Firm-level innovation, government policies and the middle-income trap: insights from five Latin American economies

Eva Paus and Michael Robinson

Abstract

Latin American economies need higher productivity to escape from the middle-income trap. This article analyses the drivers of innovation at the firm level, which is a critical driver of productivity growth. The article estimates a two-step-model where firm characteristics affect firm engagement with innovation inputs, and such engagement then generates innovation outputs. We use World Bank Enterprise Survey data to analyse this two-stage process for a pooled panel of matched firms in 2006, 2010 and 2017 for five Latin American economies (Argentina, Colombia, Ecuador, Peru and Uruguay). The findings indicate that here is no missing link per se between innovation inputs and outputs in Latin American firms to explain innovation underperformance at the aggregate level. However, a comparison with China's firms suggests possible differences in firms' innovation behaviour. The results support the use of horizontal and vertical government policies to advance firm-level innovation.

Keywords

Economic development, productivity, industrial enterprises, technological innovations, research and development, middle-income countries, comparative analysis, Latin America, China

JEL classification

O12, O31, O54, O57

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I. Introduction

With the end of the commodity price boom, economic growth in most Latin American countries declined considerably in the 2010s. For the region as a whole, growth in Gross Domestic Product (GDP) went from 6.3% in 2010, to 2.9% in 2013 and to 0.9% in 2018 (ECLAC, 2019 and 2010). The economic slowdown, dramatically exacerbated by the crisis induced by the coronavirus disease (COVID-19) in 2020, has highlighted the drastic ongoing structural challenges in the region. One critical challenge is persistently low productivity growth.

When productivity growth stays too low in relative terms, middle-income economies in Latin America and elsewhere become stuck in a middle-income trap with low economic growth (Paus, 2019, 2014 and 2012; Foxley, 2012; Ohno, 2009; Gill and Kharas, 2007). Middle-income economies, especially higher middle-income economies, can no longer compete internationally in standardized, labour-intensive goods, as their wages are too high compared with low-income economies. In order to advance, they have to be able to compete internationally based on productivity. In other words, the production structure has to shift to higher value added activities on an increasingly broader scale.

While increased productivity growth is the way out of the middle-income trap, innovation is the key to achieving it. At the aggregate level, Latin American economies lag behind other middle-income economies in important aspects of innovation, notwithstanding differences at country and sectoral levels (ECLAC, 2016; OECD, 2016). Advancing broad-based innovation is a complex, multifaceted and challenging undertaking aimed at increasing the innovation capabilities of domestic firms (Cimoli and others, 2009; Lundvall, 1992; Fagerberg, 1988; Nelson and Winter, 1982).

In this article, we study innovation at the firm level to shed light on innovation at the aggregate level. We test a two-step model of firm-level innovation based on Crepon, Duguet and Mairesse (1998). In a first step, we examine how firms' characteristics affect their engagement with innovation inputs. In a second step, we investigate how engagement with innovation inputs impacts the likelihood of a firm producing innovation outputs (in the form of new products or processes). We analyse this two-step process using a matched firm-level panel for Argentina, Colombia, Ecuador, Peru and Uruguay: the five Latin American countries for which the World Bank Enterprise Survey provides data for 2006, 2010 and 2017.[1]

This inquiry into firm-level innovation behaviour in Latin America is broader in scope and uses more recent data than existing studies, which tend to focus on the country level and use national innovation surveys from the early to mid-2000s (Chudnovsky, López and Pupato, 2006; Cimoli, Primi and Rovira, 2011; Crespi and Zuñiga, 2012; De Negri and Laplane, 2009). We use a random-effects model (controlling for country and year specifics) and a fixed-effects model, which controls for firm-specific characteristics. The pooled data analysis allows us to make broader statements about the links between the characteristics and innovation outcomes of innovating firms in Latin America, without ignoring the importance of country, year and firm contexts.

Most studies focus on research and development (R&D) spending as the main, if not only, channel for technological innovation. However, the heterogeneity of production capabilities among Latin American firms suggests that, for many, non-R&D elements of innovation remain important. We therefore consider two other possible channels for innovation inputs in addition to R&D expenditures: the use of licenses and investment in capital goods.

We compare the results for the pooled Latin American data with estimates of the model for China, the middle-income economy which has achieved very high levels of productivity growth (and economic

[1] The World Bank also has Enterprise Surveys with innovation-related questions for the Plurinational State of Bolivia, Chile, Mexico and Paraguay, but only for the years 2006 and 2010. There is no innovation-related World Bank Enterprise Survey for Brazil.

growth) for the past three decades. We also explore the impact of key aspects of the broader innovation ecosystem on firm engagement with innovation.

Overall, the results from this study suggest that there is no missing link per se between innovation inputs and outputs to explain the underperformance at the aggregate level. Exporting, internationally recognized quality certifications and virtual connectivity are firm characteristics that increase the likelihood of firm engagement with innovation inputs. Engagement with any of the innovation channels therefore raises the likelihood of a firm introducing a new product or process, although spending on R&D and investing in capital goods have a considerably stronger impact than holding a foreign-owned license.

Nonetheless, the findings suggest two possible links between micro and macro innovation performance. The first link is R&D spending by large firms. Controlling for other firm characteristics, engagement with innovation inputs increases in direct proportion with firm size. Most firms in Latin America are micro-sized, and few of them engage in innovation inputs. Large firms account for the bulk of spending on R&D, but their spending per firm is low compared with large firms in China. The second possible link is the translation of innovation inputs into innovation outputs. The comparison with model estimates for China suggests that the degree of translation is considerably lower for Latin American firms. We consider these results suggestive only, since different survey years and formulation of questions do not allow for a direct statistical comparison.

Under the market-led strategies of the past decades, Latin American governments welcomed foreign direct investment (FDI) with open arms in the expectation of substantial economic benefits. In the five economies analysed here, the share of foreign-owned firms that engage with innovation inputs and generate innovation outputs is significantly higher than the share of domestic firms. The estimates show that once we control for firm characteristics in the model, foreign ownership has no additional positive impact.

Our results support the case for active government policies to advance firm-level innovation. Based on the variables included in the analysis, the results highlight the efficacy of direct support for engagement with innovation inputs and possibilities for collaboration with other innovative institutions. They also suggest that policy measures with broader goals can have a positive indirect impact on firm innovation by facilitating: access to information and communication technology, the acquisition of internationally recognized quality certifications and the entry into foreign markets.

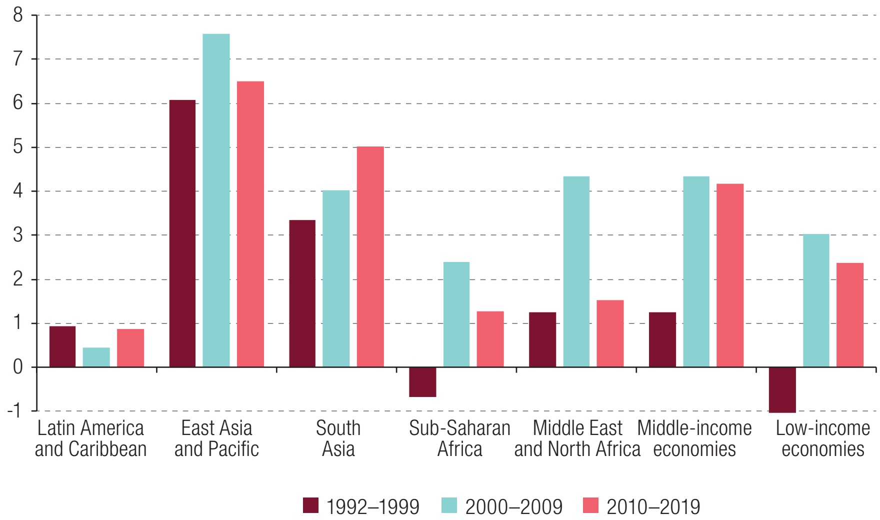
This article is structured as follows: following this introduction, section II provides a brief background on productivity and innovation performance in Latin America at the aggregate level, highlighting the challenges in the region. Section III presents the model and data sources for analysis of innovation characteristics and outcomes at the firm level. Section IV discusses the estimation results. The final section concludes with policy implications of the findings.

II. The middle-income trap, productivity growth and macro indicators of innovation

Moving from factor-driven to innovation-driven growth has always been the challenge for middle-income countries. However, it is only since Gill and Kharas (2007) first introduced the notion of the middle-income trap that economists and policymakers have become concerned with middle-income countries being trapped at their income level. That is a danger when producers can no longer compete internationally in standardized, labour-intensive goods because wages are relatively too high, but they are unable to compete in higher value added activities on a broad enough scale because productivity is relatively too low (Felipe, 2012; Foxley, 2012; Gill and Kharas, 2007; Lee, 2013; Ohno, 2009; Paus, 2019, 2014 and 2012).

Notwithstanding exceptions at the country and sectoral levels, Latin America's productivity performance at the aggregate level suggests that the region's countries are in a middle-income trap. Labour productivity in Latin America grew at an average annual rate of 0.93% during the 1990s, 0.46% during the 2000s and 0.88% between 2000 and 2019. These rates do not compare well with those of other developing economy regions (see figure 1).

Figure 1
Growth rate of GDP per worker employed, by developing country area, 1992–2019
(Average annual growth rate, based on constant 2017 purchasing power parity (PPP))



Source: Prepared by the authors, on the basis of World Bank, World Development Indicators [online database] https://databank.worldbank.org/source/world-development-indicators.

The Asian Development Bank (2017) finds productivity growth to be the differentiating factor between middle-income economies that graduated to high income levels and those that did not. To achieve higher and sustained productivity growth, Latin American producers need to innovate more, both by moving up the value chain within existing production areas and by creating new areas of competitive advantage.

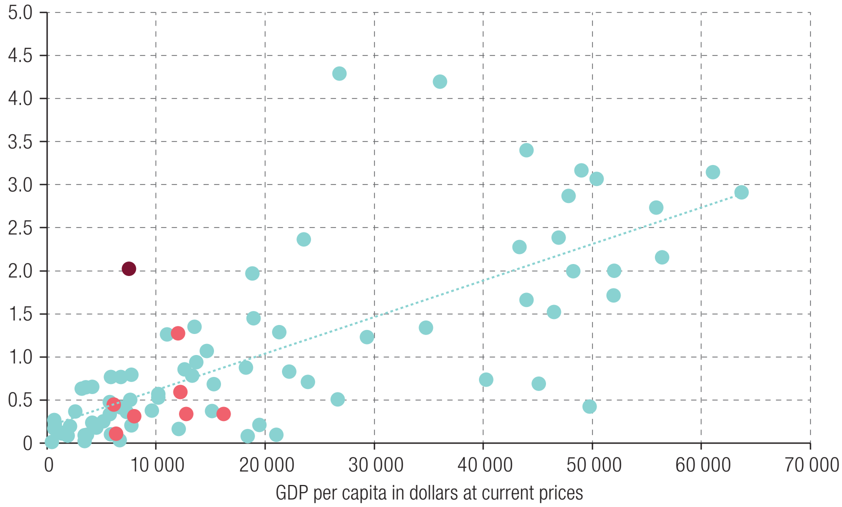
The innovation process is complex, and key factors at the micro, meso and macro levels have to co-evolve and complement each other to enable broad-based movement forwards. Aggregate innovation indices aim to capture this complexity by including a larger number of variables. The Global Innovation Index 2018, for example, includes 80 indicators on the different pillars underlying its two sub-indices of innovation inputs and innovation outputs. Latin American economies ranked in the bottom half of the 126 countries included, with the exception of Chile, Costa Rica, Mexico and Uruguay. China, in contrast, ranked seventeenth (Dutta, Lauvin and Wunsch-Vincent, 2018).

An examination of some of the common indicators of technological capabilities and innovation potential underscores Latin America's underperformance in innovation. The region's R&D intensity (R&D spending as a share of GDP) is lower than expected given countries' GDP per capita (see figure 2, in which the red dots indicate Latin American countries). The one exception is Brazil, which is just above the trend line.[2] China's R&D intensity (represented by a dark red dot), in contrast, was more than three times higher than predicted by its income level. The growth of resident patent applications over the last 15 years has also been much slower than in East Asia, especially compared to China. Access to

[2] Nonetheless, Brazil's R&D intensity over the past two decades has increased only slowly, from 1% in 2000 to 1.27% in 2016. See World Bank, World Development Indicators [online database] https://databank.worldbank.org/source/world-development-indicators.

education has increased across the region, but the quality of high school education, as measured by the results of the Programme for International Student Assessment (PISA), does not compare favourably with many Asian middle-income countries.

Figure 2
Research and development (R&D) as a share of GDP, 2014
(Percentages)



Source: Prepared by the authors, on the basis of World Bank, World Development Indicators [online database] https://databank.worldbank.org/source/world-development-indicators.
Note: The red dots in the figure represent Latin American countries; the dark red dot represents China.

The need to expand domestic innovation capabilities and increase productivity growth is particularly urgent in the current context of globalization. The rise of China, with the rapidly growing diversification and sophistication of its exports, has shifted the goalposts for other middle-income economies. They are now competing with products (and services) from China across the spectrum of technology intensities in domestic and third markets (Paus, 2019).

III. Firm-level innovation

1. General considerations

Economic theories about innovation, productivity and economic growth suggest that firm innovation on a broad level generates productivity growth, which then advances economic growth. Informed by the analytical framework of Crepon, Duguet and Mairesse (1998), we conceptualize innovation as a process where firm engagement in innovation activities (innovation inputs) leads to innovation outputs. With respect to innovation inputs, scholars typically distinguish R&D and non-R&D activities. The latter refer primarily to the incorporation of knowledge developed elsewhere, through licenses, investment in new equipment or a reorganization of the production process.

A key challenge for middle-income economies is to make the process of innovation increasingly more endogenous and to increase domestic R&D efforts. Nonetheless, focusing exclusively on R&D is too limiting in terms of innovation in middle-income economies, since many firms are nowhere near the technological frontier. Structural heterogeneity is a key characteristic of Latin American economies: there are a few large and internationally competitive firms and a large number of micro and small enterprises with much lower productivity levels.

The statistical offices of many countries and international organizations choose employment as the criterion for distinguishing firms by size. In Latin America, each country uses its own criteria for firm size. These often combine data on employment, sales and taxable units; sometimes employment does not figure at all.[3] Using the country-specific classifications of firm size, Dini and Stumpo (2020) find that, in 2016, micro firms accounted for 88.4% of all firms in Latin America, small firms for 9.6%, medium-sized firms for 1.5% and large firms for a mere 0.5%.[4] The same study shows that the productivity level of micro firms in Latin American countries is less than 10% that of large firms (see table 1). The distribution of firms across size brackets in the European Union is similar to that in Latin America.[5] However, the productivity gap between firms of different sizes is much smaller. In Spain, for example, the labour productivity of micro firms is 45% of that of large firms, and in France it is 74%.[6]

Table 1
Productivity of micro, small and medium-sized companies relative to large companies, 2016
(Percentages)

	Micro-enterprises	Small companies	Medium-sized companies	Large companies
Brazil	4.5	22.4	50.7	100
Chile	7.2	16.6	22.4	100
Ecuador	8.2	29.7	46.2	100
Mexico	8.1	23.9	48.3	100
France	73.6	76.0	85.4	100
Germany	62.5	64.3	83.4	100
Italy	40.4	69.2	91.1	100
Spain	45.2	69.9	96.1	100

Source: M. Dini and G. Stumpo (coords.), "Mipymes en América Latina: un frágil desempeño y nuevos desafíos para las políticas de fomento", *Project Documents* (LC/TS.2018/75/Rev.1), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2020.

Size is not the only factor behind structural heterogeneity. In a study of 4,000 Brazilian manufacturing firms (with more than 30 employees), Catela, Cimoli and Porcile (2015) use cluster analysis to separate firms into five groups based on productivity levels. In 2004, the average productivity level of firms in the lowest productivity group (group 1: 15.5% of total firms) was only 0.79% of that in the highest productivity group (group 5: 7.7% of all firms). In group 2 (25% of all firms), the average productivity level was 2.5% that of the top group. In group 3 (28.7% of firms), it was 8%. In group 4 (23% of firms), it was 23%. In light of such productivity differentials, knowledge developed elsewhere is likely to be an important avenue for innovation engagement for many Latin American firms.

Innovation outcomes include the introduction of a new product or process, a new organizational method in business practices or a new marketing method (UIS, 2015, p. 9). They may be new to the firm, the country or the world.

The theoretical links between innovation inputs, innovation outputs, productivity growth and economic growth are straightforward. Empirical studies, however, reveal greater complexity. They generally show a positive impact of innovation on productivity growth, as summarized in Ortega-Argilés, Piva and Vivarelli (2011). For example, based on panel data for 65 countries for 1965–2005, Bravo-Ortega and García (2011) estimate that a 10% increase in R&D per capita spending generates a 1.6% increase in long-term total factor productivity. Using data on R&D expenditures by United States and European

[3] For the criteria used in Central American countries, for example, see Monge-González (2019).

[4] The firm size shares are based on data for Argentina, Brazil, Chile, Ecuador and Mexico.

[5] Eurostat uses the following employment cut-offs in distinguishing between firms in member countries: micro (1–9 persons employed), small (10–49), medium (50–249) and large (250 or more). Based on this size classification, 92.9% of firms in the European Union are micro, 5.9% are small, 1% are medium-sized and 0.2% are large (Dini and Stumpo, 2020).

[6] The data for European Union countries are based on the Eurostat size definition.

manufacturing and services firms during 1990–2008, Ortega-Argilés, Piva and Vivarelli (2011) find that cumulative R&D expenditures have a significant impact on firms' productivity. Reviewing the literature on R&D and economic growth, Mazzucato (2013) concludes that empirical findings differ —a result she attributes to differences in the innovation ecosystem across countries.

Empirical analyses of the impact of innovation outputs on productivity growth in Latin American countries reveal a positive link, though there are exceptions. Arza and López (2010) show that product and process innovation are important determinants of labour productivity in Argentina. Crespi and Zuñiga (2012) find a positive impact of product innovation on productivity growth in Brazil and Mexico, but not in Argentina. Their results indicate that the introduction of a new process has a positive impact on productivity in Argentina, Chile, Colombia, Panama and Uruguay, but not in Costa Rica.

One reason for the different findings may be the measurement of productivity. Labour productivity is value added per employee, but analysts often use sales per employee as a proxy. We consider that a poor proxy, since the correlation between sales per employee and value added per employee probably varies across firms in an industry, and across industries, countries and time. The input intensity of a firm's sales is also likely to differ with firm size and the level of incorporation into global value chains. Another possible explanation for the differences in empirical outcomes is the lag time between the year when a firm engages in innovation and the year when productivity results materialize. In the case of Chile, for example, Álvarez, Bravo-Ortega and Navarro (2010) find that process innovation has a contemporaneous impact on labour productivity, while product innovation affects productivity with a lag of two years.

2. Model

This study of firm innovation behaviour focuses on two steps in the innovation sequence: innovation inputs and innovation outputs. We consider three channels for innovation inputs: R&D expenditures, use of a license and investment in capital goods. With respect to innovation outputs, the focus is on the introduction of a new product or process. Given that the analysis covers developing economies, the vast majority of these innovations will be new to the firm or country, but not to the world.

In the first step, we explore the characteristics of firms that engage in one of the three innovation channels. In a second step, we investigate whether engagement in one of the three channels increases the likelihood of firms introducing a new product or process. Due to data limitations, the impact of innovation outputs on productivity growth is not investigated. The Enterprise Surveys do not have data on value added, only on sales. Sales per worker are a poor proxy for labour productivity, especially given variations over time and the absence of deflators at the industry level.

Equation (1) specifies our hypotheses about the links between firms' characteristics and their use of innovation inputs.

$$Innovation_{it}^{k} = B_0 + \sum_{j=1}^{m} B_j X_{jit} + B_{2010} Year_t + B_{2017} Year_t + \sum_{c=1}^{4} C_i CD_i + \alpha_i + \varepsilon_{it} \qquad (1)$$

where:

i: firm

t: 2006, 2010 or 2017

k: channel of innovation engagement

X_j: vector of firm characteristics

CD: country dummies

α_i: firm-specific individual effect

ε_{it}: normal error term.

The Enterprise Surveys include information on R&D spending and use of a license. They have data on investment in fixed assets, but not on investment in capital goods. We use the former as a proxy for the latter, well aware that this may not always be the best fit, since investment in fixed assets also includes investment in building structures. The vector X includes a set of firm characteristics. Following previous studies (Crespi and Zuñiga, 2012; Pires, Sarkar and Carvalho, 2008; Chudnovsky, López and Pupato, 2006; Crepon, Duguet and Mairesse, 1998), we include a dummy for 'size'. The underlying assumption is that larger firms are better able to absorb the fixed costs of innovation, shoulder the risks inherent in innovation and access necessary (internal or external) financial resources.

It would be straightforward to use the number of employees as the uniform criterion for firm size across the five economies. However, a company may be small in terms of employees, but medium or large in terms of sales or other criteria. A proxy for firm size was therefore constructed that combines information on employment as well as sales. Each firm is classified by employment size (1–9, 10–49, 50–199 and 200 or more) in each of the three years, and by its sales relative to the sales of all firms by year and country (lowest quartile, second lowest quartile, second highest quartile and highest quartile). A firm's size is then determined in each country and year by its highest ranking in the two groupings. There are four firm sizes: micro, small, medium and large. For example, a firm with eight employees and sales in the second lowest quartile is a small firm, and a firm with 220 employees and sales in the second highest quartile sales is a large firm. Micro firms are the omitted category in the regressions.

In addition to firm size, we include a set of variables to capture a firm's awareness of the need to be competitive. If a firm exhibits behaviour that indicates an interest in expanding markets or communicating virtually with customers and suppliers, it is more likely to engage with innovation inputs. The relevant firm characteristics are whether a firm exports, holds an internationally recognized quality certification (IRQC), is part of a multi-plant company (multi-plant) and has virtual connectivity (VC). The first three variables enter the regression as dummy variables. However, VC is an index composed of two indicators: 'email use to communicate with clients' and 'existence of a firm website'. If the firm has neither, VC = 0; if it has either, VC = 1; and, if it has both, VC = 2. The hypothesis is that the coefficient for each of these variables is positive.

We also investigate any differences in innovation behaviour between domestic and foreign-owned firms. Firm nationality is of interest because a sustained advance in innovation ultimately depends on increased technological capabilities of domestic firms. Furthermore, governments in Latin America and elsewhere have been keen to attract foreign direct investment in the hope that this would bring new investment and technological know-how to the country. In the regressions, 'foreign ownership' is a continuous variable of the share of foreign ownership of a company's assets. The minimum share is 10%, on the assumption that this gives a foreign owner some control over the firm.[7] Thus, 'foreign' ranges in value from 0.1 to 1.

Finally, we include dummies for years and countries. The year dummies capture the broader economic environment for growth. The year 2010 is close to the 'Great Recession of 2008', 2017 is a year in a period of low economic growth in the five countries and 2006 is the omitted year.[8] The country dummies account for country-specific characteristics, with Uruguay as the omitted country.

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[7] A threshold of 10% is quite common. In the balance of payments statistics, for example, a foreign investment is only considered 'foreign direct investment' if it gives the investor control of more than 10% of the firm's assets.

[8] Between 2014 and 2017, GDP per capita (in constant local currency units) grew at an average annual rate of 0.04% in Argentina, 0.77% in Colombia, -1.28% in Ecuador, 1.74% in Peru, and 1.19% in Uruguay. See World Bank, World Development Indicators [online database] https://databank.worldbank.org/source/world-development-indicators.

In a second step, we analyse the likelihood that firms engaging in one of the three innovation channels introduce a new product or new process.

$$New\ product\ (Process)_{it} = B_0 + \sum_{k=1}^{3} \phi_k\ Innovation_{it}^{k} + \sum_{j=1}^{m} B_j X_{jit} + B_{2010} Year_t + B_{2017} Year_t + \sum_{c=1}^{5} C_i CD_i + \alpha_i + \varepsilon_{it} \quad (2)$$

We include all the variables from the innovation input model in the innovation output model to test whether these variables have an impact on introducing new products or processes that goes beyond their impact on R&D, licenses and capital investment.

3. Estimation, data and descriptive statistics

We use a linear probability model to estimate equations (1) and (2). The results of both random- and fixed-effects models are presented to harness the advantages of both models. The advantage of fixed-effects models is that they generate unbiased estimates, even where the individual company effects correlate with both 'Y' and 'X' variables in the model. However, the fixed-effects model estimates will be relatively inefficient, since this panel is short, with a maximum of three observations per company, and many of the variables do not change between years for a specific firm. For example, only 9% of the firms switch export status between years, and only 7.6% switch between having an IRQC or not.[9] Thus, significant coefficients in the fixed-effects estimates are particularly compelling because they are unbiased and significant in spite of the relatively small effective sample size. The random-effects model estimates, on the other hand, have the advantage of generating considerably more efficient estimates on the variables of interest (such as exports and IRQC). Even though the Hausman tests indicate that some model estimates are biased, the results of all the random-effects models are shown to avoid leaving out the very variables of interest for the step 1 estimates.

The empirical analysis uses data from the World Bank's Enterprise Surveys. They offer innovation-related information for five Latin American countries (Argentina, Colombia, Ecuador, Peru and Uruguay) for three years (2006, 2010 and 2017). Annex A1 lists the survey questions and the definitions of the variables included in this model. The vast majority of the companies surveyed are in the manufacturing sector.

The five economies differ considerably in income level and population size (see table 2). Argentina and Uruguay have significantly higher income levels than the other three economies. Even though the World Bank classifies them as high-income economies based on their GDP per capita, both economies are more similar to upper middle-income economies when indicators of technological capabilities are considered. Population size varies from a low of 3.4 million in Uruguay to a high of 49 million in Colombia. However, the five countries do share an important common characteristic: they all have a relatively small manufacturing sector.

[9] If a variable for a firm does not change between years, that firm is not included in the coefficient estimate for that variable in the fixed-effects model.

Table 2
Latin America (5 countries): key economic indicators, 2014 and 2017

	Gross national income (GNI) per capita *(current US$)*	Population	Manufacturing value added as a share of GDP	R&D as a share of GDP
	2017	2017	2017	2014
Argentina	13 120	44 044 811	12.9	0.61
Colombia	5 930	48 901 066	11.4	0.20
Ecuador	5 860	16 785 361	14.4	0.34[a]
Peru	6 060	31 444 297	13.0	0.16[b]
Uruguay	15 150	3 436 646	11.7	0.33

Source: Prepared by the authors, on the basis of World Bank, World Development Indicators [online database] https://databank.worldbank.org/source/world-development-indicators.
[a] 2011.
[b] 2004.

The descriptive statistics in table 3 show the variable means for all firms in the five countries jointly, as well as by nationality of ownership and firm size. The number of observations for each variable changes with data availability.

Table 3
Latin America (5 countries):[a] variable means, 2006, 2010 and 2017
(Percentages)

	All	Nationality of ownership		Firm size			
		Domestic	Foreign[b]	Micro	Small	Medium	Large
Firm characteristics							
Foreign (%)	10.4	0.0	100.0	2.2	3.7	7.4	26.8
Exporting (%)	24.3	21.4	49.5	5.9	15.1	25.4	45.9
Virtual connectivity[c] (0-2)	1.6	1.6	1.8	1.2	1.5	1.7	1.8
Multi-plant (%)	15.8	13.5	35.6	5.5	9.9	14.5	29.2
Internationally recognized quality certification (IRQC) (%)	21.5	18.1	51.0	3.2	10.1	20.1	48.3
Micro (%)	14.9	16.5	2.9				
Small (%)	27.2	29.4	9.1				
Medium (%)	29.3	30.6	19.4				
Large (%)	28.6	23.5	68.6				
Innovation inputs							
R&D (%)	42.6	41.2	55.4	25.6	35.5	46.5	58.6
License (%)	12.7	10.5	33.2	4.9	7.8	13.3	23.5
Capital goods (%)	60.7	58.9	75.3	35.5	50.3	65.9	80.7
Innovation outputs							
New product (%)	68.3	67.4	76.8	58.7	67.1	70.3	76.2
New process (%)	57.8	57.3	61.7	48.5	54.8	60.3	65.2

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.
[a] Argentina, Colombia, Ecuador, Peru and Uruguay.
[b] Foreign ownership of assets > 10%.
[c] This variable is not expressed in percentages, but in values from 0 to 2.

Domestic firms account for roughly 90% of firms in the sample: 16.5% of them are micro-sized, 29.4% are small, 30.6% are medium and 23.5% are large. Foreign firms, in contrast, are predominantly large (68.6%), followed by medium-sized (19.4%), small (9.1%) and micro-sized (2.9%). Compared to the above-mentioned country-specific data for Latin America, micro firms are very under-represented in the World Bank Sample, while the other size groups are over-represented. That is immaterial for this analysis, however, since the focus is on the behaviour of firms and not their absolute numbers.

Regarding the different channels of innovation inputs, spending on capital goods is the most frequently used channel (60.7%), followed by spending on R&D (42.6%) and use of a license from a foreign-owned company (12.7%).[10] Size and foreign ownership are distinguishing traits for all firm characteristics related to innovation inputs and the generation of innovation outputs. For each of them, variable incidence increases with firm size. For example, 48.3% of large firms hold an IRQC, compared to 3.2% of micro firms; and the share of large firms spending on R&D or capital goods is more than double the share of micro firms.

Comparing foreign-owned and domestic-owned firms, a larger proportion of foreign-owned firms demonstrates awareness of the need to be competitive, while a larger proportion also engages in each of the three innovation input channels. Relatively more foreign-owned firms introduce a new product (76.8% compared to 67.4% for domestic-owned firms), while the incidence of new process introduction is roughly similar for the two groups (61.7% versus 57.3%).

IV. Results

1. General model

When interpreting the regression results, two caveats must be kept in mind. First, this study primarily explores associations between firm characteristics and innovation engagement and outcomes, not causality. Nonetheless, the fixed-effects estimates do suggest causal relations, since they capture changes in firm behaviour from one of the three years to another. Second, with the exception of 'virtual connectivity' and 'foreign ownership', we use dummies, not absolute values for all the variables. We estimate the likelihood of firms engaging in particular innovation activities or not, and not the impact of the degree of engagement. For instance, the data capture whether firms spend on R&D or not, but not how much they spend. Similarly, the analysis captures whether a firm introduces a new product or process, but not the nature of that innovation. For example, it does not distinguish between minor adjustments to the production process and a major change.

Table 4 shows estimates of the first step: the impact of firm characteristics on engagement with innovation inputs. The results for spending on R&D are particularly strong, because the coefficients are unbiased in the random-effects model. All firm characteristics that indicate awareness of the need to be competitive have the expected signs and are statistically significant in the random-effects models for engagement with each of the three innovation input channels (with the exception of exporting for 'holding a license'). The coefficients on these firm characteristics are highest for spending on R&D. However, the results show that the other innovation input channels are also important particularly investment in capital goods. With the exception of IRQC and VC, the coefficients in the fixed-effects models are not statistically significant. That most likely reflects the fact that not enough firms switched between years to generate efficient estimates. Being part of a multi-plant corporation does not generally have a significant impact.

Firm size matters greatly for engagement with innovation inputs. The likelihood that a firm engages with the three innovation inputs increases in proportion with the firm's size. For example, compared to micro firms, the likelihood of investing in capital goods increases by 12% for small firms, 25% for medium-sized firms and 35% for large firms. The likelihood of spending more on R&D than micro firms rises from 4.4% for small firms to 9.3% for medium-sized firms, and to 13% for large firms. These are robust results, as the coefficients are quite similar when employment is the sole criterion used for size.[11]

[10] Of the 5,721 observations, 6.7% engaged with all three innovation channels, 1.6% used licenses and R&D, 28.6% spent on R&D and capital goods and 3.2% held a license and spent on capital goods. Only 10.5% spent on R&D, 1.3% only held a license and 24.1% only spent on capital goods. The results found that 24% did not engage with any of the innovation inputs.

[11] Based on employment data only, 21.2% of firms are micro (1–9 employees), 44.8% are small (10–49), 24.2% are medium sized (50–199) and 9.8% are large (> 200).

Table 4

Latin America (5 countries):[a] firms using innovation inputs (linear probability model)

	R&D		License		Capital goods	
	RE	FE	RE	FE	RE	FE
Foreign	-0.041*	-0.059	0.203***	0.027	0.003	0.059
	(0.02)	(0.08)	(0.02)	(0.06)	(0.02)	(0.07)
Exporting	0.089***	0.054	0.010	0.027	0.044***	0.032
	(0.02)	(0.04)	(0.01)	(0.04)	(0.01)	(0.03)
Internationally recognized quality certification (IRQC)	0.172***	0.138***	0.050***	-0.032	0.064***	0.005
	(0.02)	(0.04)	(0.01)	(0.03)	(0.01)	(0.03)
Virtual connectivity (VC)	0.136***	0.067**	0.024**	0.032	0.075***	0.030
	(0.01)	(0.03)	(0.01)	(0.02)	(0.01)	(0.02)
Multi-plant	0.009	0.011	0.046***	0.019	0.020	0.014
	(0.02)	(0.04)	(0.01)	(0.03)	(0.01)	(0.03)
Small	0.044**	0.017	0.010	-0.061	0.119***	0.138***
	(0.02)	(0.06)	(0.02)	(0.05)	(0.02)	(0.05)
Medium	0.093***	0.049	0.042***	-0.045	0.249***	0.265***
	(0.02)	(0.07)	(0.02)	(0.06)	(0.02)	(0.05)
Large	0.130***	0.089	0.078***	-0.086	0.349***	0.233***
	(0.02)	(0.08)	(0.02)	(0.07)	(0.02)	(0.06)
Year 2010	-0.038***	-0.017	0.015	-0.016	-0.0345***	-0.059***
	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)
Year 2017	-0.269***	-0.210***	0.004	-0.008	-0.104***	-0.146***
	(0.02)	(0.023	(0.01)	(0.02)	(0.01)	(0.02)
Argentina	0.062***		0.041**		0.019	
	(0.02)		(0.02)		(0.02)	
Colombia	0.095***		0.003		-0.054***	
	(0.02)		(0.02)		(0.02)	
Ecuador	0.184***		0.064***		-0.003	
	(0.03)		(0.02)		(0.02)	
Peru	0.074***		0.004		0.025	
	(0.02)		(0.02)		(0.02)	
Constant	0.113***	0.325***	-0.004	0.139	0.307***	0.429***
	(0.07)	(0.05)	(0.02)	(0.06)	(0.02)	(0.04)
Observations	5 964	5 964	4 856	4 856	8 259	8 259
Wald stat chi^2	1141.77		437.69		1087.21	
Model F		10.19		0.75		7.32
R^2	0.182	0.167	0.087	0.0003	0.128	0.093
Hausman test	13.46		27.9**		34.86***	

Source: Prepared by the authors, on the basis of World Bank, “Enterprise Surveys” [online] https://databank.worldbank.org/source/enterprise-surveys.

Note: Standard errors in parentheses. ***p<0.01; ** p<0.05; * p<0.1.

[a] The omitted country is Uruguay.

In comparison with domestic firms, a larger share of foreign-owned firms export, hold an IRQC, are part of a multi-plant establishment and are large. The average VC index is higher as well. However, once we control for these characteristics in the estimates, foreign ownership does not have an additional positive impact on innovation engagement. The coefficient in the R&D model is actually slightly negative and statistically significant. In other words, what distinguishes domestic and foreign firms are not inherent differences, but a different incidence of key firm characteristics.

Specificities of time and place influence a firm’s likelihood of spending on R&D. The coefficients for many of the country dummies are statistically significant, especially in the R&D model. The significance of the year dummies illustrates the impact of the broader economic context in which firm innovation unfolds; innovation engagement is lower in years of slower growth. In 2010, firms were less likely to use innovation inputs than in 2006 before the ‘Great Recession’. In 2017, firms were even less likely to spend on R&D or new capital goods, as economic growth was low.

How does engagement with innovation inputs affect the production of innovation outputs? Table 5 shows the estimates of the second step model. The results indicate that firms that spend on R&D or new capital goods are significantly more likely to introduce a new process or product. These findings are particularly robust, as they are statistically significant in both the fixed- and the random-effects model. In the random-effects model, spending on R&D increases the likelihood that a firm will introduce a new process by 21% and a new product by 20%. The increased likelihood resulting from spending on capital goods is 17% for a new process and 10% for a new product. The use of foreign-owned licenses, on the other hand, has a much smaller impact on the introduction of a new process or product.

Table 5

Latin America (5 countries):[a] firms introducing a new product or process (linear probability model)

	New process		New product	
	Random effects	Fixed effects	Random effects	Fixed effects
R&D	0.210***	0.121***	0.204***	0.146***
	(0.02)	(0.03)	(0.01)	(0.03)
License	0.037*	0.039	0.066***	0.025
	(0.02)	(0.04)	(0.02)	(0.04)
Capital goods	0.165***	0.130***	0.098***	0.070**
	(0.02)	(0.03)	(0.01)	(0.03)
Foreign	-0.024	-0.212**	0.007	-0.106
	(0.03)	(0.10)	(0.03)	(0.08)
Exporting	-0.021	0.011	0.02	-0.021
	(0.02)	(0.04)	(0.02)	(0.04)
Internationally recognized quality certification (IRQC)	0.055***	0.022	0.005	0.032
	(0.02)	(0.05)	(0.02)	(0.04)
Virtual connectivity (VC)	0.055***	0.041	0.076***	0.062*
	(0.01)	(0.04)	(0.01)	(0.03)
Multi-plant	0.002	-0.040	0.036*	-0.022
	(0.02)	(0.04)	(0.02)	(0.04)
Small	0.001	-0.011	0.015	-0.062
	(0.02)	(0.07)	(0.02)	(0.06)
Medium	-0.010	-0.012	-0.01	-0.051
	(0.02)	(0.08)	(0.02)	(0.07)
Large	-0.036	-0.069	-0.038	0.019
	(0.03)	(0.10)	(0.03)	(0.00)
Year 2010	-0.181***	-0.191***	-0.135***	-0.092***
	(0.02)	(0.03)	(0.02)	(0.02)
Year 2017	-0.130***	-0.163***	-0.013	-0.006
	(0.02)	(0.03)	(0.02)	(0.03)
Argentina	-0.011		-0.036	
	(0.03)		(0.02)	
Colombia	0.038*		-0.043***	
	(0.02)		(0.02)	
Ecuador	-0.008		-0.004	
	(0.04)		(0.03)	
Peru	0.081***		-0.005	
	(0.02)		(0.02)	
Constant	0.40***	0.561***	0.486***	0.558***
	(0.02)	(0.09)	(0.03)	(0.08)
Observations	4 557	4 557	4 673	4 673
Wald stat chi^2	658.69		583.52	
Model F		8.23		5.03
R^2	0.130	0.088	0.118	0.092
Hausman test	19.45		31.15***	

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.

Note: Standard errors in parentheses. ***p<0.01; ** p<0.05; * p<0.1.

[a] The omitted country is Uruguay.

The independent variables capturing firm characteristics are not significant in the estimate of the second step. This indicates that they do not have an impact on innovation outcomes beyond their impact on firm engagement with innovation inputs. A notable and robust exception is virtual connectivity, which is significant in three of the four estimates. One possible explanation for this is that firms using the Internet for business transactions also use it to learn about new technologies and products relevant to their particular production area. The use of an IRQC also has an additional positive impact but only for the introduction of a new process. Interestingly, once we control for other variables, foreign ownership has a slightly negative impact on the likelihood of introducing a new process in the fixed-effects model.

We also estimated equations 1 and 2 for each of the five countries individually.[12] Overall, the individual country models confirm the findings from the pooled model. Most importantly, in all five economies, engagement with R&D and capital goods significantly increases the likelihood of a firm introducing a new process or product.

2. National innovation system

Firms operate in a national environment of institutions and incentives that enable or hinder the development of their innovation capabilities. A set of interconnected micro, macro and meso factors shape firms' desire or willingness to innovate. They include, but are not limited to, the prevalence of Schumpeterian entrepreneurial spirit, policies affecting relative prices (such as exchange rate and technology support policies), the availability of necessary human capital and infrastructure and possibilities for collaboration with and spillovers from other firms and institutions.

According to the United Nations Industrial Development Organization (UNIDO, 2015, p. 6), "learning and innovation involve complex interactions between firms and their environment —not just the firms' network of customers and suppliers but also the technological infrastructure, institutional and organizational framework, and knowledge-creating and diffusing institutions." The different components of a national innovation system have to work in complementary fashion to enhance firm level innovation (Edler and Fagerberg, 2017; Lundvall, 1992).

Data from the Enterprise Surveys reveal the impact of two key elements of the national innovation context on firm innovation behaviour. The first variable captures whether the firm has engaged in cooperative innovation activities with external partners, and the second shows whether the firm received public support for innovation activities.[13] In order to test the impact of the two variables, we added them to equations (1) and (2) above. As the information is only available for the 2010 surveys, we cannot include it in the full panel estimates. Instead, we use OLS estimates for 2010 only. Given these restrictions, we consider the results tentative, with more research needed in the future.

Table 6 shows the variable means. The proportion of foreign firms that collaborate in innovation with external partners is considerably larger than the proportion of domestic firms, while the share of domestic firms receiving government support is slightly higher than the share of foreign firms.

[12] The results are available from the authors upon request.

[13] ECLAC (2011) offers an extensive discussion for Latin America of the importance of national innovation systems generally and research collaborations and public support specifically.

Table 6
Latin America (5 countries):[a] variable means, 2010
(Percentages)

	All	Nationality of ownership		Firm size			
		Domestic	Foreign[b]	Micro	Small	Medium	Large
Elements of innovation Ecosystem							
Innovation cooperation with external partners (%)	21.9	20.9	30.4	16.4	16.9	21.3	32.4
Government support for innovation (%)	11.6	11.8	10.8	6.1	9.9	12.7	17.1
Firm characteristics							
Foreign (%)	10.4	0.0	100.0	0.2	3.1	7.5	30.9
Exporting (%)	37.0	32.5	49.5	5.8	17.9	31.5	53.9
Virtual connectivity[c] (VC) (0-2)	1.6	1.6	1.9	1.2	1.6	1.75	1.9
Multi-plant (%)	12.3	9.9	33.1	4.0	8.7	12.9	26.9
Internationally recognized quality certification (IRQC) (%)	29.8	25.0	71.1	3.9	13.1	26.4	57.5
Micro (%)	14.3	16.2	0.2				
Small (%)	26.7	29.5	6.9				
Medium (%)	29.8	31.4	18.5				
Large (%)	29.2	22.9	74.4				
Innovation inputs							
R&D (%)	53.3	51.9	65.3	30.0	46.6	60.9	71.3
License (%)	13.8	11.1	37.2	4.8	8.3	13.9	26.8
Capital goods (%)	63.1	60.9	82.4	34.3	53.1	67.8	85.1
Innovation outputs							
New product (%)	68.1	63.1	73.2	51.3	62.8	67.5	72.0
New process (%)	55.3	55.1	56.5	46.1	53.4	59.9	63.7

Source: Prepared by the authors, on the basis of World Bank, “Enterprise Surveys” [online] https://databank.worldbank.org/source/enterprise-surveys.
[a] Argentina, Colombia, Ecuador, Peru and Uruguay.
[b] Foreign ownership of assets > 10%.
[c] This variable is not expressed in percentages, but in values from 0 to 2.

Table 7 shows the estimates for equations (1) and (2), with and without the inclusion of the two indicators of the national innovation system. Cooperation with other institutions has significant positive effects on engagement with R&D, spending on capital goods and the introduction of new products and processes, even after considering their impacts on R&D and capital goods. Public support is only significant for the R&D innovation channel. That is not surprising, given that public support often takes the form of subsidies or tax credits for R&D spending. Again, there is an independent impact on the introduction of a new process or product over and above the impact on R&D.

Table 7
Latin America (5 countries): ordinary least-squares (OLS) models with innovation cooperation and public support, 2010

	New product	New process	R&D	License	Capital goods	New product	New process	R&D	License	Capital goods
R&D	0.287***	0.207***				0.303***	0.229***			
	(0.02)	(0.02)				(0.02)	(0.02)			
License	0.061**	0.016				0.062**	0.017			
	(0.03)	(0.03)				(0.03)	(0.03)			
Capital goods	0.084***	0.168***				0.087***	0.173***			
	(0.02)	(0.02)				(0.02)	(0.02)			
Cooperation	0.050*	0.010***	0.209***	0.025	0.075***					
	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)					

Table 7 (concluded)

	New product	New process	R&D	License	Capital goods	New product	New process	R&D	License	Capital goods
Public support	0.086***	0.069**	0.108***	-0.001	0.008					
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)					
Foreign	0.056	-0.057	-0.083	0.236***	0.01	0.047	-0.06	-0.10**	0.236***	0.008
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.040)
Exporting	-0.005	-0.028	0.093***	-0.004	-0.011	-0.0004	-0.024	0.104***	-0.004	-0.010
	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)
Internationally recognized quality certification (IRQC)	0.013	0.081***	0.128***	0.049**	0.015	0.023	0.095***	0.162***	0.052**	0.025
	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)
Virtual connectivity (VC)	0.054**	0.061**	0.139***	0.025	0.076***	0.054**	0.062***	0.150***	0.026	0.080***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.0221)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Multi-plant	0.030	-0.015	0.010	0.058**	0.023	0.029	-0.020	-0.001	0.057**	0.0187
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Small	0.012	-0.031	0.099***	0.020	0.171***	0.010	-0.036	0.094***	0.019	0.169***
	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)
Medium	-0.010	-0.049	0.163***	0.046*	0.306***	-0.013	-0.05	0.161***	0.0454	0.304***
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)
Large	-0.051	-0.088*	0.168***	0.097***	0.449***	-0.048	-0.086*	0.184***	0.098***	0.453***
	(0.04)	(0.05)	(0.04)	(0.03)	(0.04)	(0.04)	(0.05)	(0.04)	(0.03)	(0.04)
Argentina	0.019	-0.008	0.079**	0.054*	-0.008	0.021	-0.006	0.087**	0.055*	-0.005
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.028)	(0.04)
Colombia	-0.062*	0.040	0.101***	0.017	-0.067**	-0.062*	0.039	0.104***	0.017	-0.066**
	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.035)	(0.03)	(0.03)
Ecuador	-0.107**	-0.049	0.080	-0.019	0.050	-0.108**	-0.050	0.081	-0.018	0.051
	(0.05)	(0.06)	(0.05)	(0.04)	(0.05)	(0.05)	(0.06)	(0.06)	(0.04)	(0.05)
Peru	-0.036	0.090***	0.111***	0.033	0.072**	-0.046	0.080**	0.098***	0.033	0.070**
	(0.03)	(0.03)	(0.03)	(0.025)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)
Constant	0.349***	0.212***	-0.019	-0.014	0.232***	0.361***	0.225***	0.009	-0.012	0.239***
	(0.04)	(0.04)	(0.04)	(0.03)	(0.042	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)
Observations	1 887	1 886	1 895	1 891	1 894	1 887	1 886	1 895	1 891	1 894
R^2	0.157	0.135	0.197	0.104	0.164	0.151	0.126	0.159	0.103	0.160

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.

Note: Standard errors in parentheses. ***p<0.01; ** p<0.05; * p<0.1.

Another indicator of the importance of R&D support and innovation cooperation is the increase in R^2 when the two variables are included in the model. The increase is most pronounced for 'engagement with R&D' and 'introduction of a new process'. Taken together, the results offer empirical support for active government policies to advance innovation capabilities at the firm level.

3. Comparison with firms in China

Among upper middle-income economies, China stands out for its exceptional economic performance, which has made Chinese producers the fiercest competitors for Latin American firms in domestic and third markets alike over the past two decades (Jenkins, 2019; Paus, 2019; Gallagher and Porzecanski, 2010). A middle-income economy with GDP per capita roughly equal to that of aggregate Latin America, China has seen extraordinary growth in output and productivity over the last three decades (Zhu, 2012). Commenting on China's ranking in the Global Innovation Index 2016, Dutta, Lauvin and Wunsch-Vincent (2016, p. 18) point out that "China is now the only middle-income economy with innovation quality scores that display a balance similar to that of high-income economies".

Given China's performance in productivity and innovation, this model explores whether the connections between innovation inputs and outputs for firms in China are different from what has been observed in the five Latin American countries. We estimate equations (1) and (2) for 2012, the only year for which the World Bank has an Enterprise Survey for China.[14] A comparison of the regression results has to be treated with caution, since the China survey is a different survey for a different year, compared with the surveys for Latin American countries.

The descriptive statistics for the firms in China are summarized in table 8. The overwhelming majority of firms in the survey are privately owned; only about 5% are State-owned. Foreign firms account for 7.4% of all firms. With respect to firm size, 2% of the firms included in the survey are micro, 24.4% are small, 38.7% are medium-sized and 34.9% are large. Compared with Latin America, a smaller share of Chinese firms export (20.9% versus 37%). That may be a reflection of China's large internal market. On the other hand, many firms may be indirect exporters as first- or second-tier input suppliers to exporters that participate in global value chains (GVCs). Across firm sizes, a much higher percentage of domestic and foreign firms hold an internationally recognized quality certification, which is generally a requirement for GVC participation.

Table 8
China: variable means, 2012
(Percentages)

	All	Nationality of ownership		Firm size			
		Domestic	Foreign[a]	Micro	Small	Medium	Large
Firm characteristics							
Foreign	7.4	0.0	100.0	0.0	3.6	8.1	9.6
Exporting (%)	20.9	18.6	51.6	0.0	8.5	18.8	33.3
Virtual connectivity[b] (VC)	1.6	1.6	1.7	1.3	1.4	1.7	1.8
Multi-plant (%)	11.2	10.0	25.0	0.0	3.4	8.1	20.7
Internationally recognized quality certification (IRQC) (%)	71.9	70.8	85.4	31.4	49.5	73.7	88.0
Micro	2.0	1.9	0.0				
Small	24.4	25.4	12.1				
Medium	38.7	38.4	42.7				
Large	34.9	33.9	45.2				
Innovation inputs							
R&D (%)	41.3	40.2	53.2	11.4	22.7	45.6	51.2
License (%)	24.2	21.8	52.9	2.9	13.1	24.4	32.9
Capital goods (%)	56.5	55.5	69.4	17.1	45.5	58.2	64.8
Innovation outputs							
New product (%)	45.7	44.8	55.3	8.6	36.4	48.5	51.4
New process (%)	62.5	61.6	72.6	20.0	52.2	66.3	68.1

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.
[a] Foreign ownership of assets > 10%.
[b] This variable is not expressed in percentages, but in values from 0 to 2.

A larger proportion of domestic and foreign-owned firms in Latin America is engaged in R&D and capital investment, but relatively more firms in China have a license. With respect to innovation outputs, a higher percentage of China's firms introduces a new process (62.5% versus 55.3% in Latin America), while a smaller share introduces a new product (45.7% versus 68.1%).

[14] Even though some of the questions were slightly different, a data set has been compiled with the same variables as for Latin America. The Enterprise Survey for China does not include questions about public support for innovation or collaboration with other entities.

Table 9 shows the OLS estimates of equations (1) and (2) for China's firms. The characteristics of firms engaging in R&D are the same in China as in Latin America. Exports, firm size, holding a recognized production standards certification and using virtual connections for interactions with clients and others are all positive and statistically significant. The findings for licenses and investment in capital equipment are slightly more varied. Engagement with R&D, licenses and new capital equipment increases the likelihood that a firm in China introduces a new process or product. Again, these results are in line with the findings for Latin America.

Table 9
China: OLS models, 2012

	New product	New process	R&D	License	Fixed assets
R&D	0.432***	0.263***			
	(0.02)	(0.02)			
License	0.223***	0.195***			
	(0.03)	(0.03)			
Capital goods	0.146***	0.181***			
	(0.02)	(0.02)			
Foreign	-0.001	-0.001	0.000	0.003***	0.001
	(0.00)	(0.00)	(0.001)	(0.00)	(0.001)
Exporting	-0.012	0.004	0.137***	0.107***	0.138***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Internationally recognized quality certification (IRQC)	0.017	0.047	0.049**	0.117***	0.019
	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)
Virtual connectivity (VC)	0.020	0.079***	0.074***	0.068***	-0.031
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Multi-plant	0.108***	0.106***	0.120***	0.085***	0.016
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)
Small	0.157**	0.193**	0.072	0.047	0.269***
	(0.07)	(0.08)	(0.08)	(0.07)	(0.09)
Medium	0.131*	0.195**	0.255***	0.093	0.384***
	(0.07)	(0.08)	(0.08)	(0.07)	(0.09)
Large	0.087	0.143*	0.259***	0.120*	0.430***
	(0.07)	(0.08)	(0.08)	(0.07)	(0.09)
Cons	-0.026	0.020	0.006	-0.094	0.205**
	(0.07)	(0.08)	(0.08)	(0.07)	(0.09)
R^2	0.32	0.23	0.09	0.11	0.05
Observations	1 631	1 629	1 656	1 654	1 660

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.
Note: Standard errors in parentheses. ***p<0.01; ** p<0.05; * p<0.1.

Overall, the estimates of the model suggest that the same attributes characterize firm engagement with innovation inputs in Latin America and China, and that engagement increases the likelihood of introducing a new product and process in all countries. However, comparing the estimates for China and Latin America suggests a possible link between innovation performance at the firm level and the aggregate level. Firms engaging with R&D seem to be more likely to introduce a new product or process in China than in Latin America. That difference in translation from firm innovation inputs into outputs may indicate differences in firm behaviour in the two areas.

Differences in average firm spending on R&D support that hypothesis. In both Latin America and China, the largest firms account for most of the R&D expenditures, generally more than 80%.[15] The reason is that average spending on R&D is so much higher for large firms than for firms in the other size

[15] The highest share was 97% for Colombia in 2006, and the lowest share was 72% for Peru in 2006. In China, the largest firms account for 85% of all R&D expenditures in 2012. The World Bank Enterprise Surveys for Ecuador do not have values for R&D.

categories. There is a large gap between the average R&D spending of micro, small and medium-sized firms on the one hand and large firms on the other (see table 10). Firm spending on R&D is higher in China than in Latin America across firm size categories, especially in large firms. The average large firm in China in 2012 spent much more than any Latin American country across all three years. State-owned enterprises do not drive this result, even though their average R&D expenditures are considerably higher than that of non-State-owned firms. Furthermore, the average R&D spending of large domestic firms in China is much higher than that of foreign-owned firms, in contrast to the Latin American countries where it tends to be lower (not shown).

Table 10
Latin America and China: average R&D spending, 2010 and 2012
(Percentages and current United States dollars)

	R&D spending/firm relative to large firms *(percentages, 2010)*				R&D/firm for large firms *(current US$)*		
	Micro	Small	Medium	Large	2006	2010	2017
Argentina	3.4	3.3	12.8	100	505 882	621 109	634 058
Colombia	1.4	1.7	4.8	100	622 581	658 390	284 956
Peru	1.5	5.2	21.8	100	146 611	304 911	312 482
Uruguay	0.7	9.6	24.6	100	226 778	141 257	84 852
China[a]	4.1	3.8	13.8	100		1 479 201	
State-owned		0.6	13.4	100		4 278 922	
Not State-owned (domestic)	3.8	9.7	20.8	100		1 189 651	

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.
[a] 2012.

One possible reason for the higher degree of engagement with R&D in China may be a more supportive overall innovation ecosystem in China compared to Latin American countries. Dutta, Lauvin and Wunsch-Vincent (2016, p. xxv) argue that "Asian economies have benefited from a strong and strategic coordination role of governments in innovation".

V. Conclusions

Increased and broad-based innovation is the key for escaping the middle-income trap. Advancing innovation at the national level is a complex and multifaceted process, in which firms are central actors.

In this paper we analysed the innovation behaviour of firms in five Latin American countries between 2006 and 2017. Estimates of the two-step model demonstrate that, while R&D spending tends to be the most significant channel for innovation inputs, capital investment —and to a lesser extent use of a license— are important channels as well. The results show that exporting, having an internationally recognized quality certificate and using the Internet for business purposes are key characteristics of firms that engage with innovation inputs. In addition, engagement with innovation inputs significantly increases the likelihood of firms introducing a new process or product.

The results suggest that there is no missing link per se between innovation inputs and outputs to explain innovation underperformance at the aggregate level. However, the larger coefficient for China's estimates on R&D spending for the introduction of a new product, and the considerably higher R&D spending by the average large firm in China, suggest that there may be lower translation of innovation inputs into outputs in Latin America, and thus a difference in firm behaviour.

To account for possible differences in firm behaviour, quantitatively as well as qualitatively, it may be useful to look at the larger innovation ecosystem in which firms operate, as well as the structure of the economy. In all developed and developing economies, R&D expenditures tend to be concentrated in the manufacturing sector. That sector no longer plays such a significant role in Latin American economies. The share of manufacturing value added in output declined from 24.7% in 1980, to 14.2% in 2010 and 13.3% in 2017. In contrast, the manufacturing sector in China accounted for 31.6% of total value added in 2010, and 28.1% in 2017.

However, China and a few other Asian latecomers are the exception. Over the past three decades, middle-income economies have generally witnessed a decline in the relative position of the manufacturing sector. Some economists have referred to this phenomenon as premature de-industrialization (Rodrik, 2016; Palma, 2005). It is termed premature because the weight of manufacturing in today's middle-income economies, both in terms of employment and value added, started to decrease at much earlier GDP per capita levels than in today's industrialized economies. The decline accelerated after 2000 and was most pronounced in Latin America.

A number of authors have argued that the decline in the manufacturing sector and the concomitant rise of the informal sector with its many small low-productivity firms is linked to the move to a market-led strategy. Government support for technological learning in its different facets was limited and disjointed, which was not conducive to broad-based innovation (Paus, 2019; Cimoli and others, 2017; Ocampo, 2004). The market-based approach pursued by Latin American governments stands in stark contrast to the State-led approach followed by China, especially in terms of its increasingly deliberate focus on advancing innovation (Gallagher and Porzecanski, 2010).

The empirical findings support the case for active government policies to advance innovation in Latin America. First, the results demonstrate the interconnections between innovation policies and competitiveness policies, a link which other authors have highlighted (Mytelka, 1999). Firm characteristics that increase the likelihood of company engagement with innovation inputs are exports, virtual connections for client interactions and use of internationally recognized production standards. All of these factors indicate an awareness of the means, if not the ability, to compete nationally and internationally . Thus, on a broad level, provision of good broadband infrastructure for firms to have Internet access and support for acquiring certification in internationally recognized production standards play an important role in increasing firms' ability to compete and in increasing the likelihood that they will engage in innovation. Equally important are export support policies —especially avoiding overvalued exchange rates— and access to finance, given the importance of the capital investment channel for innovation outcomes.

With respect to innovation-specific policies, the results suggest that direct support for firm innovation and facilitation of innovation collaboration across organizations have a significant impact on advancing innovation engagement and outcomes. Furthermore, in Latin America's current low-growth context, pro-active policies may be necessary to crowd in private sector innovation engagement. In today's highly competitive international markets, such policies need to be part of a comprehensive and cohesive innovation-focused strategy that will enable an escape from the middle-income trap.

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Annex A1

Variables used in the analysis

Variable name, Survey question text, Variable name in survey, Dummy definition

Innovation inputs

Research and development

2006, 2010, 2017 (h8): During last fiscal year, establishment spent on R&D (excl. market research)?

Yes=1, No=0

Investment in fixed assets

2006, 2010, 2017 (k4): Purchase any new/used fixed assets?

Yes=1, No=0

License

2006, 2010, 2017 (E6): Do you use technology licensed from a foreign-owned company?

Yes=1, No=0

Innovation outputs

New product

2006, 2010, 2017 (h1): New products/services introduced over last 3 years?

Yes=1, No=0

New process

2006, 2010, 2017 (h5): During last 3 years establishment introduced new/significantly improved processes?

Yes=1, No=0

Other variables

Internet use

2006, 2010, 2017 (c22a): Do you currently communicate with clients and suppliers by email?

2006, 2010, 2017 (c22b): Establishment has its own website

Composite Index: Internet (based on c22a and c22b) (VC)

0=none

1=either email or website

2=both email and website

Internationally Recognized Quality Certification (IRQC)

2006, 2010, 2017 (b8): Does establishment have an internationally recognized quality certification?

Yes=1, No=0

Multi-plant member

2006, 2010, 2017 (a7): Establishment is part of a large firm?

For Ecuador (_2006_2010_2017_a7)

Yes=1, No=0

Employees

2006, 2010, 2017 (l1): Permanent, full-time employees at end of last fiscal year

Sales

2006, 2010, 2017 (n3): What were the establishment sales three years ago?

Foreign

2006, 2010, 2017 (b2b): % owned by private foreign individuals, companies or organizations

If b2b <= 10%, foreign=0

Exports

2006, 2010, 2017 (d3c): % of Sales - Direct exports

Exports=1, if d3c > 0, 0 otherwise

Innovation cooperation

2010 (_2010_LACe9): Last 3 years - cooperate on innovation w/other enterprises/science & technology institutions?

Yes=1, No=0

Public support

2010 (_2010_LACe10): Last 3 years - receive any public support for innovation-related activities?

Yes=1, No=0