concludes that: (i) venture capital only partly mitigates the high cost of capital faced by small and new innovative firms; (ii) large firms tend to rely on internal funds for financing innovation; and, (iii) venture capital does not solve the funding gap completely, particularly in countries where public equity markets are not highly developed.

The purpose of this study is to contribute to the extant literature by examining how private companies fund innovation and R&D activities in Latin America. The information source is the World Bank's World Enterprise Survey 2006 and 2010. Specifically, this study seeks to identify whether innovative companies exhibit financing patterns different from those of non-innovative ones. In addition, this study aims at gauging the association between innovation and firm features, such as age, size, female participation in ownership, financial constraints, and foreign ownership, among others.

Related research by Barona, Rivera, and Aguilera (2015)—based on the World Enterprise Survey 2010—showed that innovative firms in Colombia tend to rely heavily on retained earnings and bank debt to fund

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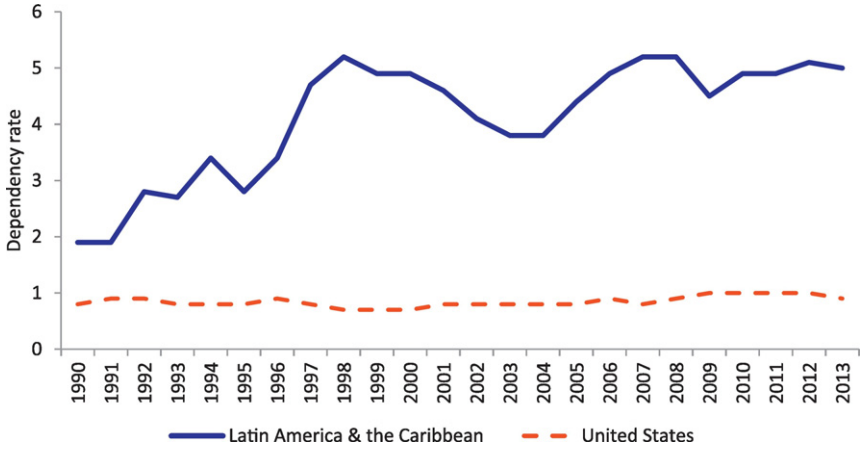

Fig. 1. Dependency rate. Note: The dependency rate is the number of patents requested by non-residents to that of residents. A value >1 indicates the preeminence of patents applied for by non-residents, while a value between 0 and 1 indicates the preeminence of patents applied for by residents. The information source is the Ibero-American and Inter-American Network on Science and Technology Indicators, www.ricyt.org.

R&D activities,[1] whereas non-innovative firms on trade credit (i.e., credit from customers and suppliers). In addition, Barona et al. found that innovation in Colombia is positively associated with firm size.

In another strand of the literature on innovation in Latin America, Hall and Maffioli (2008) analyzed the impact of government technology development funds (TDF) on innovation in Latin American countries. By focusing on Argentina, Brazil, Chile, and Panama, the authors concluded that TDF do not crowd out private investment, and that such funds have a positive impact on R&D intensity. However, the empirical analysis did not show a very statistically significant impact of TDF on patents, new products sales or increases in firm productivity. Hall and Maffioli speculate that these inconclusive findings may have been due to the short evaluation period.

Other examples of recent contributions to the innovation literature in Latin America are Benavente, Crespi, Garone, and Maffioli (2012), who analyzed the impact of national research funds in Chile (FONDECYT) on principal researchers' quantity (number) and quality (citations) of their academic publications; Giuliani (2013), who focused on a wine cluster in Chile to measure network dynamics; Crespi, Giuliodori, Giuliodori, and Rodriguez (2016), who studied a tax-credit scheme for promoting innovation investment at the firm level in Argentina; and, Alvarez (2016), who found that information and communication technology (ICT) contributes positively to innovation and productivity in the services industry in Chile.

This article is in line with Barona et al.'s (2015), but it extends it in various ways by considering a more comprehensive sample of Latin American countries and alternative definitions of firm innovation. Its organization is as follows. In order to provide some background information, Section 2 presents figures on innovation in Latin America and the Caribbean and in Organization for Economic Co-operation and Development (OECD) countries. Section 3 presents the data and some descriptive statistics. Section 4 in turn focuses on the estimation process and discussion of the empirical results, while Section 5 summarizes the main findings and draws some policy implications of this research.

2. Some figures on invention in Latin America and the Caribbean

The Ibero-American and Inter-American Network on Science and Technology Indicators, www.ricyt.org, gathers information on science and technology indicators of countries belonging to the Americas and the Iberian Peninsula. For illustration purposes, Figs. 1 and 2, respectively, depict the dependency rate and the invention coefficient of Latin America and the Caribbean (LAC) and the United States (US) for the period of 1990–2013. The dependency rate is the number of patents requested by non-residents to that of residents, whereas the invention coefficient is the number of patents per 100,000 inhabitants.

As can be seen from Fig. 1, the US dependency rate fell into the (0, 1) range during the sample period, suggesting the preeminence of patents applied for by country residents. This pattern contrasts with that of the LAC economies where the dependency rate averaged 4.1 over 1990–2013. Fig. 2 in turn depicts the sizeable gap between the invention coefficients of the US and LAC: during 1990–2013 the number of patents per 100,000 inhabitants averaged 60.2 in the US as opposed to 1.7 in the LAC economies.

The above figures are a reflection of the much limited resources allocated to R&D in LAC economies as opposed to the US (Fig. 3). Table 1 provides figures of R&D expenditure to GDP during 2007–2013 for Argentina, Brazil, Chile, Colombia, Mexico, the United States, Ibero-America, Latin America & the Caribbean, and OECD. While, on average, the US allocated 2.7% of GDP to R&D during 2007–2013, Latin American and the Caribbean only averaged 0.70% of GDP over that period. OECD countries in turn averaged a slightly lower figure than the US during 2007–2013: 2.31% of GDP. Among Latin American countries, Brazil stood out as the one that invested the most on R&D: a maximum of 1.2% in 2013, with an average of 1.1% during 2007–2013. For the sake of illustration, longer time series of US and LAC R&D expenditure/GDP series are provided in Fig. 4 for the period of 1990–2013.

R&D usually requires of highly specialized human capital. As can been seen from Fig. 4, there was a sizeable difference between the number of Full-Time Equivalent (FTE) researchers per 1000 labor force in the US and LAC economies in the period of 1990–2012. Specifically, the number of FTE per thousand labor force in the US steadily increased from 5.7 in 1990 to 7.9 in 2012, averaging 6.9 in that time period. Meanwhile, in the LAC economies, such an indicator rose from only 0.5 in 1990 to 0.8 in 2012, averaging 0.6 in 1990–2012. Fig. 4 also shows that the number of FTE per 1000 labor force in OECD countries kept the pace with that of the US during 1990–2012, reaching an average of 6.0 in that time period.

Moreover, figures from the OECD Main Science and Technology Indicators suggest that the gross domestic expenditure on R&D (GERD) receives more government support in Latin America than in the US and the OECD countries. For instance, in 2014 the percentage of GERD financed by the government in Chile and Mexico was, respectively, 44% and 72%,[2] as opposed to 27% and 26% in the US and OECD countries,

[1] This is also documented in a review article by Kerr and Nanda (2014).

[2] Argentina's government contributed 76% of GERD in 2013.

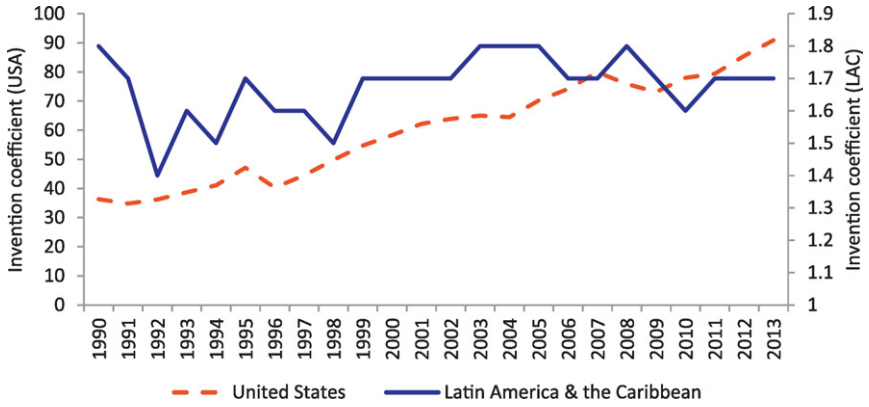

Fig. 2. Invention coefficient. Note: The invention coefficient is the number of patents per 100,000 inhabitants. The information source is the Ibero-American and Inter-American Network on Science and Technology Indicators, www.ricyt.org.

respectively. In the latter, industry plays a much more important role in financing innovation. Indeed, in 2014 the percentage of GERD financed by the US and OECD industry reached 62% and 61%, respectively, as opposed to 32% and 20% in Chile and Mexico, respectively. (In Argentina it reached 20% in 2013).

Latin America also lags behind developed nations in the resources allocated to R&D at higher-education institutions. The OECD Main Science and Technology Indicators show, for instance, that the higher education expenditure on R&D (HERD) as a percentage of GDP reached 0.37% and 0.43% in the US and OECD countries, respectively, in 2014. By contrast HERD to GDP reached only 0.18% in Argentina, 0.15% in Chile, and 0.14% in Mexico in 2014.

3. Data

The information source is the World Bank's Enterprise Surveys Indicator Database, https://www.enterprisesurveys.org. We utilize the Central America plus Ecuador Panel Data Enterprise Surveys Indicator Database, which contains information for 2006 and 2010, and full data for selected countries for 2010. In particular, the full 2010 data contains specific questions on R&D and other innovation initiatives. The data is described below.

3.1. Enterprise Surveys Indicator Database

From the World Bank's Central America plus Ecuador Panel Data Enterprise Surveys Indicator Database, we selected Latin American countries for the years 2006 and 2010. Details of specific countries and number of observations, per country and year, are provided in Table 2. Information for Brazil in the fore-mentioned database is available only for 2009.

Descriptive statistics of a set of variables regarding firm characteristics, financing sources and use of technology are provided in Table 3 for Argentina, Colombia, Chile, Mexico, Peru, and Latin America as a whole for the years 2006 and 2010. Except for firm's age, all the other variables are measured in percentages.

As can be seen from the table, the mean firm's age (car1) in Latin America was 22 years in 2006 and rose to 25 years in 2010. The oldest firms among the depicted countries were located in Argentina and Chile: 29 and 27 years old, respectively, in 2006 and 33 and 32 years old, respectively, in 2010.

On average, about 60% and 57% of Latin America's firm investment was financed with internal sources (fin1) in 2006 and 2010, respectively. Bank financing (fin2) in turn provided about 22% in 2006 and 24% in 2010. Among the depicted countries, Mexico was the one with the largest internal financing: 73% in 2006 and 62% in 2010.

Regarding technological variables, only 18% of Latin American firms had an ISO certification (t1)[3] in 2006, whereas such a figure rose to 25% in 2010. Within the reported countries, the largest percent increase in t1 between 2006 and 2010 was experienced by Colombia: 12% in 2006 versus 31% in 2010. On the other hand, a small percentage of Latin American firms used technology licensed by foreign firms (t4): 13% in 2006 and 16% in 2010. By contrast, a large percentage of firms used email to communicate with clients/suppliers (t6): 78% in 2006 and 89% in 2010. Nevertheless, usage of the web to communicate with clients/suppliers (t5) was not as widespread: 43% in 2006 and 60% in 2010.

When comparing Brazil's mean figures for 2009 with those of Latin America in 2010, it can be seen that Brazil exhibited noticeably lower means for exporter, private-foreign ownership (car3), financial statements reviewed by an external auditor (t2), and use of technology licensed from foreign firms (t4). However, Brazil presented higher means for female participation in ownership (gend1) and use of web and email to communicate with clients/suppliers (t5 and t6, respectively).

Table 4a in turn provides descriptive statistics of the same variables reported in Table 2 by firm size —small, medium, and large—for 2010. Noticeably differences arise for variables such as an ISO certification (t1), financial statements reviewed by an external auditor (t2), exporting firms (exporter), and private-foreign ownership (car3). Table 4b in turn shows that the hypothesis of an ISO certification and firm size being independent is strongly rejected.

3.2. Full data for selected countries

Table 5 presents some innovation indicators for Argentina, Colombia, Chile, Mexico, and Peru in 2010. The full data set for Brazil corresponds to 2009 and it does not include innovation-related questions. Hence we concentrate on the fore-mentioned 5 countries. As can be seen from the table, about one third of the sampled firms of each country exhibited a non-zero expenditure on R&D activities. However, the amount on such activities represented a relatively low share of total annual sales: 2.4% on average for the 5 countries, with a maximum of 3.1% for Colombia and a minimum of 1.6% for Chile. On the other hand, on average 25% of the sampled firms introduced improved processes and 22% launched products (good or services) that were also new to their industry in the past 3 years. In these two categories, Peru stood out as the most innovative with corresponding figures of 29% and 27%. On the other hand the percentage of firms that filed patent/trademark/copyright in last 3 years in the manufacturing sectors

[3] An International Organization for Standardization (ISO) certification is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose. However, an ISO certification is not a license that permits an economic activity. (Source: http://www.iso.org).

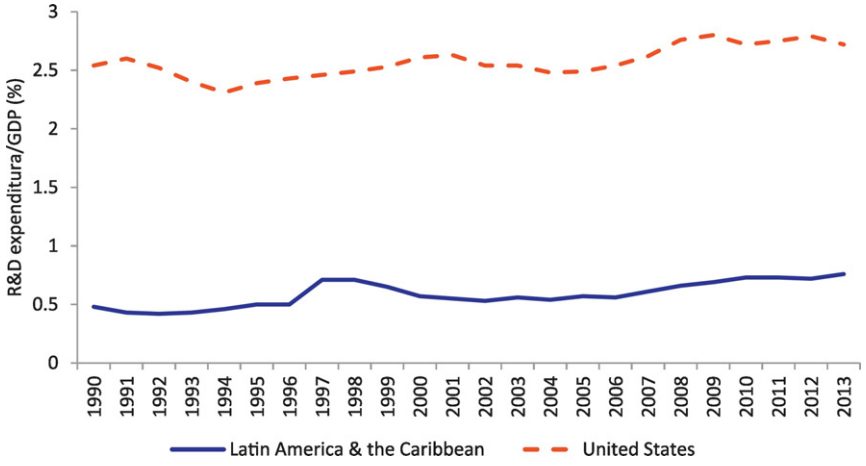

Fig. 3. R&D expenditure to GDP: 1990–2013.
Source: Ibero-American and Inter-American Network on Science and Technology Indicators, www.ricyt.org.

of Argentina, Colombia, Chile, Mexico, and Peru reached 21.5%, 20.7%, 17.0%, 17.4%, 20.0%, respectively. (This information is unavailable for firms of other economic sectors).

As a matter of comparison, evidence reported for the US shows that manufacturing firms exhibit considerably more patenting activity than non-manufacturing ones. For instance, Author, Dorn, Hanson, Shu, and Pisano (2016) report that around 19% of 36,273 firms covered by Compustat along the period of 1975–2014 showed patenting activity. In turn 72% of the firms with patents along that time period belonged to the manufacturing sector. On average, the global R&D expenditure to global sales of manufacturing firms reached 4.5% during 1975–2014. Such a figure clearly exceeds those reported here, where Colombia exhibits the largest R&D expenditure/sales ratio with 3.1% and Chile the smallest, with 1.6%.

On the other hand, a moderate percentage of the sampled firms cooperated on innovation with other firms and/or research and technology institutions in the past 3 years. The largest figure is exhibited by Chile, with around 18%, whereas the smallest one by Mexico, with 10.5%. In addition, innovation was financed primarily with private funds, as public support only represented around a 9%, on average. Moreover, Table 5 shows that over 70% of the sampled firms of each country belong to the manufacturing sector and, with the exception of Mexico and Peru, <10% of them are publicly listed.

4. Methodology and results

The empirical results of this section are based on a latent regression of the form

$$y^* = \mathbf{x}'\boldsymbol{\beta} + \varepsilon \tag{1}$$

Table 1
R&D expenditure to GDP (%).
Sources: Ibero-American and Inter-American Network on Science and Technology Indicators, www.ricyt.org, and OECD Main Science and Technology Indicators, http://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#.

Country/region	2007	2008	2009	2010	2011	2012	2013	Average
Argentina	0.40	0.42	0.51	0.51	0.53	0.61	0.62	0.51
Brazil	1.08	1.12	1.12	1.15	1.14	1.15	1.23	1.14
Chile	0.31	0.37	0.35	0.33	0.35	0.36	0.38	0.35
Colombia	0.18	0.19	0.19	0.19	0.20	0.20	0.25	0.20
Mexico	0.36	0.40	0.43	0.45	0.42	0.43	0.49	0.43
United States	2.62	2.76	2.80	2.72	2.75	2.79	2.72	2.74
Ibero-America	0.83	0.89	0.90	0.90	0.88	0.85	0.88	0.88
Latin America & the Caribbean	0.61	0.66	0.69	0.73	0.73	0.72	0.76	0.70
OECD-total	2.22	2.29	2.34	2.30	2.33	2.34	2.37	2.31

where y^* is an unobservable index variable, $\mathbf{x}$ is a vector of explanatory variables, $\boldsymbol{\beta}$ is a vector of parameters, and ε is an error term (see, for instance, Liu, 2015, chap. 3 and 11). For the binary case (Section 4.1), $y = 1$ (i. e, innovative firm) if $y^* > 0$, and $y = 0$ (i.e., non-innovative firm) if $y^* \le 0$. For the ordered case where y denotes a firm innovation level, which ranges from 1 to J (Section 4.2), $y = 1$ if $y^* \le \alpha_1$; $y = 2$ if $\alpha_1 < y^* \le \alpha_2$, ..., $y = J$ if $\alpha_{J-1} \le y^*$, such that $\alpha_1 < \alpha_2 < \ldots < \alpha_{J-1}$ are the threshold parameters or cutoffs.

For binary data, the odds ratio of a logit model is given by

$$\frac{p}{1-p} = \frac{1 + e^{\mathbf{x}'\boldsymbol{\beta}}}{1 + e^{-\mathbf{x}'\boldsymbol{\beta}}} = e^{\mathbf{x}'\boldsymbol{\beta}} \tag{2}$$

The odds ratio represents the probability of success or having an event, p, to the probability of failure or not having an event, $(1 - p)$. By taking natural logarithm of both sides of Eq. (2), one obtains the logistic regression model

$$\ln\left(\frac{p}{1-p}\right) = \mathbf{x}'\boldsymbol{\beta} = \beta_1 + \beta_2 X_2 + \ldots + \beta_k X_k \tag{3}$$

For the ordered model, $\Pr(y < j) \equiv p_j = \Pr(\mathbf{x}'\boldsymbol{\beta} + \varepsilon < \alpha_j) = \Pr(\varepsilon < \alpha_j - \mathbf{x}'\boldsymbol{\beta})$ so that the odds of being at or below category j is given by

$$\frac{p_j}{1-p_j} = \frac{1 + e^{\alpha_j - \mathbf{x}'\boldsymbol{\beta}}}{1 + e^{-(\alpha_j - \mathbf{x}'\boldsymbol{\beta})}} = e^{\alpha_j - \mathbf{x}'\boldsymbol{\beta}}, \quad j = 1, \ldots, (J-1) \tag{4}$$

and the ordinal logistic regression can be represented by

$$\ln\left(\frac{p_j}{1-p_j}\right) = \alpha_j - \mathbf{x}'\boldsymbol{\beta} = \alpha_j - (\beta_1 + \beta_2 X_2 + \cdots + \beta_k X_k), \tag{5}$$

$j = 1, \ldots, (J-1)$

4.1. Innovation as a binary variable

In the spirit of Barona et al. (2015), we define an innovative firm as one that spent a non-zero amount on R&D activities and responded "Yes" to at least one of the following questions: introduced improved products (goods or services) in the last 3 years (LACe1); introduced new/significantly improved products new to the market in the last 3 years (LACe3); introduced new/significantly improved process for producing/supplying products in the last 3 years (LACe4); introduced new/significantly improved processes also new to the industry in the last 3 years (LACe5); cooperated on innovation with other enterprises/science and technology institutions in the last 3 years (LACe9),

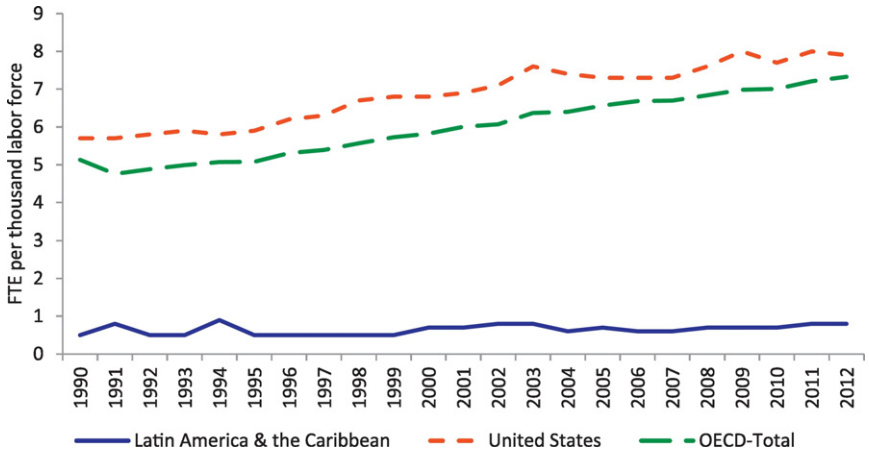

Fig. 4. Highly-qualified human capital: FTE per thousand labor force during 1990–2012. Note: FTE stands for Full-Time Equivalent researchers. The data sources are the Ibero-American and Inter-American Network on Science and Technology Indicators, www.ricyt.org, and the OECD Main Science and Technology Indicators, http://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#.

received any public support for innovation-related activities in the last 3 years (LACe10), or filed for patent/trademark/copyright in last 3 years (LACe8c).[4]

Frequency tables of size versus the condition of being innovative are shown in Table 6. As can be seen, there is a positive association between innovation and size, as measured by Cramér's V and the statistical significance of the chi-squared test. This is specially so for Chile and Mexico. Altogether, for the 5 countries, it is apparent that medium and large firms are the most innovative ones in number.

Table 7 in turn presents statistics of working capital funding versus non-innovative and innovative firms. As can been, firms mostly fund working capital with internal resources and trade credit (i.e., credit from customers and/or suppliers), and to a lesser extent with bank borrowing. Differences in funding sources according to firm type are quantified by the Mann-Whitney test for independence of two samples. Surprisingly, in Chile there are no statistical differences across firms. Moreover, as the figures show for the 5 countries, innovative firms do not necessarily have a greater share of internal resources allocated to working capital. For instance, in Mexico, 64% of working capital in non-innovative firms was funded by internal resources, as opposed to 55% in innovative firms. In addition, the figures show that innovative firms tend to rely more heavily on bank borrowing than non-innovative ones. For instance, in Peru 34% of working capital is funded with bank borrowing, as opposed to 27% of non-innovative firms.

4.2. Innovation as an ordered variable

We define 4 innovation levels: high, medium, moderate, low or none, which are defined in decreasing order as follows:

- High (4): Expenditure in R&D > 0 and answered 'Yes' to at least one of these questions: introduced new/significantly improved products (goods or services) new to the market in the last 3 years (LACe3); introduced new/significantly improved processes also new to the industry in the last 3 years (LACe5); filed for patent/trademark/copyright in last 3 years (LACe8c).
- Intermediate high (3): Expenditure in R&D > 0, answered 'Yes' to at least one of these questions: introduced improved products (goods or services) in the last 3 years (LACe1); and, introduced new/significantly improved processes for producing/supplying products in the last 3 years (LACe4), but answered 'No' to LACe3, LACe5, and LACe8c.

[4] Barona, Rivera, and Aguilera do not consider either LACe9 or LACe10 in their definition of an innovative firm. By contrast we deem relevant to account for firm cooperation and public funding reception as well when pursuing innovation initiatives. As stated at the end of Section 2, public funding plays an important role to R&D in Latin America.

Table 2
Selected countries from the Enterprise Surveys Indicator Database.
Source: Central America Plus Ecuador Panel Data Enterprise Surveys Indicator Database.

Country	wbcode	No. Obs	% sample
2006			
Argentina	ARG	1063	10.31
Bolivia	BOL	613	5.95
Chile	CHL	1017	9.87
Colombia	COL	1000	9.7
Ecuador	ECU	658	6.38
Guatemala	GTM	522	5.06
Honduras	HND	436	4.23
Mexico	MEX	1480	14.36
Nicaragua	NIC	478	4.64
Panama	PAN	604	5.86
Peru	PER	632	6.13
Paraguay	PRY	613	5.95
El Salvador	SLV	693	6.72
Venezuela	VEN	500	4.85
	Total	**10,309**	**100**
2010			
Argentina	ARG	1054	9.35
Belize	BLZ	150	1.33
Bolivia	BOL	362	3.21
Chile	CHL	1033	9.16
Colombia	COL	942	8.35
Costa Rica	CRI	538	4.77
Dominica	DMA	150	1.33
Dominican Republic	DOM	360	3.19
Ecuador	ECU	366	3.25
Grenada	GRD	153	1.36
Guatemala	GTM	590	5.23
Guyana	GUY	165	1.46
Honduras	HND	360	3.19
Jamaica	JAM	376	3.33
Santa Lucia	LCA	150	1.33
Mexico	MEX	1480	13.12
Nicaragua	NIC	336	2.98
Panama	PAN	365	3.24
Peru	PER	1000	8.87
Paraguay	PRY	361	3.20
Salvador, El	SLV	360	3.19
Suriname	SUR	152	1.35
St. Vincent & Grenadines	VCT	154	1.37
Venezuela	VEN	320	2.84
	Total	**11,277**	**100**

Table 3
Descriptive statistics of Latin America and selected countries.
The data source is the Central America Plus Ecuador Panel Data Enterprise Surveys Indicator Database.

Variable	2006						2009	2010					
	Argentina	Colombia	Chile	Mexico	Peru	Latin America	Brazil	Argentina	Colombia	Chile	Mexico	Peru	Latin America
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
car1	28.6	16.9	26.8	18.3	19.4	21.6	21.6	33.0	23.8	31.7	23.9	21.5	25.0
car2	88.2	97.6	93.6	93.7	90.5	91.1	94.7	88.0	92.7	89.1	91.1	90.5	88.2
car3	11.6	2.0	5.7	5.6	9.4	8.4	4.7	11.7	7.0	10.6	7.8	9.3	10.5
exporter	28.3	10.3	13.3	9.0	19.1	14.3	7.0	27.6	18.0	16.9	15.4	23.0	16.4
fin1	69.0	47.4	55.9	73.0	44.9	59.5	49.8	61.4	43.3	55.3	61.7	37.0	56.6
fin2	5.3	33.6	30.2	7.5	41.1	22.7	29.4	19.7	33.1	29.2	12.5	46.7	24.8
fin3	4.7	7.8	7.4	12.1	9.2	7.7	14.1	12.3	11.9	9.3	16.3	8.2	9.9
fin15	98.4	97.1	96.3	54.8	93.8	87.8	97.9	98.7	99.4	96.8	65.5	95.1	89.4
gend1	30.7	46.8	35.2	24.3	33.8	36.0	54.9	30.3	42.2	27.2	25.9	27.1	34.2
obst1	15.9	14.5	11.6	9.5	9.5	12.4	9.8	13.9	16.1	13.0	10.4	7.6	12.3
t1	25.0	11.9	26.0	23.9	14.9	18.3	19.1	34.5	31.3	35.1	25.4	25.4	24.5
t2	68.2	54.0	47.0	31.1	33.0	53.7	22.6	73.7	62.2	55.4	60.1	37.5	63.6
t3	75.1	69.0	71.1	74.2	72.0	71.0	79.2	71.9	69.3	71.6	73.3	70.9	71.6
t4	15.4	6.6	15.1	10.1	10.6	12.7	14.8	18.6	12.1	17.9	15.6	14.5	16.2
t5	73.3	43.7	68.5	36.7	43.2	45.9	63.7	83.2	69.7	75.0	67.5	66.1	61.4
t6	96.2	87.3	91.5	63.5	91.8	79.7	94.6	98.0	99.0	95.5	91.3	93.9	89.8

Notes: Variable definitions are as follows: car1: firm's age (years); car2: ownership - private domestic (%); car3: ownership - private foreign (%); exporter: exporter (exporters vs. non exporters); fin1: internal finance for investment (%); fin2: bank finance for investment (%); fin3: supplier credit financing (%); fin15: % of firms with a checking or savings account: gend1: % of firms with female participation in ownership: obst1: obstacles: access to finance; t1: % of firms with ISO certification ownership; t2: % of firms with annual financial statement reviewed by external auditor; t3: capacity utilization (%) (Manufacturing only); t4: % of firms using technology licensed from foreign companies; t5: % of firms using the web to communicate with clients/suppliers; t6: % of firms using email to communicate with clients/suppliers.

- Moderate (2): Expenditure in R&D > 0, answered 'Yes' to least one of these questions: cooperated on innovation with other enterprises/science and technology institutions in the last 3 years (LACe9); and, received any public support for innovation-related activities in the last 3 years (LACe10), but answered 'No' to LACe1, LACe2, LACe3, LACe4, LACe5, and LACe8c.
- Low or none (1): all remaining firms.

Table 4a
Descriptive statistics by firm size: Latin America in 2010.
The data source is the Central America Plus Ecuador Panel Data Enterprise Surveys Indicator Database.

Variable	Small (<20 employees)			Medium (20–99 employees)			Large (>100 employees)		
	Obs	Mean	Std. dev.	Obs	Mean	Std. dev.	Obs	Mean	Std. dev.
car1	4128	19.8	14.7	4080	24.6	17.5	2907	32.9	23.8
car2	4179	94.3	21.9	4110	90.0	28.2	2937	76.8	39.7
car3	4179	4.3	19.1	4110	8.4	26.0	2937	22.0	38.9
exporter	4181	6.7	25.0	4121	14.9	35.6	2939	32.6	46.9
fin1	1578	60.0	42.6	2347	56.5	42.7	2195	54.2	42.6
fin2	1578	20.7	35.0	2347	24.4	36.7	2195	28.1	38.2
fin3	1578	9.0	24.1	2347	10.3	25.8	2195	10.2	25.1
fin15	4171	86.0	34.8	4120	91.0	28.6	2939	92.0	27.2
gend1	4168	39.0	48.8	4074	34.6	47.6	2848	26.7	44.2
obst1	4133	16.3	36.9	4053	11.8	32.3	2896	7.2	25.8
t1	4073	8.9	28.5	3921	23.0	42.1	2803	49.2	50.0
t2	4126	45.4	49.8	4078	65.9	47.4	2927	86.2	34.5
t3	1912	67.6	21.8	2180	71.0	19.5	1820	76.3	16.8
t4	2140	7.1	25.6	2352	15.2	35.9	1863	28.0	44.9
t5	4196	38.1	48.6	4120	66.2	47.3	2943	87.8	32.8
t6	4194	79.0	40.7	4124	94.5	22.9	2944	98.4	12.4

Notes: Variable definitions are as follows: car1: firm's age (years); car2: ownership - private domestic (%); car3: ownership - private foreign (%); exporter: exporter (exporters vs. non exporters); fin1: internal finance for investment (%); fin2: bank finance for investment (%); fin3: supplier credit financing (%); fin15: % of firms with a checking or savings account: gend1: % of firms with female participation in ownership: obst1: obstacles: access to finance; t1: % of firms with ISO certification ownership; t2: % of firms with annual financial statements reviewed by external auditor; t3: capacity utilization (%) (Manufacturing only); t4: % of firms using technology licensed from foreign companies; t5: % of firms using the web to communicate with clients/suppliers; t6: % of firms using email to communicate with clients/suppliers.

The high level refers to firms that invested on R&D and introduced novel products and/or production processes in their industries, and/or whose R&D activities translated into a patent in the last 3 years. The intermediate-high level involves firms that spent on R&D and improved their products and/or production processes, but which are not included in the upper level. The moderate level refers to firms which spent on R&D and cooperated on innovation and/or received public support for innovation, but whose efforts did not translate into better products/processes in the 3 last years. In practice, this category would include firms unsuccessful in innovation and/or firms whose R&D activities take longer to embody in new products/processes. Finally, the low- or none-innovation level gathers all remaining firms which are not included in the upper categories.

Descriptive statistics of innovation category per country are presented in Table 8. As can be seen, in the five countries, over 60% of the sampled firms fall into the lowest innovation level. The following levels with highest percentages are, in decreasing order, intermediate high, moderate, and high. Among the sampled countries, Colombia and Peru exhibit the highest percentage of firms in the upper two levels: 24% and 23.8%, respectively, while Chile and Mexico, the lowest: 14.8% and 15.6%, respectively.

Estimation results of binary and ordered logit models are reported in Table 9 for each country. The dependent variable is a binary one indicating whether the firm is innovative and an ordered variable indicating

Table 4b
ISO certification versus size: Latin American firms in 2010.

		Firm size			Total
		Small	Medium	Large	
ISO certification	No	3710	3018	1424	8152
	%	91.09	76.97	50.8	75.5
	Yes	363	903	1379	2645
	%	8.91	23.03	49.2	24.5
	Total	4073	3921	2803	10,797
	%	100	100	100	100

Pearson's $\chi^2(2) = 1.5e + 03$; Pr = 0.000; Cramér's V = 0.37.
Notes: (1) Pearson's chi-squared statistic is computed for the hypothesis that the rows and columns in a two-way table are independent. (2) Cramér's V is a measure of association between two nominal variables, giving a value between 0 and 1. It is based on Pearson's chi-squared statistic.

Table 5
Innovation indicators in selected Latin American countries: 2010.

Indicator	Argentina	Colombia	Chile	Mexico	Peru	Average
Sampled firms	1054	942	1033	1480	1000	1102
Firms w/R&D expenditure >0 (%)	34.5	39.9	27.5	26.5	37.5	33.2
R&D expenditure/sales (%)	2.9	3.1	1.6	2.5	2.0	2.4
Firms with improved products in last 3 years (%)	54.3	46.0	43.3	37.9	49.3	46.2
Firms with improved products also new to industry in last 3 years (%)	28.7	24.6	23.8	18.6	29.1	25.0
Firms with improved processes in last 3 years (%)	42.8	43.0	37.3	31.4	46.4	40.2
Firms with improved processes also new to industry in last 3 years (%)	20.5	22.6	22.9	18.1	27.0	22.2
Firms that cooperated on innovation in last 3 years (%)	17.8	17.2	17.9	10.5	14.9	15.7
Firms that filed patent/trademark/copyright in last 3 years (%)	21.5	20.7	17.0	17.4	20.0	19.3
Firms that have patents abroad (%)	9.1	5.9	8.1	9.5	7.0	7.9
Firms that have patents domestically (%)	21.3	22.3	43.1	28.4	33.2	29.7
Public support for innovation in last 3 years (%)	12.3	10.6	10.4	7.1	3.8	8.8
Firms in manufacturing sector (%)	75.0	74.8	75.0	77.8	76.0	75.7
Publicly listed company (%)	2.9	2.2	6.0	10.5	10.5	6.4

Note: The innovation-related statistics are based on the following questions: introduced improved products (goods or services) in the last 3 years (LACe1); introduced new/significantly improved products new to the market In the last 3 years (LACe3); introduced new/significantly improved process for producing/supplying products In the last 3 years (LACe4); introduced new/significantly improved processes also new to the industry (LACe5) in the last 3 years; cooperated on innovation with other enterprises/science and technology institutions In the last 3 years (LACe9), and received any public support for innovation-related activities in the last 3 years (LACe10).

Table 6
Innovation versus firm size in 2010.

(a) Argentina

Innovative	Firm size			Total
	Small	Medium	Large	
No	273	244	186	703
%	73.98	64.38	60.78	66.70
Yes	96	130	120	351
%	26.02	35.62	39.22	33.3
Total	369	379	306	1054
%	100	100	100	100

Pearson $\chi^2(2) = 14.55$; Pr = 0.001; Cramér's V = 0.118

(b) Colombia

Innovative	Firm size			Total
	Small	Medium	Large	
No	185	221	172	578
%	66.07	63.14	55.13	61.36
Yes	95	129	140	364
%	33.93	36.86	44.87	38.64
Total	280	350	312	942
%	100	100	100	100

Pearson $\chi^2(2) = 8.20$; Pr = 0.017; Cramér's V = 0.093

(c) Chile

Innovative	Firm size			Total
	Small	Medium	Large	
No	276	257	226	759
%	86.79	68.53	66.47	73.48
Yes	42	118	114	274
%	13.21	31.47	33.53	26.52
Total	318	375	340	1033
%	100	100	100	100

Pearson $\chi^2(2) = 42.20$ Pr = 0.000; Cramér's V = 0.202

(d) Mexico

Innovative	Firm size			Total
	Small	Medium	Large	
No	317	265	521	1103
%	87.57	75.50	67.93	74.53
Yes	45	86	246	377
%	12.43	24.50	32.07	25.47
Total	362	351	767	1480
%	100	100	100	100

Pearson $\chi^2(2) = 50.21$ Pr = 0.000; Cramér's V = 0.184

(e) Peru

Innovative	Firm size			Total
	Small	Medium	Large	
No	260	237	145	642
%	74.29	62.70	53.31	64.20
Yes	86	141	127	358
%	25.71	37.30	46.69	35.08
Total	350	378	272	1000
%	100	100	100	100

Pearson $\chi^2(2) = 28.33$ Pr = 0.000; Cramér's V = 0.168

Note: An innovative firm is one that spent a non-zero amount on R&D activities and responded "Yes" to at least one of the following questions: introduced improved products (goods or services in the last 3 years (LACe1); introduced new/significantly improved products new to the market in the last 3 years (LACe3); introduced new/significantly improved process for producing/supplying products in the last 3 years (LACe4); introduced new/significantly improved processes also new to the industry in the last 3 years (LACe5); cooperated on innovation with other enterprises/science and technology institutions in the last 3 years (LACe9), received any public support for innovation-related activities in the last 3 years (LACe10), or filed for patent/trademark/copyright in last 3 years (LACe8c).

the innovation degree, respectively. Explanatory variables are the natural logarithm of firm age, internal, bank, and trade credit funding dummies, access to finance as an obstacle (1: No obstacle; 2: Minor obstacle; 3: Moderate obstacle; 4: Major obstacle; 5: Very severe obstacle), firm size (1: small, 2: medium and 3: large), percentage of foreign private property (individuals, firms or organizations), and a dummy indicating whether the top manager is female.

Each funding dummy is defined as 1 if the funding percentage of a particular firm is greater than the median across all sampled firms of a given country. For instance, if the median value of bank funding is 30%, the corresponding dummy takes on the value of 1 for all firms whose bank funding is greater than such a figure. The reason for using such dummies is that they usually have more explanatory value than the percentage level of each funding category.

Altogether for the binary and ordered logit models, the estimation results show that firm age, bank funding, and firm size have a positive impact on innovation. For instance, in Colombia the odds of being an innovative firm increase by 1.4 when log-age increases by 1 unit (i.e., about a 2.8-year increase in firm age) in the bivariate model. In the ordered model in turn, the odds of being beyond a particular level of innovation increase by 1.3 if log-age increases by 1 unit. Regarding top manager gender, this variable seems to matter only in Chile. In particular, for the bivariate case, the odds of being an innovative firm in Chile increase by 1.9 if the top manager is female. In the ordered model in turn, the odds of being beyond a particular level of innovation increase by 1.8 if the top manager is female.

Working capital funding from customers and suppliers (trade credit) in turn is only relevant to innovation in Colombia and Mexico. In particular, this funding source is associated with less innovative firms in the former as opposed to the latter.[5] Moreover, foreign property does not have any statistically significant impact on innovation in any of the 5

[5] This outcome is also reported by Barona et al. (2015) in the case of Colombia.

Table 7
Innovation versus working capital funding in 2010.

Firm type	Argentina			Colombia		
	Working capital funding (%)			Working capital funding (%)		
	Internal	Bank	Trade credit	Internal	Bank	Trade credit
Non-innovative	59.14	11.39	26.17	37.12	19.41	38.16
Innovative	55.45	13.33	28.05	40.19	23.10	30.86
Total	57.91	12.04	26.8	38.31	20.84	35.33
p-Value MW test (H_0: non-innovative = innovative)	0.07	0.01	0.08	0.06	0.02	0.00

Firm type	Chile			Mexico			Peru		
	Working capital funding (%)			Working capital funding (%)			Working capital funding (%)		
	Internal	Bank	Trade credit	Internal	Bank	Trade credit	Internal	Bank	Trade credit
Non-innovative	54.39	19.17	23.07	63.76	8.34	23.66	44.43	26.98	23.79
Innovative	54.50	20.47	21.43	54.73	12.18	28.45	36.08	34.29	23.78
Total	54.42	19.52	22.63	61.45	9.32	24.88	41.43	29.61	23.79
p-Value MW test (H_0: non-innovative = innovative	0.96	0.11	0.74	0.00	0.00	0.00	0.00	0.00	0.19

Notes: (1) Percentages are mean values across firms within countries. (2) The Mann-Whitney (MW) test corresponds with the two-sample Wilcoxon rank-sum test. (3) An innovative firm is one that spent a non-zero amount on R&D activities and responded "Yes" to at least one of the following questions: introduced improved products (goods or services in the last 3 years (LACe1); introduced new/significantly improved products new to the market in the last 3 years (LACe3); introduced new/significantly improved process for producing/supplying products in the last 3 years (LACe4); introduced new/significantly improved processes also new to the industry in the last 3 years (LACe5); cooperated on innovation with other enterprises/science and technology institutions in the last 3 years (LACe9), received any public support for innovation-related activities in the last 3 years (LACe10), or filed for patent/trademark/copyright in last 3 years (LACe8c).

countries. An interesting finding is that higher levels of financial barriers (i.e., finance as an obstacle variable) are associated with more innovative firms in Mexico and Peru. A similar conclusion was drawn by Lee, Sameen, and Cowling (2015) for UK medium-sized enterprises for waves data of 2007–2008, 2010, and 2012. Specifically, the authors found that innovative firms are more likely to be turned down for finance than other firms, and this effect worsens during a financial crisis.

For illustrative purposes, Fig. 5 depicts the probability of belonging to an innovation level predicted by the ordered logit model against four values of firm age— 5, 10, 15, 25, and 30 years old—for Colombia, Chile, and Mexico. As can been seen, the probability of falling into innovation levels 2, 3, or 4 is positively associated with age, whereas the opposite occurs with innovation level 1. In other words, as a least-innovative firm grows older, the probability of belonging to the lowest innovation category drops, whereas it increases in the more innovative levels 2, 3, and 4.

Table 10 in turn presents mean probabilities predicted by the ordered logit model (Panel (a)) and actual frequencies (Panel (b)). As can been seen, the model provides a reasonable approximation of the actual frequencies, particularly in the first and fourth innovation levels. When comparing actual frequencies and predicted probabilities, overall Mexico and Peru exhibits lowest discrepancies. Moreover, the figures show that regardless of size and country, firms are concentrated in the lowest innovation level. Even among large firms, the observed percentage of highly innovative ones (level 4) is very low: 4.0% in Peru followed by 3.3% in Argentina and 2.9% in Colombia, Chile, and Mexico.

4.3. Innovation in other middle-income economies

As a matter of comparison with the previous evidence, we consider three upper-middle income countries, as classified by the World Bank Development Indicators: China, Romania, and Turkey. Except for Chile, which falls into the category of high-income countries, the remaining Latin American countries under consideration are upper-middle income. The Enterprise Survey for China is available for 2012 whereas the corresponding surveys for Hungary and Turkey, for 2013.

In the China 2012 survey, when firms are asked whether they introduced new products and services in the last year (CNo1), 45.7%, 50.6%, 48.3% of the firms belonging to the manufacturing, retail, and services, respectively, answered 'Yes'. The analogous question for Latin American firms—new/significantly improved products (goods or services) introduced in the last 3 years (LACe6)—is asked only to manufacturing firms. As Table 5 shows, on average 46.2% of Latin America firms within the manufacturing sector responded 'Yes', which is line with that reported by Chinese manufacturing firms with the caveat that the time frame of the two questions is not equal.

Table 8
Innovation level in 2010.

Innovation level	Argentina		Colombia		Chile		Mexico		Peru	
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
Very low/none	717	68.03	600	63.69	781	75.61	1140	77.03	664	66.40
Moderate	121	11.48	116	12.31	99	9.58	109	7.36	96	9.60
Intermediate high	201	19.07	199	21.13	134	12.97	197	13.31	216	21.60
High	15	1.42	27	2.87	19	1.84	34	2.30	24	2.40
Total	1054	100	942	100	1033	100	1480	100	1000	100

Note: Innovation levels are defined as: (4) High: expenditure in R&D > 0 and answered 'Yes' to at least one of these questions: introduced new/significantly improved products new to the market in the last 3 years (LACe3); introduced new/significantly improved processes also new to the industry in the last 3 years (LACe5); filed for patent/trademark/copyright in last 3 years (LACe8c). (3) Intermediate high: expenditure in R&D > 0, answered 'Yes' to at least one of these questions: introduced improved products (goods or services in the last 3 years (LACe1); and, introduced new/significantly improved process for producing/supplying products in the last 3 years (LACe4), but answered 'No' to LACe3, LACe5, and LACe8c). (2) Moderate: expenditure in R&D > 0, answered 'Yes' to least one of these questions: cooperated on innovation with other enterprises/science and technology institutions in the last 3 years (LACe9); and, received any public support for innovation-related activities in the last 3 years (LACe10), but answered 'No' to LACe1, LACe2, LACe3, LACe4, LACe5, and LACe8c. (1) Low or none: all remaining firms.

Table 9
Binary and ordered logit models for innovation in 2010.

Regressor	(a) Argentina				(b) Colombia			
	Binary logit		Ordered logit		Binary logit		Ordered logit	
	Dep: innovative		Dep: innovation level		Dep: innovative		Dep: innovation level	
	Coef	Odds ratio	Coef	Odds ratio	Coef	Odds ratio	Coef	Odds ratio
Log(firm age)	−0.106 (0.095)	0.900 (0.085)	−0.092 (0.094)	0.912 (0.086)	0.342*** (0.105)	1.407*** (0.147)	0.234** (0.101)	1.264** (0.128)
Internal funding	0.006 (0.211)	1.006 (0.212)	0.028 (0.210)	1.028 (0.216)	−0.046 (0.179)	0.955 (0.171)	0.028 (0.175)	1.028 (0.180)
Bank funding	0.231 (0.154)	1.260 (0.195)	0.231 (0.150)	1.259 (0.189)	0.104 (0.151)	1.109 (0.168)	0.180 (0.152)	1.197 (0.181)
Trade credit funding	0.182 (0.194)	1.200 (0.232)	0.164 (0.194)	1.179 (0.229)	−0.461*** (0.167)	0.631*** (0.105)	−0.353** (0.162)	0.702** (0.114)
Finance as obstacle	0.038 (0.057)	1.039 (0.059)	0.032 (0.058)	1.033 (0.060)	0.065 (0.056)	1.068 (0.060)	0.071 (0.053)	1.073 (0.057)
Medium-sized firm	0.448*** (0.166)	1.565*** (0.259)	0.409** (0.170)	1.506** (0.257)	0.043 (0.174)	1.044 (0.182)	0.071 (0.174)	1.074 (0.187)
Large-sized firm	0.595*** (0.193)	1.813*** (0.350)	0.547*** (0.192)	1.729*** (0.332)	0.249 (0.184)	1.282 (0.235)	0.257 (0.177)	1.293 (0.230)
% foreign property	−0.000 (0.002)	1.000 (0.002)	0.000 (0.002)	1.000 (0.002)	0.003 (0.003)	1.003 (0.003)	0.002 (0.003)	1.002 (0.003)
Female top manager	0.330 (0.287)	1.391 (0.399)	0.394 (0.273)	1.482 (0.404)	0.205 (0.182)	1.228 (0.223)	0.214 (0.183)	1.239 (0.227)
Constant 1			1.794*** (0.667)				1.863*** (0.500)	
Constant 2			2.401*** (0.667)				2.470*** (0.506)	
Constant 3			5.283*** (0.683)				4.853*** (0.546)	
Constant	−1.594** (0.680)				−1.917*** (0.509)			
Observations	1041		1041		941		941	
p-Value χ^2 test	0.005		0.009		0.000		0.001	
Mc Fadden R^2	0.017		0.012		0.027		0.013	
Count R^2	0.667		0.679		0.615		0.637	

Regressor	(c) Chile				(d) Mexico				(e) Peru			
	Binary logit		Ordered logit		Binary logit		Ordered logit		Binary logit		Ordered logit	
	Dep: innovative		Dep: innovation level		Dep: innovative		Dep: innovation level		Dep: innovative		Dep: innovation level	
	Coef	Odd ratios	Coef	Odds ratio	Coef	Odds ratio	Coef	Odds ratio	Coef	Odds ratio	Coef	Odds ratio
Log(firm age)	0.253** (0.109)	1.288** (0.140)	0.256** (0.109)	1.289** (0.142)	0.186** (0.084)	1.204** (0.101)	0.157* (0.086)	1.170* (0.101)	0.023 (0.096)	1.024 (0.099)	0.029 (0.095)	1.029 (0.098)
Internal funding	0.242 (0.189)	1.273 (0.240)	0.300 (0.189)	1.294 (0.255)	0.066 (0.194)	1.068 (0.207)	0.015 (0.197)	1.015 (0.200)	0.084 (0.167)	1.088 (0.181)	0.085 (0.162)	1.089 (0.177)
Bank funding	0.260 (0.170)	1.297 (0.220)	0.337** (0.169)	1.367* (0.235)	0.484*** (0.144)	1.622*** (0.234)	0.515*** (0.146)	1.674*** (0.244)	0.478*** (0.149)	1.612*** (0.240)	0.504*** (0.145)	1.655*** (0.239)
Trade credit funding	0.231 (0.173)	1.259 (0.217)	0.265 (0.173)	1.279 (0.223)	0.424** (0.172)	1.529** (0.262)	0.348** (0.173)	1.416** (0.245)	0.248 (0.154)	1.281 (0.197)	0.187 (0.151)	1.206 (0.182)
Finance as obstacle	0.044 (0.062)	1.045 (0.065)		0.991 (0.061)	0.200*** (0.053)	1.222*** (0.065)	0.216*** (0.054)	1.242*** (0.067)	0.121** (0.062)	1.129** (0.070)	0.122** (0.061)	1.130** (0.068)
Medium-sized firm	1.050*** (0.204)	2.857*** (0.583)	0.885*** (0.211)	2.441*** (0.516)	0.679*** (0.208)	1.971*** (0.410)	0.591*** (0.216)	1.805*** (0.390)	0.498*** (0.166)	1.646*** (0.273)	0.471*** (0.166)	1.601*** (0.266)
Large-sized firm	1.035*** (0.218)	2.816*** (0.613)	0.939*** (0.222)	2.567*** (0.574)	0.990*** (0.183)	2.691*** (0.492)	0.954*** (0.191)	2.596*** (0.495)	0.837*** (0.191)	2.310*** (0.442)	0.882*** (0.191)	2.416*** (0.462)
% foreign property	0.004 (0.002)	1.004 (0.002)	0.003 (0.002)	1.002 (0.002)	0.001 (0.002)	1.001 (0.002)	0.002 (0.002)	1.002 (0.002)	0.002 (0.003)	1.002 (0.003)	0.002 (0.003)	1.002 (0.003)
Female top manager	0.624** (0.307)	1.867** (0.572)	0.597* (0.308)	1.836** (0.565)	0.298 (0.225)	1.348 (0.304)	0.155 (0.228)	1.168 (0.266)	0.066 (0.210)	1.069 (0.224)	0.035 (0.219)	1.036 (0.227)
Constant 1			4.293*** (0.769)				3.370*** (0.556)				1.817*** (0.510)	
Constant 2			4.938*** (0.776)				3.884*** (0.560)				2.312*** (0.514)	
Constant 3			7.191*** (0.825)				5.986*** (0.585)				4.907*** (0.561)	
Constant	−4.295*** (0.763)				−3.634*** (0.564)				−1.777*** (0.518)			
Observations	1030		1030		1467		1467		997	997	997	997
p-Value χ^2 test	0.000		0.000		0.000		0.000		0.000		0.000	
Mc Fadden R^2	0.052		0.033		0.056		0.038		0.035		0.026	
Count R^2	0.736		0.755		0.744		0.768		0.647		0.664	

Robust standard errors in parentheses.
Notes: (1) In the logit model, the dependent variable equals 1 if a firm is innovative, and zero otherwise. (2) In the ordered logit model, the innovation level (dependent variable) is 1: Very low/None, 2: Moderate, 3: Intermediate high, and 4: High.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

By contrast Turkish firms were less active than Latin American ones when introducing new products/services in the last 3 years (h1): 13.7%, 10.0%, and 8.1% of manufacturing, retail, and services, respectively. Romania in turn did much better than Turkey and slightly better than Latin American manufacturing firms in this regard: 50.3%, 31.5%, and 40% for manufacturing, retail, and services firms, respectively, answered "Yes".

Regarding spending on R&D in the past 3 years (CNo3), 41.3% of Chinese manufacturing firms responded affirmatively. (Retail and services firms are not asked this question.) Such a percentage is greater than that of Mexico (37.0%) only, but less than those of Argentina (59.4%), Colombia (57.3%), Chile (42.7%), and Peru (55.9%) as reported by question LACe6: "Did this establishment spend on R&D activities within the establishment?".

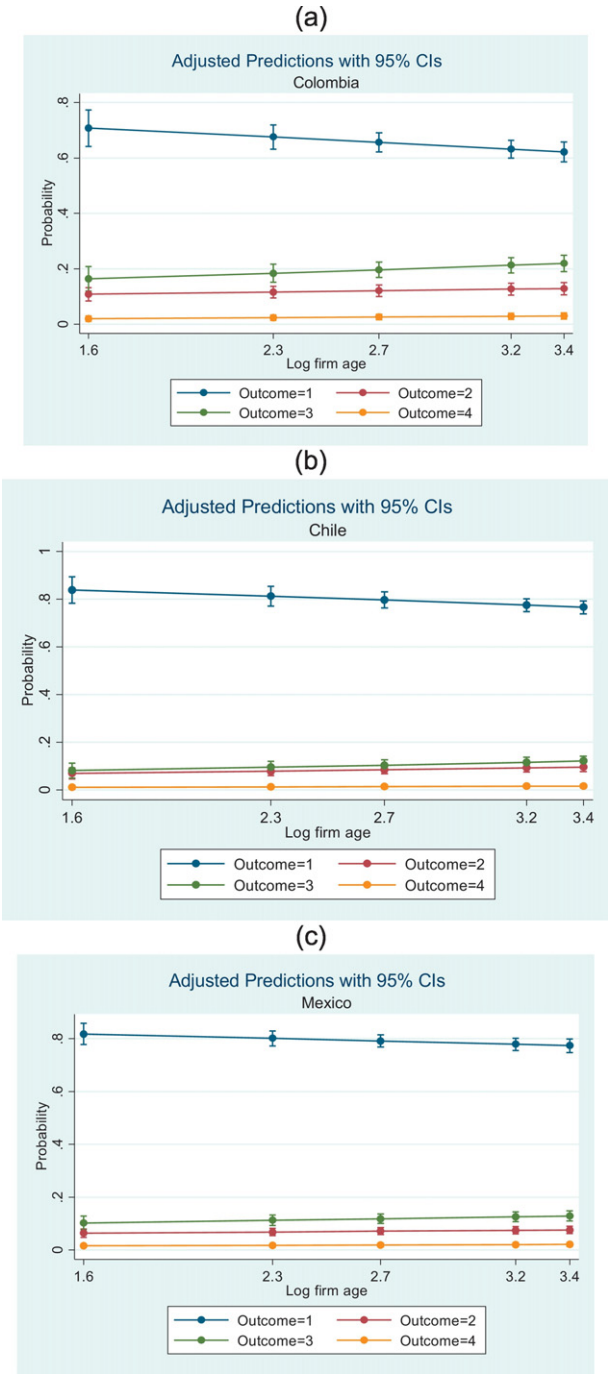

Fig. 5. Predicted probability of belonging to a given innovation level versus log firm age. Note: Probabilities computed from ordered logit model. Remaining regressors are set at their mean values. Outcomes correspond with innovation levels 1 through 4.

In the case of Romania, 12.4% of the sampled firms responded 'Yes' to question h6: "Spending on R&D". In the manufacturing sector, such a figure increased to 21.0%. On average, the money spent on R&D to annual sales reached 2.9%. In Turkey, in turn, 15.9% of the sampled firms spent on R&D—16.6% in the manufacturing sector—and the R&D expenditure/annual sales ratio averaged 3.5%.[6] In both countries, the money spent on R&D relative to annual sales exceeded the average for Latin American firms reported in Table 5: 2.4%.

[6] There is no information in the China 2012 survey with respect to the money spent on R&D.

Unfortunately, the China 2012 survey does not contain information on patenting activities. However the Turkey and Romania ones do. In particular, the question ECAo23b of the 2013 survey asks whether the firm applied for a patent/trademark within the past 3 years. Among Turkish firms, 44.7%, 54.6% and 57.1% of manufacturing, retail, and services firms, respectively, responded affirmatively. Such percentages drop dramatically in Romania to 8.2%, 5.5%, and 7.3%, respectively. When looking at Table 5, it is apparent that Latin American manufacturing firms lag behind in patent/trademark filing with respect to Turkish manufacturing firms, but outdo Romanian firms by a great extent in this regard.

On the other hand, question ECAo23a, "Ever been granted a patent?" shows that 42.5% of Turkish manufacturing firms answered 'Yes' whereas only 7.7% of Romanian manufacturing firms did so. In the case of the sampled Latin American manufacturing firms, the closest question of the questionnaire is E7b, which asks whether the establishment has any patents registered domestically. According to the information provided in Table 5, on average, about 30% of the sampled manufacturing firms had patents in 2010. That is, the sampled Latin American firms do worse than Turkish ones but much better than Romanian ones.

In order to have a better grasp of innovation initiatives, we collected data of total patent applications (direct and Patent Cooperation Treaty (PCT) national phase entries) from the World Intellectual Property Organization (WIPO), http://www.wipo.int. In 2015 the patent applications per 100,000 inhabitants in Argentina, Colombia, Chile, Mexico, and Peru were, respectively, 2.1, 4.7, 1.2, 2.0 and 0.4. In China, Romania, and Turkey, in turn, they reached 73.7, 6.2, and 9.3, respectively. These figures suggest that Chile is the most competitive country in the sample, exhibiting an application number not too far from Romania's. Clearly China's figure lies considerably further away from Romania and Turkey's, and lies closer to those of high-income economies, such as Germany, the US, Japan, and the Republic of Korea, which exhibited 215.0, 164.8, 358.4, and 470.3 patent applications per 100,000 inhabitants, respectively, in 2015.

An alternative measure of patenting applications is one which controls for GDP. In particular, WIPO statistics on the number of resident patent applications per 100 billion GDP (in 2011 PPP U.S. dollars) show that in 2015 the top-three countries were the Republic of Korea (9610), Japan (5694), and China (5269). Turkey and Romania in turn exhibited 389 and 255 applications per 100 billion GDP, respectively, in 2015. Among Latin American countries, Chile, Colombia, Mexico and Peru's applications per 100 billion GDP reached 111, 51, 65, and 18, respectively, in 2015. (Statistics for Argentina are not available). Once again Chile appears as the most competitive country relative to Turkey and Romania.

On the other hand, figures on patents grants per 100,000 inhabitants show that in 2015 Argentina, Colombia, Chile, Mexico, and Peru had a number of 3.6, 2.1, 5.9, 7.4, and 1.2, respectively. In turn China, Romania, Turkey, Germany, the US, Japan, and the Republic of Korea had 26.2, 1.5, 2.2, 18.2, 92.8, 149.2, and 201.3, respectively, in 2015. When using this statistics, Chile and Mexico outdo Romania and Turkey, but clearly are very distant from China and the high-income economies referred to.

All in all, the above figures show that Latin American firms fall short in the ratio of R&D/total sales and in patenting activities, but do not necessarily do worse in other innovation aspects, such as the introduction of new products, when compared with firms of other upper-middle income countries.

5. Conclusions and policy implications

Based on the 2010 World Bank's Enterprise Surveys Indicator Database, this study showed that firm size, firm age, financial constraints, and funding sources are the main drivers of innovation in Latin American countries. Unfortunately, the figures show that most firms in the region are non-innovative. Indeed, in the countries here analyzed in detail —Argentina, Colombia, Chile, Mexico, and Peru— over 60% of the sampled

Table 10
Mean probabilities predicted by ordered logit model against firm size versus actual frequencies.

(a) Predicted mean probabilities

Size	Argentina				Colombia				Chile				Mexico				Peru			
	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4
Small	75.0%	9.6%	14.4%	1.0%	68.2%	11.4%	18.1%	2.3%	87.1%	5.6%	6.4%	0.8%	88.4%	4.2%	6.4%	1.0%	76.1%	7.7%	14.7%	1.4%
Medium	66.2%	12.0%	20.2%	1.5%	65.2%	12.1%	20.0%	2.7%	72.4%	10.8%	14.7%	2.1%	78.4%	7.2%	12.3%	2.0%	65.7%	10.0%	21.9%	2.4%
Large	62.2%	12.9%	23.1%	1.8%	58.8%	13.3%	24.4%	3.5%	68.8%	11.8%	16.9%	2.5%	70.8%	9.0%	17.1%	3.1%	55.0%	11.5%	29.8%	3.7%

(b) Actual frequencies

Size	Argentina				Colombia				Chile				Mexico				Peru			
	Innovation level				Innovation level				Innovation level				Innovation level				Innovation level			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Small	75.3%	6.5%	17.3%	0.8%	68.6%	9.3%	19.6%	2.5%	87.4%	3.5%	7.9%	1.3%	88.7%	3.0%	7.7%	0.6%	76.3%	7.4%	14.6%	1.7%
Medium	66.5%	11.1%	21.9%	0.5%	66.0%	9.7%	21.1%	3.1%	72.3%	10.7%	15.7%	1.3%	78.6%	7.4%	11.1%	2.8%	65.3%	10.3%	22.5%	1.9%
Large	61.1%	18.0%	17.6%	3.3%	56.7%	17.9%	22.4%	2.9%	68.2%	14.1%	14.7%	2.9%	70.8%	9.4%	16.9%	2.9%	55.1%	11.4%	29.4%	4.0%

Notes: (1) Innovation levels are 1: very low/none, 2: moderate, 3: intermediate high, and 4: high. (2) P_i indicates the probability of belonging to level 'i'.

firms do not reach a moderate or higher innovation level. This means that such firms do not spend on R&D and have not improved existing products or productive processes or introduce new ones in the past 3 years. Moreover, among large firms, which tend to be more innovative, the observed percentage of highly innovative firms does not exceed 4.0%.

The relatively low innovation level in Latin American firms is not surprising, given that the R&D expenditure/GPD ratio and the number of highly-qualified human capital per thousand labor force lag behind those of the United States and OECD countries (Section 2 of this article). An additional explanation to such low innovation level is that most researchers are employed at higher-education institutions as opposed to public and private enterprises. Indeed, figures collected by the Ibero-American and Inter-American Network on Science and Technology (Ricyt) show that in 2012 the shares of researchers (Full-Time Equivalent, FTE) employed in the government, public and private enterprises, higher education, and private non-profit organizations were 15.7%, 24.2%, 58.4%, and 1.8%, respectively, in Latin America and the Caribbean. In Ibero-America in turn, which includes also Portugal and Spain, these shares were 15%, 27.7%, 55.1%, and 2.3%, respectively, in 2012. That is, in both regions, over 50% of FTE worked at higher-education institutions in 2012.

The above pattern is not observed, however, in more developed economies. For instance, Ricyt shows that in Canada the proportion of FTE employed in public and private enterprises reached 56.8%, as opposed to that of FTE employed in higher education, 36.7%, in 2012. Meanwhile, in the United States FTE employed in enterprises reached around 68% of the total in 2012 (source: OECD).[7] These figures suggest that a pending task in Latin America is to increase both the R&D expenditure/GPD ratio and patent activities (Section 4.3 of this article), and to attract an increasing number of highly-qualified researchers to industry.

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[7] Detailed figures for the United States are available for 1997: shares of researchers (FTE) employed in the government, public and private enterprises, higher education, and private non-profit organizations were 4.3%, 79.2%, 15.4%, and 1.1%, respectively (Source: www.ricyt.org).