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Interplay Between Innovation Barriers and Cooperation in Latin America

Lessons for Public Policy

Prepared for the Inter-American Development Bank by:

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Abstract*

This paper investigates whether firms in Latin America that confront more barriers to innovation are more likely to engage in cooperative innovative efforts with other economic actors. Data from the Harmonized Latin American Innovation Surveys Database (LAIS) allows us to explore the relationship between these obstacles and the cooperation of innovation-active manufacturing firms with other economic agents in innovative activities. Our findings robustly suggest that cooperation is a coping strategy for innovation obstacles: firms perceiving obstacles tend to cooperate more, especially with research institutions. For small and (some) medium-sized companies, we also find a positive relationship between financial barriers and cooperation with other firms, and between market obstacles and cooperation with research institutions. These results suggest that, from a public policy perspective, efforts to increase innovation should go beyond a financial market failure approach and embrace a more comprehensive systemic failure approach.

JEL Codes: O30, O31, O38
Keywords: innovation barriers, cooperation, Latin America, public policy

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1. Introduction

Productivity is one of the key drivers of economic development, and the problem of slow productivity growth remains a relevant issue in Latin American and Caribbean (LAC) countries (see, for example, Pagés, 2010). Understanding what determines productivity growth is a pertinent question in the literature, and the existing evidence suggests that innovation is an important determinant (Syverson, 2011).

Nevertheless, innovation is a risky investment, and most of the literature has focused on financial obstacles that prevent, delay, or block innovation. However, due to the availability of different waves of innovation surveys in different countries, the literature documents other barriers that may be as relevant as financial constraints in hampering innovative activities (Pellegrino and Savona, 2017). Moreover, this literature also covers LAC countries (Arza and López, 2021; Bukstein, Hernández, and Usher, 2019; Cânedo-Pinheiro et al., 2018; Mohan, Strobl, and Watson 2016; Zahler, Goya, and Caamaño, 2022).

There is also a growing empirical literature on various aspects related to cooperation for innovation, mostly for European countries (Antonioli, Marzucchi, and Savona, 2017; Becker and Dietz, 2004; De Faria, Lima, and Santos, 2010; Odei et al., 2018; Tiwari and Buse, 2007). However, only a few efforts use Latin American data (ECLAC, 2011; Fuentes-Solís, Soto-Caro, and Paredes, 2019). Furthermore, recently, the dominant approach has been changing to consider that obstacles hinder the effect of the various determinants of innovation—collaboration among them—over company innovativeness. In other words, instead of considering obstacles alongside innovation determinants as explanatory variables, it is more appropriate to explicitly recognize the moderating role of obstacles in the innovation process (Moraes Silva and Vonortas, 2022). In that sense, to the best of our knowledge, no work has attempted to investigate the interplay between barriers to innovation and cooperation in Latin America, except for Brazil (Cânedo-Pinheiro et al., 2018; Moraes Silva, Lucas, and Vonortas, 2020) and Colombia (Salazar-Elena et al., 2023).

So far, the literature has shown different perspectives on this subject, but cooperation is perceived as an effective coping strategy in the presence of

obstacles (Antonioli, Marzucchi, and Savona, 2017) and, for this reason, boosts innovation. However, contrary to their counterparts in Europe, Brazilian firms cooperate less due to organizational and financial barriers, especially with other firms. In the Brazilian context, cooperation (especially with research institutions) is a coping strategy only for knowledge obstacles (Cânedo-Pinheiro et al., 2018).

Are the results found for Brazil concerning the interplay between barriers to innovation and cooperation valid for the rest of Latin America? If so, what are the implications for public policy on innovation in these countries? The Brazilian experience also indicates that the increase in public funding for innovation mitigated the market failures associated with credit but exacerbated the lack of qualified personnel to work on innovative activities (Cânedo-Pinheiro and Sousa, 2021). It seems that, at least for Brazil, it is not enough to deal with financial obstacles to innovation; there are also knowledge obstacles (see Pereira Cabral, Lage de Sousa, and M. Canêdo-Pinheiro, 2020 for a discussion about this issue). That is, instead of a narrow financial market failure approach, it is more appropriate to pursue a more comprehensive systemic failure approach (Bleda and del Río, 2013). Does this also hold for all of Latin America? Answering these questions is particularly relevant in the context of fiscal constraints in most Latin American countries (World Bank, 2022) and could help improve the design of public policies in these countries.

2. Literature

This section presents theoretical and empirical elements regarding two research pillars: innovation barriers and cooperation. It also explores aspects of the interplay between both pillars.

2.1. Cooperation and Innovation

From a theoretical perspective, there is no definitive integrated model that explains the reasons for business cooperation for innovation activities. Hagedoorn, Link, and Vonortas (2000) and Lee and Vonortas (2002) name and explore several distinct and nonexclusive explanatory theoretically relevant perspectives: transaction costs, industrial organization models, and strategic management approaches, such as competitive forces, resourced-based view of the firm, strategic network, dynamic

capabilities, and strategic options to new technologies. Depending on the motivations for collaboration, companies pursue different strategies in terms of partners, alliance structures, and control mechanisms. Moreover, depending on the reasons for engaging in collaboration, it makes more sense to use a specific subset of those theoretical perspectives to investigate the phenomena.

Those theoretical complexities are mirrored in the empirical literature. The industrial organization literature suggests that firms cooperate to internalize knowledge that could be appropriated by competitors (Arvanitis, 2012) or share cost-risk (López, 2008). The management literature also suggests that firms may cooperate if the partnership offers a chance to emphasize resources and capabilities and learn to use new technologies, and if it presents itself as an opportunity to shape the competitive environment (Caloghirou, Ionnides, and Vonortas, 2003). According to De Faria, Lima, and Santos (2010, p. 1083), cooperation is based on how firms "manage the trade-off between generating and receiving knowledge spillovers to and from partners."

The empirical literature also suggests that cooperation depends on several factors, including the type of partner, the partner's absorptive capacity, and the type of innovation (De Faria, Lima, and Santos, 2010; Wang, 2021). Also, evidence shows that small and less research and development (R&D)-intensive firms cooperate more to innovate than larger firms in high-tech sectors (Barge-Gil, 2010) and that geographical proximity to a university positively affects firms' product innovation (Maietta, 2015). Specifically, cooperation for R&D is usually used to complement firms' internal resources and results in higher R&D intensity and commitment (Becker and Dietz, 2004).

Finally, a significant part of the empirical literature also focuses on the effects of cooperation on firms' outputs (Barge-Gil, 2010). Usual variables for this analysis include a percentage of sales from innovative products (Fritsch and Lukas, 2001), sales of innovative products (Negassi, 2004), and labor productivity (Belderbos, Carree, and Lokshin, 2004). Overall, cooperation in innovation generates positive outputs for firms involved in the partnership, but it can also raise appropriability issues that may lead to competitive disadvantage (Veugelers, 2016).

2.2. Innovation Barriers

Overall, innovation barriers are seen as factors that prevent, delay, or block innovation (Mirow, Hoelzle, and Gemuenden, 2008). Additionally, the terms used to describe these factors (barriers, hurdles, impediments, or obstacles) are used interchangeably (Hueske and Guenther, 2015) and are related to the firm's awareness of the difficulties associated with innovation efforts (D'Este et al., 2012).

Innovation barriers used to be an understudied topic in innovation studies (Hadjimanolis, 2003), but this trend started to change following recent efforts by governments and agencies to promote innovation policies in different countries (Hölzl and Janger, 2012). Understanding innovation barriers and their impacts on innovation efforts is critical to policymakers since it allows for better design of new innovation policies and evaluation of already established ones (D'Este, Rentocchini, and Vega-Jurado, 2014; De Fuentes, Santiago, and Temel, 2020; Pellegrino and Savona, 2017). In many ways, minimizing innovation barriers is key to innovative success (Hall and Martin, 2005).

Innovation barriers are generally classified into different groups for research and survey purposes, but so far, there is no widely accepted taxonomy in the literature (Hueske and Guenther, 2015). The most general division categorizes barriers as financial and nonfinancial (Pellegrino and Savona, 2017) or external and internal (Hadjimanolis, 2003).

Among all the innovation barriers perceived by firms, the literature has mostly focused on financial ones. Theoretically, financial barriers are the result of positive externalities associated with innovation that lead to underinvestment in innovative activities. They also result from the intangible nature of assets produced and used in the innovation process, which makes them difficult to use as collateral when negotiating external funds in the presence of asymmetric information and moral hazard (Moraes Silva and Vonortas, 2022). Overall, the empirical literature shows that, in fact, financial constraints negatively affect firms' investments in innovation (see Hall et al., 2016) for a comprehensive review on this subject). There is also evidence that financial barriers are associated with a loss of firm productivity (Coad, Pellegrino, and Savona, 2016). These barriers hamper their innovation efforts throughout the entire innovation cycle but are especially deleterious in the early

stages of the innovation process—especially for radical innovations (Pereira Cabral, Lage de Sousa, and M. Canêdo-Pinheiro, 2020).

Among nonfinancial obstacles, knowledge barriers have probably been the most studied subgroup. As firms need a robust and diversified (internal and external) knowledge base to be able to draw the most from their innovative activities, these obstacles predicate the low absorptive capacity of new knowledge (Moraes Silva and Vonortas, 2022). Knowledge obstacles usually refer to, for example, scarcity of qualified personnel and lack of information on markets and technologies. Empirical evidence of the impact of knowledge barriers on innovation is mixed: from a negative effect (e.g., Amara et al., 2016), to a negative effect only among companies more engaged in innovative activities (e.g., D'Este et al., 2012), to no significant effect at all (e.g., Pellegrino and Savona, 2017).

In turn, market obstacles are usually associated with external (to firms) hurdles to innovation, such as market size, market structure, market dominance by incumbents, and demand uncertainty. The empirical literature shows a negative relationship between market obstacles and innovation for developed countries (e.g., Pellegrino and Savona, 2017) and developing countries (e.g., Bukstein, Hernández, and Usher, 2019).

More detailed classifications also include barriers associated with economic risk (Mohnen et al., 2008), lack of customer responsiveness (e.g., Galia and Legros, 2004), organization (Madrid-Guijarro, Garcia, and Van Auken, 2009), demand (Zahler et al., 2022), regulation (D'Este et al., 2012), and access to public support (Santiago et al., 2017). In many cases, the research involves more than one barrier, but there are also studies of only one (Hueske and Guenther, 2015).

Other contributions dedicated to innovation barriers include but are not limited to the mediating role of external knowledge search to surpass innovation hurdles (Torres de Oliveira, Gentile-Lüdecke, and Figueira, 2021), how firm age can affect a firm's perception of innovation obstacles (Pellegrino, 2018), and how the perception of innovation barriers may change for successful and unsuccessful innovators (De Fuentes et al., 2020). There is evidence that small, independent, and highly innovative companies are more likely to consider barriers to innovation as highly important (Hölzl and Janger, 2014) and that radical innovation barriers are more evident than incremental ones (Sandberg and Aarikka-Stenroos, 2014). In

addition, firms belonging to a group tend to perceive innovation barriers as less important than do single firms (Iammarino, Samma-Randaccio, and Savona, 2009).

Many studies on innovation barriers show a positive correlation between companies more engaged in innovation and perceived barriers to innovating (Hölzl and Janger, 2014; Pellegrino and Savona, 2017). Although it seems counterintuitive, it was initially hypothesized that this correlation exists because more innovative firms would be more aware of the barriers and better equipped to overcome them (Baldwin and Lin, 2002). However, more recent work attests that this correlation is due to a spurious correlation between innovation intensity and perceived obstacles due to inappropriate sample selection (Savignac, 2008). This perception has led many subsequent studies to restrict the analysis to groups called 'potential innovators'—those firms that invest in innovative activity and those that do not but have experienced barriers (D'Este et al., 2012). This procedure is fundamental to guarantee consistent results (Pellegrino and Savona, 2017).

A systematic review of almost 200 empirical studies on innovation barriers showed that the literature on innovation barriers became more popular at the beginning of the 2000s, especially after 2010. It also shows that most of the literature focuses on countries of the Global North, large companies, and multi-sectoral companies (Hueske and Guenther, 2015). The disproportionate distribution of studies focused on developed economies compared to studies focused on recently industrialized and developing economies draws attention to part of the literature (De Fuentes, Santiago, and Temel, 2020), especially considering that barriers to innovation are contextual and the results of studies conducted in rich countries may not be of much value for less developed economies (Hueske and Guenther, 2015). For example, for companies in countries far from the technological frontier, financial barriers are very relevant, since their financial and innovation systems are less developed than in countries near the frontier (Hölzl and Janger, 2014).

2.3. The Interplay Between Innovation Barriers and Cooperation

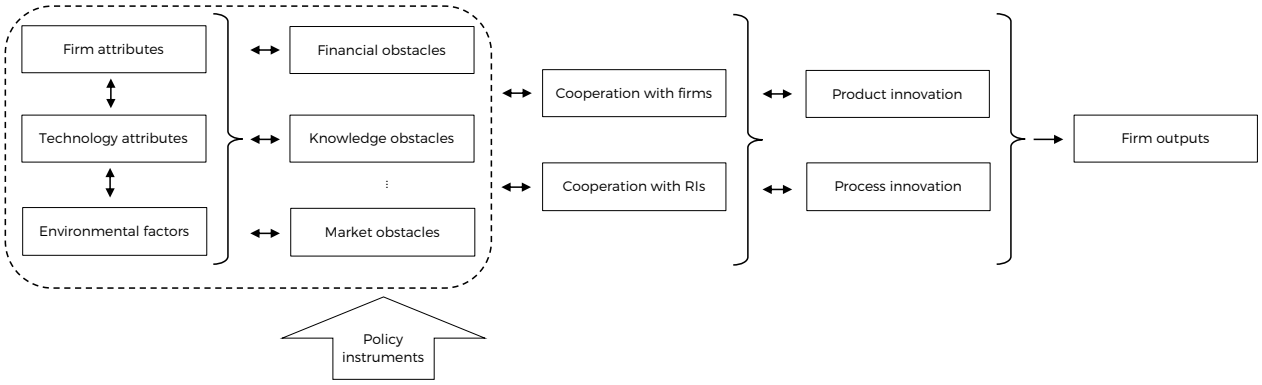
Most empirical studies include obstacle variables as additional independent variables alongside determinants of innovation (e.g., collaboration). However, there is a growing understanding that the more appropriate approach is to consider that

obstacles hamper the effect of the various determinants on company innovativeness. That is, analyses should instead explicitly recognize the moderating role of obstacles in the innovation process (Moraes Silva and Vonortas, 2022). Figure 1 combines and adapts Lee and Vonortas (2002) and Moraes Silva and Vonortas' (2022) approaches to illustrate this point graphically. In practice, instead of including collaboration indicators (inside the figure in dashed lines) as additional (product and process) innovation explanatory variables, it makes more sense to investigate how obstacles (alongside other attributes and factors) affect the way firms collaborate with other firms or with universities and research institutes.

In that sense, many aspects of innovation barriers have been explored in recent years, but the interplay of these barriers with cooperation has not been studied, especially for developing economies. It is this gap that this article aims to fill. In this regard, there is evidence that the perception of financial barriers is associated with the propensity of small- and medium-sized firms to cooperate with universities and research institutions (Moraes Silva, Lucas, and Vonortas, 2020). A closer examination of this connection also showed that perceiving innovation barriers is generally associated with adopting cooperation strategies, especially for financial barriers. These barriers are associated with cooperation with different partners, while knowledge barriers are associated with partnerships with research organizations (Antonioli, Marzucchi, and Savona, 2017). Evidence also shows that financial obstacles may prompt firms to access university knowledge, particularly in developed countries (Kanama and Nishikawa, 2017).

Moreover, the current empirical literature shows some aspects of the interplay between innovation barriers and cooperation, including that cooperation may reduce internal financial constraints and the cost of external funding to innovate (López, 2008). Evidence suggests that these partnerships may also reduce innovation costs through economies of scale and scope derived from collaboration with external partners (Arvanitis, 2012; Becker and Dietz, 2004). Other research also shows that the effects of obstacles to innovation are related and may affect firms' decisions to invest in science, technology, and innovation in middle-income developing countries (Tello, 2021).

Figure 1: Conceptual Framework: Interplay between Innovation Barriers and Cooperation



Source: Adapted from Lee and Vonortas (2002) and Moraes Silva and Vonortas (2022).

The pursuit of innovation may also lead companies to cooperate to surpass capabilities and skills shortages since these partnerships grant access to valuable external knowledge (Arranz, Arroyabe, and Fernandez de Arroyabe, 2019; Barge-Gil, 2010) and may lead to an upgrade in competencies and skills (Caloghirou, Ionnides, and Vonortas, , 2003). Companies can also cooperate to address market-related barriers, such as entering new markets, expanding existing ones, increasing capacity to cope with changes in demand, and bringing technologies to market more quickly (Hagedoorn, Link, and Vonortas, 2000; Mowery, Oxley, and Silverman, 1998; Wu, 2012).

3. Dataset and Relevant Sample

3.1. Data Source

We will use multi-country, firm-level (unbalanced panel) data from the Harmonized Latin American Innovation Surveys Database – LAIS (Crespi et al., 2022). LAIS contains variables at the firm level from innovation surveys in 10 Latin American countries. However, we will focus our analysis on six countries: Chile (2009, 2011, 2013, 2015, 2017), El Salvador (2013, 2016), Ecuador (2013, 2015), Paraguay (2013, 2016), Peru (2012, 2015), and Uruguay (2007, 2010, 2013, 2016).[1] Moreover, for

[1] Argentina, Colombia, Dominican Republic, and Panama are not included in the sample because they do not have all the variables necessary for this analysis and/or their questions regarding cooperation or obstacles to innovation differ substantially from the countries considered. For

harmonization, our sample will include only manufacturing firms, because not all surveys cover the other sectors properly. Table 1 shows the distribution of observations across countries and years.

In total, we have 7,539 firm-year observations from these six countries, and all countries have at least 200 firm-year observations. Therefore, enough variability across firms can be observed in all countries. In this 11-year period, we also have information from 9 years (no country conducted an innovation survey in 2008 or 2014). Apart from El Salvador, all other countries have information for at least two years. In summary, LAIS provides rich and detailed information on innovation in these developing countries.

Table 1. Observations per Country/Year

Countries	2007	2009	2010	2011	2012	2013	2015	2016	2017	Total
Chile	0	438	0	350	0	419	379	0	308	1,894
Ecuador	0	0	0	0	0	673	912	0	0	1,585
El Salvador	0	0	0	0	0	279	0	0	0	279
Paraguay	0	0	0	0	0	222	0	216	0	438
Peru	0	0	0	0	752	0	1,077	0	0	1,829
Uruguay	352	0	398	0	0	325	0	439	0	1,514
Total	352	438	398	350	752	1,918	2,368	655	308	7,539

Source: Authors' elaboration based on LAIS.

3.2. Defining Cooperation for Innovation

Innovation surveys in the LAIS database follow the Oslo Manual, which provides information on cooperation and obstacles. For cooperation, firms report which economic agent they have cooperated with. The economic agents vary across different countries and even across different waves. However, it is feasible to classify all economic agents into two broad categories: with firms and with research institutions and related. Table 2 provides a detailed list of all economic agents reported in the surveys and how they were considered in this study.

instance, Dominican Republic does not report firm size, Argentina and Colombia do not report the firm's age, and Panama does not collect information on whether the companies are foreign-owned.

Table 2: Cooperation for Innovation

With firms	With research institutions and related
▪ Headquarters	▪ Consultants, laboratories, and private R&D organizations
▪ Other firms of the group	▪ Laboratories and R&D firms
▪ Group	▪ Public R&D organizations
▪ Related firms	▪ R&D organizations
▪ Clients	▪ Universities
▪ Suppliers	▪ Tertiary non-university institutions
▪ Competitors	▪ Universities and other tertiary institutions
▪ Other firms	▪ Technology intermediaries
▪ Competitors and other firms	▪ IP office
▪ Consultants	▪ Public institutions of support to STI
▪ Business associations	▪ Government
▪ Consultants and business associations	▪ Others

Source: Authors' elaboration.

3.3. Defining Innovation Obstacles

In terms of innovation obstacles, LAIS makes it possible to identify the main barriers perceived by all firms in these six countries, innovation-active or not. As happens in cooperation, different categories of obstacles are considered in each country and/or wave; thus, we group these obstacles into three categories to harmonize the data and to obtain the most detailed classification of barriers possible, as discussed in our literature review: (1) financial (Mohnen et al., 2008); (2) knowledge (De Fuentes, Santiago, and Temel, 2020); and (3) market (Antonioli, Marzucchi, and Savona, 2017) (see Table 3 for further details). These three obstacles are generally the most frequently reported by firms in developing countries (e.g. Cânedo-Pinheiro et al., 2018).

The answer to obstacles is obtained on a four-level Likert scale, which means that firms report whether a particular barrier is considered high, medium, low, or of no importance. For the sake of comparison with the previous literature, we define that a firm perceives a certain type of obstacle if it considers this obstacle important or very important (Pellegrino and Savona, 2017). For example, a firm is said to perceive market obstacles if it considers important or high important barriers associated with sectoral technological dynamic, dominated market, market

structure, demand uncertainty, or market size. The same logic holds for the remaining obstacles.[2]

Table 3: Innovation Obstacles

Financial	Knowledge	Market
▪ Innovation uncertainty	▪ Qualified employees in the firm	▪ Sectoral technological dynamic
▪ Internal financing	▪ Qualified employees in the country	▪ Dominated market
▪ External financing	▪ Market information	▪ Market structure
▪ Technical risk	▪ Technology information	▪ Demand uncertainty
▪ Cost	▪ Cooperation partners	▪ Market size
▪ Period of return	▪ Cost of training	
▪ Expected return		

Source: Authors' elaboration.

3.4. Relevant Sample

In the innovation literature, scholars generally sort firms into two layers. The first layer is whether firms are active or inactive in innovation. In the second layer, innovation-active firms are divided into successful and unsuccessful. Regarding innovation-inactive firms, they are considered innovative-oriented or not, depending on whether they have perceived any barrier to innovate. In summary, from the innovation (and innovation barriers) perspective, it is feasible to sort firms into four groups:

- Innovators (innovation-active) – firms that have implemented product or process innovation.
- Failed innovators (innovation–active): those who have not yet innovated and have tried to do so by investing in innovation activities.
- Non-innovative (innovation-inactive): firms that were not active in innovative activities but reported perceiving obstacles to innovate in their business activities.
- Non-innovation-oriented (innovation–inactive): firms that did not engage in innovative activities and did not perceive innovation barriers.

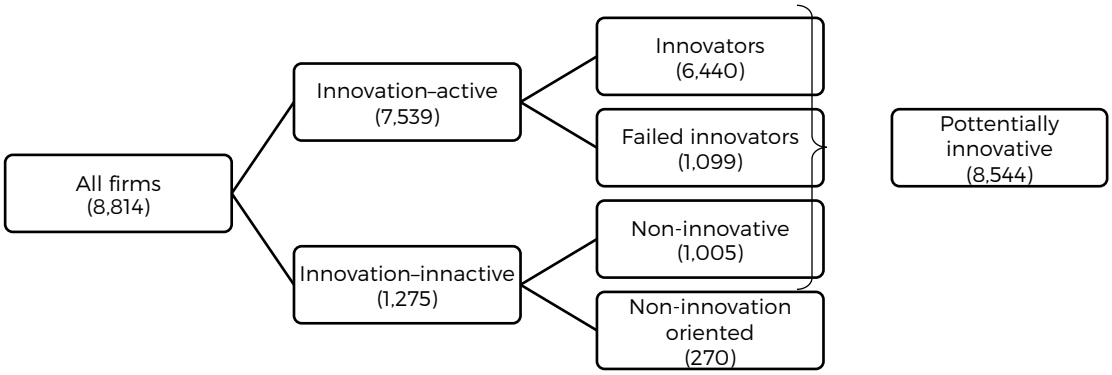
[2] In Argentinean surveys, innovation obstacles are measured only by a binary variable that captures whether a firm has experienced a particular obstacle. Therefore, even without dropping observations from Argentina due to the absence of control variables (see footnote 1), the approach we use to define if a firm perceives an obstacle would imply not using data from this country.

In practical terms, we follow Savignac (2008) and D'Este et al. (2012) by defining the non-innovation-oriented status as negative answers to all questions on obstacles and no expenditure on innovation activities in the relevant period. Moreover, as Savignac (2008), we call the group of innovation-active and non-innovative firms potentially innovative. Figure 2 shows how we split our sample into different groups of firms.

Firms with no interest in innovation tend to report that barriers to innovation are not relevant. This fact may generate a positive correlation between these barriers and the propensity to innovate (Savignac, 2008), possibly concerning cooperation with other partners and other innovation-related activities. Therefore, to correct this sample selection problem, we exclude the non-innovation-oriented firms from our sample, as in Savignac (2008) and Pellegrino and Savona (2017).

Furthermore, for Chile, Ecuador, and Uruguay, the countries with the largest number of firms included in our sample, the non-innovative firms do not answer the questions about cooperation and obstacles. For this reason, we decided to focus on innovation-active firms (7,539 observations from all six refereed countries, see Figure 2), which means we can address only what D'Este et al. (2012) define as revealed barriers, that is, hampering factors encountered in the production of innovations.

Figure 2. Sorting Firms According to Innovation (and Innovation Barriers) Status



Source: Authors' elaboration.
Note: The number of sampled (firm-year) observations in each group is in parenthesis.

3.5. Some Descriptive Statistics

Table 4 describes the interplay between innovation barriers and cooperation in our dataset from the six countries considered in this study. We sort firms into eight groups, considering whether the company perceives no barrier; only financial barriers; only knowledge barriers; only market barriers; both financial and knowledge obstacles; both financial and market obstacles; both knowledge and market obstacles; and all three kinds of barriers simultaneously. Concerning cooperation, we also divided the firms into four groups: no cooperation; cooperating only with firms; cooperating only with research institutions and related; and with both firms and research institutions.

Only 11.3 percent of the firms reported perceiving no innovation barrier. Most of the firms in our sample report perceiving more than one obstacle, and nearly half of them (49.6 percent) attest to perceiving all three barriers considered in this investigation. Furthermore, 73.6 percent (5.5+10.8+7.7+49.6) of the companies perceive financial obstacles, 72.1 percent (4.7+10.8+7.0+49.6) perceive knowledge obstacles, and 67.8 percent (3.5+7.0+7.7+ 49.6) perceive market obstacles. Initially, we might infer that there is an order of importance of the hurdles among these barriers: firms tend to perceive financial obstacles as the most important, which is a standard pattern in the literature, especially in developing countries. However, the difference between knowledge and financial obstacles is very small, raising the question of whether knowledge barriers might be as relevant as financial barriers in Latin American countries. According to Canêdo-Pinheiro et al. (2018), the effects of knowledge and financial obstacles on innovation outcomes are quite similar, although most firms tend to report the latter more than the former in Brazil.

Table 4: Cooperation × Innovation Barriers (Innovation-Active Firms)

		Cooperation				
		No cooperation	Only with firms	Only with research institutions and related	With both	Total
Innovation barriers	No barrier	318 (4.2%)	296 (3.9%)	24 (0.3%)	211 (2.8%)	849 (11.3%)
	Only financial	147 (1.9%)	135 (1.8%)	17 (0.2%)	113 (1.5%)	412 (5.5%)
	Only knowledge	102 (1.4%)	116 (1.5%)	18 (0.2%)	120 (1.6%)	356 (4.7%)
	Only market	82 (1.1%)	93 (1.2%)	5 (0.1%)	83 (1.1%)	263 (3.5%)
	Financial and knowledge	268 (3.6%)	261 (3.5%)	28 (0.4%)	256 (3.4%)	813 (10.8%)
	Financial and market	171 (2.3%)	191 (2.5%)	30 (0.4%)	191 (2.5%)	583 (7.7%)
	Knowledge and market	130 (1.7%)	169 (2.2%)	21 (0.3%)	206 (2.7%)	526 (7.0%)
	All	1,204 (16.0%)	1,136 (15.1%)	124 (1.6%)	1,273 (16.9%)	3,737 (49.6%)
	Total	2,422 (32.1%)	2,397 (31.8%)	267 (3.5%)	2,453 (32.5%)	7,539 (100%)

Source: Authors' elaboration.
Notes: In parenthesis, the percentage relative to the total number of innovation-active firms in the sample.

As for cooperation, a small proportion of the firms (3.5 percent) cooperate only with research institutions. The remaining firms are nearly evenly divided into the remaining three categories: around one-third of the firms either do not cooperate at all, cooperate only with firms, or cooperate with both firms and research institutions. In the end, when they cooperate, firms in our sample tend to do so always with another firm.

Some insights emerge when comparing these four groups of cooperation with the barriers they perceive. The first is that among those not perceiving any barrier, the percentage of firms that do not cooperate is higher than those cooperating with firms, which is also higher than those cooperating with firms and research institutions. This is an indication of a positive relationship between perceived barriers and cooperation. The other is that regardless of how they are classified by cooperation, most of the firms report perceiving all three barriers.

When looking at the other side, firms perceiving knowledge and financial barriers tend to cooperate more, because the percentage of those cooperating

(either with other firms or with firms and research institutions) is higher than those not cooperating at all. Overall, these preliminary statistics show a possible correlation between cooperation and innovation hurdles, which should be investigated further under econometric scrutiny.

Before moving to the econometric analysis, it is also important to evaluate how countries differ regarding firms' attributes in this sample. Table 5 presents a brief description of the relevant variables. Table 6 shows some descriptive statistics by country.

Table 5: Variables

Name	Description
$\mathcal{C}_{(F)}$	Cooperation with firms (dummy) (see Table 2)
$\mathcal{C}_{(R)}$	Cooperation with research institutions and related (dummy) (see Table 2)
$B_{(1)}$	Financial barrier (dummy) (see Table 3)
$B_{(2)}$	Knowledge barrier (dummy) (see Table 3)
$B_{(3)}$	Market barrier (dummy) (see Table 3)
GROUP	Firm belonging to a corporate group (dummy)
AGE	Number of years since firm foundation
FOREIGN	Company with foreign capital (dummy)
SIZE	Number of employees (in logs)
EXPORT	Exporter firm (dummy)

Source: Authors' elaboration.

In terms of representation, Paraguay and El Salvador have fewer firms than the other four countries (which is within the range of 1,500 and 1,900). Thus, no single country dominates the sample, although El Salvador and Paraguay have fewer observations because of the size of their economy.

The last column shows that firms in the sample are, on average, 26 years old (AGE) and have 70 ($e^{4.28}$) employees (SIZE). A quarter of them belong to a group (GROUP), 14 percent of them have some foreign capital (FOREIGN), and 45 percent are exporters (EXPORT). In terms of cooperation, while nearly two-thirds cooperate with other firms [$\mathcal{C}_{(F)}$], only one-third do so with research institutions [$\mathcal{C}_{(R)}$]. Around 70 percent of them report at least one barrier, but no substantial difference is found between distinct obstacles.

Table 6: Descriptive Statistics – Mean and Standard Deviations

	Chile	Ecuador	El Salvador	Paraguay	Peru	Uruguay	All countries
$C_{(F)}$	0.21 (0.41)	0.87 (0.34)	0.49 (0.50)	0.66 (0.47)	0.87 (0.34)	0.70 (0.46)	0.64 (0.48)
$C_{(R)}$	0.17 (0.37)	0.35 (0.48)	0.20 (0.40)	0.33 (0.47)	0.48 (0.50)	0.51 (0.50)	0.36 (0.48)
$B_{(1)}$	0.84 (0.37)	0.69 (0.46)	0.35 (0.48)	0.62 (0.49)	0.73 (0.45)	0.77 (0.42)	0.74 (0.44)
$B_{(2)}$	0.81 (0.39)	0.64 (0.48)	0.23 (0.42)	0.65 (0.48)	0.82 (0.39)	0.68 (0.47)	0.72 (0.45)
$B_{(3)}$	0.72 (0.45)	0.58 (0.49)	0.27 (0.45)	0.61 (0.49)	0.73 (0.44)	0.76 (0.43)	0.68 (0.47)
GROUP	0.39 (0.49)	0.21 (0.41)	0.22 (0.42)	0.17 (0.38)	0.22 (0.42)	0.22 (0.42)	0.26 (0.44)
AGE	28.52 (24.04)	23.88 (16.72)	28.24 (15.54)	25.84 (18.37)	22.13 (17.28)	33.15 (22.30)	26.76 (20.51)
FOREIGN	0.15 (0.35)	0.11 (0.31)	0.18 (0.39)	0.08 (0.26)	0.14 (0.35)	0.19 (0.39)	0.14 (0.35)
SIZE	4.58 (1.51)	4.00 (1.40)	4.59 (1.30)	3.92 (1.41)	4.40 (1.60)	4.12 (1.23)	4.28 (1.46)
EXPORT	0.46 (0.50)	0.28 (0.45)	0.73 (0.45)	0.28 (0.45)	0.55 (0.50)	0.50 (0.50)	0.45 (0.50)
Observations	1,894 [25.1%]	1,585 [21.0%]	279 [3.7%]	438 [5.8%]	1,829 [24.3%]	1,514 [20.1%]	7,539 [100%]

Source: Authors' elaboration.
Notes: For each variable, we report the mean and the standard deviation (in parenthesis). In brackets is the percentage relative to the total number of innovation-active firms in the sample.

Most variables do not show substantial differences across countries. One exception is whether firms are exporters. While only 28 percent of the firms in Ecuador and Paraguay are exporters, 73 percent of Salvadoran firms are. Another is on cooperation; only 21 percent of the firms in Chile cooperate with other firms, yet 87 percent of Ecuadorian and Peruvian firms do this type of cooperation. Finally, Salvadoran firms show the lowest perception of obstacles to innovation (around half of other countries). Despite these differences, the final sample of our investigation seems to be very homogeneous in different aspects, as this table shows.

4. Empirical Strategy

4.1. The Model

We are interested in the impacts of barriers to innovation on firms' engagement in cooperation activities with different partners. So, we define $\mathcal{C}^*_{(F)}$ and $\mathcal{C}^*_{(R)}$ as the non-observable value that firms attribute to cooperation with other firms and with research institutions, respectively (see Table 2 for details). Similarly, $B^*_{(1)}, B^*_{(2)}, B^*_{(3)}$ are latent variables referring to the three distinct innovation barriers defined in Table 3.

We model those variables as the system of equations described below:

$$\mathcal{C}^*_{(F)icst} = \alpha_{(F)cst} + \beta_{(F)} X_{icst} + \sum_{j=1}^{3} \phi_{(F)j} B_{(j)icst} + \xi_{(F)icst}, \;\; \mathcal{C}_{(F)icst} = 1[\mathcal{C}^*_{(F)icst} > 0] \qquad (1)$$

$$\mathcal{C}^*_{(R)icst} = \alpha_{(R)cst} + \beta_{(R)} X_{icst} + \sum_{j=1}^{3} \phi_{(R)j} B_{(j)icst} + \xi_{(R)icst}, \;\; \mathcal{C}_{(R)icst} = 1[\mathcal{C}^*_{(R)icst} > 0] \qquad (2)$$

where $i = 1, \dots, I$ represents firms, $c = 1, \dots, C$ denotes countries, $s = 1, \dots, S$ indicates sectors, $t = 1, \dots, T$ denotes years, and j indicates the type of obstacle to innovation: (1) financial; (2) knowledge; (3) market (see Table 3 for details). Moreover, $1[\cdot]$ is the indicator function, so $\mathcal{C}_{(F)}$ and $\mathcal{C}_{(R)}$ are observable binary variables respectively indicating cooperation with other firms and research institutions, $B_{(j)}$ represents observable binary variables that indicate if a firm has perceived the jth obstacle to innovation. Additionally, $\xi_{(F)}$ and $\xi_{(R)}$ are random error terms and X are exogenous covariates. All other variables are parameters to be estimated.

Furthermore, $\alpha_{(k)cst} = \theta_{(k)} + \sum_{c=1}^{C} \alpha_{(k)c} + \sum_{s=1}^{S} \alpha_{(k)s} + \sum_{t=1}^{T} \alpha_{(k)t}$ for $k = F, R$, that is, $\alpha_{(k)cst}$ includes a constant, as well as country, sector, and year dummies.

We complete the model description by normalizing variances of $\xi_{(F)}$ and $\xi_{(R)}$ to one and assuming that:

$$\begin{matrix} \xi_{(F)} \\ \xi_{(R)} \end{matrix} \sim N\left[\begin{matrix} 0 \\ 0 \end{matrix}, \begin{pmatrix} 1 & \rho_{FR} \\ \rho_{FR} & 1 \end{pmatrix} \right], \qquad (3)$$

where $\rho_{FR} \in [0,1]$ is the correlation between $\xi_{(F)}$ and $\xi_{(R)}$.

The off-diagonal non-zero correlation parameter in (3) is useful for dealing with unobservable firm characteristics, particularly if they cause endogeneity by influencing firm-specific cooperation behavior.[3]

4.2. Estimation

Parameters from equations (1) and (2), as well as the correlation parameters in (3), can be jointly and consistently estimated by Simulated Maximum Likelihood (SML) (Cappellari and Jenkins, 2003).[4] Similarly, some authors (Arranz, Arroyabe, and Fernandez de Arroyabe, 2019; Wang, 2021) use other estimators, but others (Chiburis et al., 2012; Denzer, 2019) show evidence that SML, even when model premises are not completely fulfilled, clearly outperforms other estimators.

The SML algorithm uses random draws from upper-truncated standard normal distributions, and the estimates may be quite sensitive to the number of draws. To deal with this issue, we set such a number at 150, much more than the square root of the sample size, the minimum suggested in Cappellari and Jenkins (2003). Moreover, as in Moraes Silva, Lucas, and Vonortas (2020), when estimating the models, we use sample weights to deal with the distinct sample designs of the different surveys.

5. Results

5.1. Main Results

Table 7 presents the results of some versions of the model described by equations (1) to (3). We also estimate simpler versions of the model, in which we replace all barrier variables – $B_{(1)}, B_{(2)}, B_{(3)}$ – by a single binary variable B that indicates if a firm perceives any innovation obstacle at all.

In Models (C) to (F), we separately consider the two possibilities of cooperation: cooperation with other firms, named as $\mathcal{C}_{(F)}$, and cooperation with research institutions, $\mathcal{C}_{(R)}$. The main difference between Models (C) and (D) and

[3] Tether (2002) and Antonioli, Marzucchi, and Savona. (2017) assumes no correlation between $\xi_{(F)}$ and $\xi_{(R)}$. That is, $\rho_{FR} = 0$ and equations (1) and (2) were estimated separately as completely independent Probits. In turn, only equation (2) is included in Kanama and Nishikawa (2017) and Moraes Silva et al. (2020), given that their interest is exclusively in cooperation between firms and universities.

[4] We perform all the estimations with the STATA module mvprobit (Cappellari and Jenkins, 2003).

Models (E) and (F) is the use of independent probits (in the former) and the use of bivariate probits (in the latter). Moreover, in Model (A) and Model (B), $\mathcal{C}_{(F)}$ and $\mathcal{C}_{(R)}$ are replaced by $\mathcal{C}$, a single binary variable that indicates if a firm cooperates with other firms or research institutions. Model (D) mimics the specification used in Antonioli, Marzucchi, and Savona (2017), Kanama and Nishikawa (2017), Moraes Silva, Lucas, and Vonortas (2020), and Salazar-Elena, Castillo, and Alvarez (2023).

Results in Table 7 indicate that firms belonging to corporate groups (GROUP) and larger companies (SIZE) cooperate more with both firms and research institutions. Exporters (EXPORT) and older companies (AGE) cooperate more only with research institutions. Companies with foreign capital (FOREIGN) cooperate more only with other firms, but this effect is only statistically significant in Model (F).

Outcomes also suggest that innovation barriers are positively correlated with cooperation after controlling for certain factors. Looking at the differences between the models, we observe very few changes, and most of them are within the standard deviation of the estimated parameters. Knowledge barriers – $B_{(2)}$ – promote cooperation with both firms and research institutions. Financial barriers – $B_{(1)}$ – show higher effects on cooperation with other firms, while market barriers – $B_{(3)}$ – seem more relevant to promote cooperation with research institutions.

Similar results are found in a sample of Colombian companies (Salazar-Elena, Castillo, and Alvarez, 2023). However, our results are somewhat different from those found in companies located in developed countries. Particularly, Dutch (Belderbos, Carree, and Lokshin, 2004), French (Antonioli, Marzucchi, and Savona, 2017), Japanese (Kanama and Nishikawa, 2017), and Spanish (Arranz, Arroyabe, and Fernandez de Arroyabe, 2019) companies perceiving financial obstacles tend also to cooperate more with research institutions (not only with other firms). Furthermore, when comparing French and Japanese companies to our sample, knowledge obstacles have a more limited impact on collaboration. Apparently, knowledge obstacles are more relevant to companies from developing countries as a collaboration-boosting factor. Finally, when comparing Model (C) with Model (E) and Model (D) with Model (F), we conclude that including correlation between cooperation equations makes no substantial difference to the results.

Table 7: Determinants of Cooperation

	(A)	(B)	(C)		(D)		(E)		(F)	
	C	C	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$
B	0.373*** (0.0957)	-	0.316*** (0.0972)	0.389*** (0.1142)	-	-	0.321*** (0.0964)	0.398*** (0.1147)	-	-
$B_{(1)}$	-	0.127 (0.0872)	-	-	0.217** (0.0990)	-0.010 (0.1152)	-	-	0.228** (0.1007)	-0.010 (0.1151)
$B_{(2)}$	-	0.203** (0.0849)	-	-	0.265*** (0.0955)	0.254** (0.1005)	-	-	0.276*** (0.0943)	0.243** (0.0994)
$B_{(3)}$	-	0.006 (0.0760)	-	-	0.050 (0.0825)	0.204** (0.0946)	-	-	0.063 (0.0832)	0.195** (0.0942)
GROUP	0.383*** (0.0880)	0.379*** (0.0877)	0.373*** (0.0906)	0.388*** (0.1262)	0.374*** (0.0895)	0.387*** (0.1199)	0.377*** (0.0953)	0.390*** (0.1276)	0.385*** (0.0944)	0.388*** (0.1212)
AGE	-0.001 (0.0019)	-0.001 (0.0019)	0.000 (0.0019)	0.006** (0.0023)	0.000 (0.0020)	0.005** (0.0022)	0.001 (0.0020)	0.005** (0.0024)	0.001 (0.0020)	0.005** (0.0023)
FOREIGN	0.082 (0.0985)	0.087 (0.0971)	0.137 (0.0954)	-0.033 (0.1236)	0.147 (0.0930)	-0.033 (0.1188)	0.153 (0.0964)	-0.033 (0.1241)	0.163* (0.0937)	-0.034 (0.1194)
SIZE	0.108*** (0.0331)	0.106*** (0.0325)	0.142*** (0.0457)	0.136*** (0.0386)	0.138*** (0.0408)	0.134*** (0.0413)	0.149*** (0.0463)	0.133*** (0.0392)	0.144*** (0.0408)	0.130*** (0.0419)
EXPORT	0.245*** (0.0823)	0.249*** (0.0842)	0.039 (0.1426)	0.184 (0.1149)	0.063 (0.1232)	0.208* (0.1219)	0.018 (0.1450)	0.202* (0.1162)	0.045 (0.1245)	0.225* (0.1230)
Model	Probit	Probit	Independent Probits		Independent Probits		Bivariate Probit		Bivariate Probit	
ρ_{FR}	-	-	-		-		0.429*** (0.0583)		0.424*** (0.055)	
Country Effects	YES	YES	YES		YES		YES		YES	
Sector effects	YES	YES	YES		YES		YES		YES	
Year effects	YES	YES	YES		YES		YES		YES	
Survey effects	NO	NO	NO		NO		NO		NO	
Observa-tions	7,539	7,539	7,539		7,539		7,539		7,539	

Source: Authors' elaboration.
Notes: All parameters were estimated by SML with 150 random draws and sample weights. All models also include constants and several fixed effects (omitted for convenience). Robust standard errors in parenthesis. Symbols *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

5.2. Extensions and Robustness Checks

5.2.1. Medium/Large Firms × Small Firms

Table 8 presents the outcomes of our benchmark specification—Model (F) in Table —estimated for subsamples of small companies (fewer than 50 employees) and medium/large companies (50 employees or more).[5] Results are qualitatively similar for medium/large firms, Model (F1), and small firms, Model (F2), and somewhat resemble the benchmark specification. However, the impact of barriers on cooperation is larger for small companies.

We also estimated Model (F3), which uses the whole sample but adds to the benchmark specification some interaction terms between innovation barriers and SIZE. There is no statistically significant parameter associated with those interaction terms. However, it does not mean that SIZE is irrelevant in shaping the relationship between cooperation and innovation obstacles. Take the relationship between financial barriers and cooperation with firms, for example. The parameter associated with the barrier itself is positive (0.516) and statistically significant (at 10 percent). Nonetheless, once the respective interaction term parameter is negative (-0.086), the total effect of $B_{(1)}$ in $\mathcal{C}_{(F)}$, that is, 0.516 - 0.086 × SIZE, decreases as SIZE increases. That is, to sufficient small firms, the total effect is positive. However, to sufficiently large companies, the total effect vanishes. The first panel from Figure 3 illustrates this point: the total effect decreases with the size of the company until it becomes statistically non-significant, around 100 employees (98, to be exact). Note that once a firm with 98 employees is around the 85th percentile in terms of company size, the effect is positive for most of the manufacturing companies from the six countries included in our sample.[6]

The argument is analogous to other combinations of obstacles and cooperation categories, and it is described in other graphs from Figure 3. The relationship between financial barriers and cooperation with RIs, as well as between market barriers and cooperation with firms, is statistically non-significant, regardless of the size of the company. The positive correlation between knowledge

[5] This is the definition of small firms usually adopted in the literature. See Zuñiga and Crespi (2012) and Moraes Silva et al. (2020), for example. Moreover, medium-sized companies usually have between 50 and 249 employees, and large companies have 250 employees or more.

[6] We use sample weights to calculate the percentiles.

barriers and cooperation with firms (with RIs) vanishes in companies with more than 172 (923) employees, evidence that firm size might be considered when designing public policies to mitigate the hurdles perceived to innovate. Furthermore, the relationship between market obstacles and cooperation with research institutions becomes statistically non-significant to firms with more than 1,364 employees.[7]

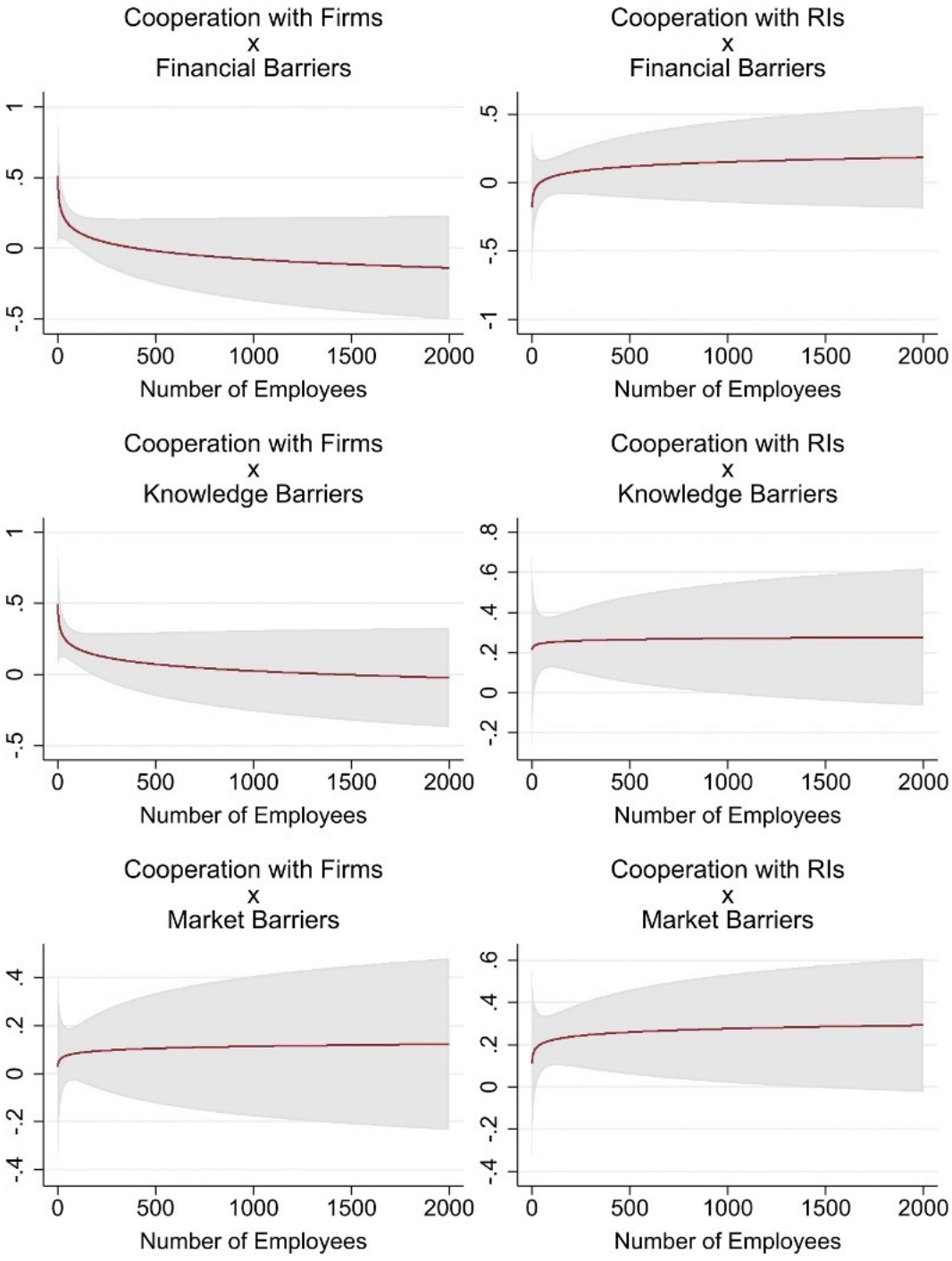
Table 8: Determinants of Cooperation – Medium/Large Firms × Small Firms

	(F1) Medium/large firms (≥ 50 employees)		(F2) Small firms (< 50 employees)		(F3) All firms	
	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$
$B_{(1)}$	0.156** (0.0790)	0.026 (0.0851)	0.244* (0.1348)	0.002 (0.1654)	0.516* (0.2964)	-0.178 (0.3348)
$B_{(2)}$	0.146* (0.0831)	0.217** (0.0849)	0.298** (0.1227)	0.237* (0.1422)	0.498* (0.2691)	0.213 (0.2900)
$B_{(3)}$	0.109 (0.0813)	0.126 (0.0777)	0.064 (0.1154)	0.213 (0.1362)	0.028 (0.2646)	0.112 (0.2736)
$B_{(1)}$ × SIZE	-	-	-	-	-0.086 (0.0654)	0.048 (0.0703)
$B_{(2)}$ × SIZE	-	-	-	-	-0.069 (0.0605)	0.008 (0.0622)
$B_{(3)}$ × SIZE	-	-	-	-	0.012 (0.0609)	0.024 (0.0581)
GROUP	0.419*** (0.0747)	0.236*** (0.0734)	0.322* (0.1650)	0.543*** (0.2005)	0.385*** (0.0937)	0.394*** (0.1216)
AGE	0.004*** (0.0015)	0.005*** (0.0014)	-0.003 (0.0042)	0.005 (0.0047)	0.001 (0.0020)	0.005** (0.0022)
FOREIGN	0.135 (0.0831)	0.009 (0.0771)	0.208 (0.2132)	-0.036 (0.2844)	0.148 (0.0926)	-0.025 (0.1198)
SIZE	0.087** (0.0351)	0.148*** (0.0356)	0.279*** (0.0941)	0.276*** (0.0996)	0.239*** (0.0913)	0.075 (0.0920)
EXPORT	0.199*** (0.0702)	0.191** (0.0749)	0.007 (0.1907)	0.275 (0.1995)	0.057 (0.1156)	0.218* (0.1177)
Model	Bivariate Probit		Bivariate Probit		Bivariate Probit	
ρ_{FR}	0.742*** (0.0276)		0.336*** (0.0699)		0.431*** (0.0516)	
Country effects	YES		YES		YES	
Sector effects	YES		YES		YES	
Year effects	YES		YES		YES	
Survey effects	NO		NO		NO	
Firm effects	NO		NO		NO	
Observations	2,979		4,560		7,539	

Source: Authors' elaboration.
Notes: All parameters were estimated by SML with 150 random draws and sample weights. All models also include constants and several fixed effects (omitted for convenience). Robust standard errors in parenthesis. Symbols *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

[7] A firm with 172 employees is around the 90th percentile in terms of company size. Moreover, firms with 923 and 1,364 employees are around the 99th percentile.

Figure 3: Total Effect of Innovation Barriers on Cooperation



Source: Authors' elaboration.
Notes: Total effect (on the vertical axis) is calculated from Table 8 as the sum of the parameters associated to $B_{(j)}$ and the parameters associated to $B_{(j)}$ times SIZE. The gray shaded area indicates confidence intervals (at the 10% significance level).

5.2.2. *Failed Innovators × Innovators*

Table 9 also presents results for our benchmark specification, but in this case, they are estimated separately for failed innovators and innovators subsamples. Results for innovators—Model (F5)—are in line with the results for the full sample: positive and statistically significant correlation between financial barriers and cooperation with firms, between knowledge barriers and cooperation with firms and RIs, and between market obstacles and cooperation with RIs. However, for failed innovators—Model (F4)—the pattern is completely different: only the impact of financial barriers on cooperation with RIs is statistically significant. This suggests that, in most cases, barriers perceived by failed innovators might not be enough to induce them to cooperate with any other economic agent.

In fact, except for the impact of market barriers on cooperation with firms, which is statistically non-significant for both innovators and failed innovators, on all occasions where an impact is significant for innovators, it is not for failed innovators, and vice versa. We do not have enough information to determine whether cooperation is less relevant as a coping strategy for failed innovators or if those companies do not have sufficient capabilities and skills to engage in such cooperation efforts. The answer to this question probably requires qualitative data beyond the quantitative data from national innovation surveys.[8]

Some interesting patterns appear when we look more closely at innovators [Models (F6) to (F8)]. Financial (market) barriers boost cooperation with firms (RIs) for product (process) innovators and for those producing both product and process innovations. For firms producing only product or only process innovations, knowledge obstacles spur cooperation only with RIs. When producing both kinds of innovations, they are more prone to cooperate only with firms.

[8] For example, Pereira Cabral et al. (2020) perform a qualitative assessment of innovation barriers perceived by Brazilian firms in natural resources-related industries, using information from case studies and semi-structured questionnaires to complement results from an econometric investigation.

Table 9: Determinants of Cooperation – Failed Innovators × Innovators

	(F4) Failed innovators		(F5) Innovators (product or process)		(F6) Innovators (only product)		(F7) Innovators (only process)		(F8) Innovators (Both Product and Process)	
	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$
$B_{(1)}$	-0.110	0.852***	0.293***	-0.182	-0.002	-0.214	0.472**	-0.064	0.309**	-0.135
	(0.2037)	(0.2212)	(0.1121)	(0.1143)	(0.1732)	(0.2085)	(0.1749)	(0.1730)	(0.1307)	(0.1457)
$B_{(2)}$	0.236	-0.183	0.282***	0.303***	0.127	0.592**	0.113	0.441***	0.389**	0.095
	(0.2192)	(0.2396)	(0.0983)	(0.1018)	(0.1656)	(0.1808)	(0.1244)	(0.1226)	(0.1268)	(0.1439)
$B_{(3)}$	-0.047	-0.063	0.105	0.225**	0.090	0.274*	0.149	0.091	0.051	0.290**
	(0.1978)	(0.2170)	(0.0875)	(0.1004)	(0.1601)	(0.1594)	(0.1234)	(0.1449)	(0.1002)	(0.1318)
GROUP	0.444**	-0.018	0.354***	0.460***	0.306	0.521***	0.269**	0.117	0.417**	0.461***
	(0.1815)	(0.1669)	(0.1027)	(0.1169)	(0.2237)	(0.1898)	(0.1296)	(0.1274)	(0.1564)	(0.1550)
AGE	-0.005	-0.001	0.001	0.006**	0.002	0.011**	-0.004	0.001	0.002	0.008**
	(0.0048)	(0.0047)	(0.0022)	(0.0023)	(0.0039)	(0.0043)	(0.0035)	(0.0031)	(0.0026)	(0.0025)
FOREIGN	0.009	0.116	0.197**	-0.060	0.232	0.238	0.288*	-0.146	0.140	-0.145
	(0.2328)	(0.2169)	(0.0948)	(0.1254)	(0.1956)	(0.2051)	(0.1572)	(0.1424)	(0.1340)	(0.1709)
SIZE	0.021	0.249***	0.166***	0.109**	0.085	0.029	0.195**	0.288***	0.180**	0.046
	(0.0669)	(0.0611)	(0.0455)	(0.0461)	(0.0660)	(0.0675)	(0.0527)	(0.0577)	(0.0608)	(0.0495)
EXPORT	0.077	0.396**	0.035	0.198	-0.228	-0.068	0.221	0.104	0.022	0.373***
	(0.2246)	(0.1817)	(0.1229)	(0.1279)	(0.1574)	(0.1630)	(0.1384)	(0.1597)	(0.1625)	(0.1308)
Model	Bivariate Probit		Bivariate Probit		Bivariate Probit		Bivariate Probit		Bivariate Probit	
ρ_{FR}	0.273*** (0.1190)		0.453*** (0.0562)		0.494*** (0.0756)		0.530*** (0.0692)		0.489*** (0.0598)	
Country effects	YES		YES		YES		YES		YES	
Sector effects	YES		YES		YES		YES		YES	
Year effects	YES		YES		YES		YES		YES	
Survey effects	NO		NO		NO		NO		NO	
Firm effects	NO		NO		NO		NO		NO	
Observa-tions	1,099		6,440		1,141		1,938		3,358	

Source: Authors' elaboration.
Notes: All parameters were estimated by SML with 150 random draws and sample weights. All models also include constants and several fixed effects (omitted for convenience). Robust standard errors in parenthesis. Symbols *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

5.2.3. Complementarity and Substitutability Between Barriers

We found that a firm experiencing specific obstacles is prone to cooperate with partners. However, does the joint experience of several barriers exert a cumulative effect since cooperation intensifies? Or is it the other way around? To deal with this possibility, we add interaction terms for each pair of barriers to our benchmark

model interaction terms.[9] Model (F9) in Table 10 presents the outcomes for this approach. Introducing those interactions does not interfere substantially with the estimates of the original parameters (see Model (F) in Table 7).

The outcomes suggest substitutability between financial and knowledge barriers regarding cooperation with firms because the parameter on $B_{(1)} \times B_{(2)}$ is negative and statistically significant in $\mathcal{C}_{(F)}$ equation, confirming the results of Antonioli, Marzucchi, and Savona (2017). All else held constant, the propensity to cooperate by a company perceiving those two obstacles concurrently is smaller than the sum of the propensities to cooperate of two firms perceiving one obstacle at a time. That is, financial and knowledge obstacle concurrence decreases the propensity to cooperate with firms more than proportionately. However, contrary to the evidence in Antonioli, Marzucchi, and Savona (2017), knowledge and market obstacle simultaneity intensifies cooperation with research institutions more than proportionately.

5.2.4. Alternatively Setting Fixed Effects

We estimate the benchmark model with a different fixed effects definition, replacing country- and year-separated fixed effects by survey effects, that is, by country-year effects.[10] There is no substantial change in the results (see Model (F10) in Table 10).

[9] The most correct way to test complementarity (substitutability) between barriers is conducting a super(sub)-modularity test (Mohnen and Röller, 2005), which is hard to implement in a multi-equation model. For this reason, and because testing for complementarity (substitutability) is not the main issue of this paper, we use the barrier interactions approach. Nonetheless, as Antonioli, Marzucchi, and Savona. (2017) find similar results using the two approaches, we are comfortable with our strategy.

[10] We are grateful to an anonymous reviewer, in the context of the project New Evidence for Innovation Policy Exploiting the Latin American Innovation Surveys Database (LAIS), for this suggestion.

5.2.5. Alternatively Defining Barrier Prevalence

We originally defined that a firm perceives a certain type of obstacle if it considers this obstacle important or very important. When we use an alternative and more restrictive definition of obstacle prevalence—if a company considers it very important—the results are quite different (see Model (F11) in Table 10). Particularly, all the parameters associated with the barriers, except the one regarding the impact of knowledge obstacles on cooperation with RIs, lost their statistical significance. This suggests that unlike at high or moderate levels, very high levels of innovation obstacles may preclude firms from cooperating.

5.2.6. Clustering Errors

Changing from robust to country-year-sector clustered standard errors slightly decreases the accuracy of the estimates but does not change the statistical significance of most parameters (see Model (F12) in Table 10).

5.2.7. Dealing with Non-Observable Firm Heterogeneity

Moreover, endogeneity is a potential problem if there is non-observable heterogeneity among firms. If this unobserved heterogeneity is time-invariant, firm fixed effects can tackle this issue effectively in linear models. However, including firm fixed effects in non-linear models makes the estimates biased and inconsistent (Greene, 2004). One possible strategy is estimating the model with random effects, but this option is inadequate if individual effects are correlated with the error terms. Considering that a correlation exists between random effects and errors, we can estimate the random effects as a function of the average (taken over time) of the time-varying variables and include these averages as additional covariates, as suggested in Zabel (1992).[11] That is, the error terms in equations (1) and (2) become:[12]

$$\xi_{(k)icst} = \varphi_{(k)}\bar{X}_i + \nu_{(k)icst}, \qquad \text{for } k = F, R, \tag{4}$$

[11] It is also necessary to assume strict exogeneity of covariates, conditional on the random effects (Wooldridge, 2010).

[12] In the context of innovation obstacles, Canêdo-Pinheiro et al. (2018) and Bukstein, Hernández, and Usher (2019) take the same approach regarding random effects.

where $\bar{X}_i = {}^{1}/_{T} \sum_{t=1}^{T} X_{icst}$, $\nu'_{(k)}$s are Multivariate Normal distributed errors like in (3) and the remaining variables are defined as before. Testing the relevance of the random effects is straightforward; it is merely a test of H_0: $\varphi_{(F)} = \varphi_{(R)} = 0$ (Wooldridge, 2010). We re-estimate our benchmark specification, including the random effects defined in Table 10, and do not notice substantial changes in the parameters (see Model (F13) in Table 10).

5.2.8. Robustness to Dropping Countries from the Sample

Despite its richness, there is a potential drawback to our dataset. Some countries, like El Salvador, are relatively less representative in the sample, while others, like Uruguay, might be more representative. The size of the economy matters for that, yet the frequency of surveys also helps create these discrepancies. Therefore, our analysis should be robust to the exclusion of any country. For this reason, we estimated different versions of our benchmark model by dropping one country at a time from our sample (see Table 11). Obviously, there is some variability when comparing such results, but most patterns are quite robust to country dropping. Knowledge barriers usually are positive and statistically significant when correlated with cooperation with both firms and RIs, and market obstacles boost cooperation with research institutions is most specifications.

5.2.9. Estimating Individual Models for Each Country

We also estimated individual models for the six countries in our sample (see Table 12). In this case, as expected, we observe more variability. For Chilean firms—Model (F20)—only knowledge obstacles are statistically significant to foster cooperation. For firms from Paraguay—Model (F23)—all barriers foster cooperation with firms, but none with RIs. For Ecuadorian companies—Model (F21)—most of the parameters related to the impact of obstacles on cooperation are positive and statistically significant. For firms from El Salvador, Peru, and Uruguay—Models (F22), (F24), and (F25), respectively—the opposite is true: most of these parameters are non-significant.

Table 10: Determinants of Cooperation – Assorted Extensions and Robustness Checks

	(F9) Complementarity substitutability		(F10) Survey effects		(F11) Alternative definition of barrier prevalence		(F12) Clustering errors		(F13) Random Firm effects	
	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$
$B_{(1)}$	0.497*** (0.1833)	0.214 (0.2149)	0.248** (0.1014)	-0.002 (0.1153)	0.091 (0.0915)	-0.038 (0.0853)	0.228*** (0.0693)	-0.010 (0.1336)	0.226** (0.0968)	0.005 (0.1074)
$B_{(2)}$	0.471*** (0.1803)	0.141 (0.2129)	0.268*** (0.0948)	0.238** (0.0997)	0.046 (0.0822)	0.165** (0.0826)	0.276*** (0.0921)	0.243*** (0.0941)	0.278*** (0.0898)	0.229** (0.0968)
$B_{(3)}$	0.143 (0.2296)	0.055 (0.1993)	0.064 (0.0833)	0.199** (0.0945)	0.107 (0.0896)	0.128 (0.0871)	0.063 (0.0820)	0.195 (0.1289)	0.080 (0.0812)	0.190** (0.0922)
$B_{(1)} \times B_{(2)}$	-0.328* (0.1978)	-0.174 (0.2095)	-	-	-	-	-	-	-	-
$B_{(1)} \times B_{(3)}$	-0.136 (0.1948)	-0.159 (0.2176)	-	-	-	-	-	-	-	-
$B_{(2)} \times B_{(3)}$	0.002 (0.1750)	0.353* (0.1962)	-	-	-	-	-	-	-	-
GROUP	0.386*** (0.0948)	0.390*** (0.1204)	0.393*** (0.0947)	0.390*** (0.1211)	0.387*** (0.0976)	0.395*** (0.1244)	0.385*** (0.1041)	0.388*** (0.0946)	0.235 (0.2681)	0.567** (0.2533)
AGE	0.000 (0.0019)	0.005** (0.0022)	0.001 (0.0020)	0.005** (0.0023)	0.001 (0.0020)	0.006** (0.0024)	0.001 (0.0024)	0.005*** (0.0018)	0.001 (0.0075)	0.016** (0.0066)
FOREIGN	0.157* (0.0941)	-0.036 (0.1199)	0.162* (0.0946)	-0.038 (0.1193)	0.154 (0.0940)	-0.040 (0.1184)	0.163** (0.0799)	-0.034 (0.1180)	-0.183 (0.2616)	-0.064 (0.2489)
SIZE	0.141*** (0.0390)	0.131*** (0.0409)	0.138*** (0.0410)	0.129*** (0.0420)	0.153*** (0.0469)	0.132*** (0.0404)	0.144*** (0.0322)	0.130*** (0.0308)	0.253** (0.1172)	0.083 (0.1068)
EXPORT	0.060 (0.1180)	0.228* (0.1194)	0.041 (0.1257)	0.224* (0.1233)	0.014 (0.1403)	0.206* (0.1183)	0.045 (0.1287)	0.225*** (0.0673)	-0.566** (0.2498)	0.289 (0.2398)
Model	Bivariate Probit		Bivariate Probit		Bivariate Probit		Bivariate Probit		Bivariate Probit	
ρ_{FR}	0.424*** (0.0544)		0.415*** (0.0558)		0.431*** (0.0565)		0.424*** (0.0847)		0.435*** (0.0507)	
Country Effects	YES		YES		YES		YES		YES	
Sector effects	YES		NO		YES		YES		YES	
Year effects	YES		NO		YES		YES		YES	
Survey effects	NO		YES		NO		NO		NO	
Firm effects	NO		NO		NO		NO		YES	
Observa-tions	7,539		7,539		7,539		7,539		7,539	

Source: Authors' elaboration.

Notes: All parameters were estimated by SML with 150 random draws and sample weights. All models also include constants, several fixed effects, and (in some cases) random effects (omitted for convenience). Robust standard errors are in parenthesis, except for model (F13), in which errors are country-year-sector clustered. Symbols *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

Table 11: Determinants of Cooperation – Dropping Countries from the Sample

	(F14) Drop firms from Chile		(F15) Drop firms from Ecuador		(F16) Drop firms from El Salvador		(F17) Drop firms from Paraguay		(F18) Drop firms from Peru		(F19) Drop firms from Uruguay	
	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$
$B_{(1)}$	0.246** (0.1083)	0.002 (0.1235)	0.084 (0.1077)	-0.075 (0.1239)	0.102 (0.0974)	-0.047 (0.1130)	0.119 (0.1011)	-0.024 (0.1139)	0.006 (0.0652)	0.092 (0.0692)	0.137 (0.1073)	-0.115 (0.1275)
$B_{(2)}$	0.322*** (0.0995)	0.271** (0.1078)	0.253** (0.1001)	0.246** (0.1088)	0.212** (0.0879)	0.230** (0.0964)	0.225** (0.0918)	0.250** (0.0976)	0.089 (0.0647)	0.124* (0.0668)	0.232** (0.0951)	0.273** (0.1112)
$B_{(3)}$	0.048 (0.0984)	0.227** (0.1051)	0.005 (0.0897)	0.170 (0.1037)	0.012 (0.0805)	0.182** (0.0916)	0.013 (0.0830)	0.186** (0.0921)	0.131** (0.0607)	0.096 (0.0646)	-0.005 (0.0872)	0.217** (0.1051)
GROUP	0.289** (0.1268)	0.396*** (0.1494)	0.226** (0.1018)	0.375*** (0.1343)	0.220** (0.0943)	0.327*** (0.1201)	0.224** (0.0942)	0.320*** (0.1202)	0.241*** (0.0689)	0.144** (0.0646)	0.231** (0.1002)	0.350*** (0.1285)
AGE	-0.002 (0.0029)	0.005 (0.0030)	0.002 (0.0020)	0.006** (0.0024)	0.001 (0.0019)	0.005** (0.0022)	0.002 (0.0019)	0.005** (0.0022)	0.002 (0.0014)	0.004*** (0.0014)	0.001 (0.0022)	0.005* (0.0026)
FOREIGN	0.134 (0.1238)	-0.088 (0.1552)	0.194* (0.1113)	-0.008 (0.1409)	0.191* (0.1049)	0.000 (0.1261)	0.213** (0.1033)	0.004 (0.1218)	0.141 (0.0957)	-0.038 (0.0851)	0.203* (0.1082)	0.091 (0.1360)
SIZE	0.157*** (0.0495)	0.124** (0.0485)	0.015 (0.0391)	0.069 (0.0427)	0.033 (0.0366)	0.077* (0.0401)	0.009 (0.0379)	0.064 (0.0399)	0.019 (0.0241)	0.111*** (0.0257)	0.025 (0.0390)	0.064 (0.0450)
EXPORT	-0.150 (0.1436)	0.193 (0.1380)	-0.056 (0.1213)	0.182 (0.1284)	-0.111 (0.1123)	0.182 (0.1166)	-0.095 (0.1138)	0.192* (0.1148)	-0.022 (0.0651)	0.139** (0.0634)	-0.146 (0.1202)	0.153 (0.1351)
Model	Bivariate probit		Bivariate probit		Bivariate probit		Bivariate probit		Bivariate probit		Bivariate probit	
ρ_{FR}	0.279*** (0.0617)		0.508*** (0.0520)		0.507*** (0.0488)		0.530*** (0.0457)		0.631*** (0.0273)		0.593*** (0.0540)	
Country effects	YES		YES		YES		YES		YES		YES	
Sector effects	YES		YES		YES		YES		YES		YES	
Year effects	YES		YES		YES		YES		YES		YES	
Survey effects	NO		NO		NO		NO		NO		NO	
Firm effects	NO		NO		NO		NO		NO		NO	
Observa-tions	5,645		5,954		7,260		7,101		5,710		6,025	

Source: Authors' elaboration.

Notes: All parameters were estimated by SML with 150 random draws and sample weights. All models also include constants and several fixed effects (omitted for convenience). Robust standard errors are in parenthesis, and p-values are in brackets. Symbols *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

Table 12: Determinants of Cooperation – Individual Country Models

	(F20) Only firms from Chile		(F21) Only firms from Ecuador		(F22) Only firms from El Salvador		(F23) Only firms from Paraguay		(F24) Only firms from Peru		(F25) Only firms from Uruguay	
	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$	$C_{(F)}$	$C_{(R)}$
$B_{(1)}$	0.112	-0.023	0.252**	0.130	-0.131	-0.041	0.311*	-0.174	0.378**	-0.116	0.014	0.334**
	(0.1307)	(0.1319)	(0.1204)	(0.1084)	(0.2270)	(0.2407)	(0.1882)	(0.1998)	(0.1887)	(0.2160)	(0.1489)	(0.1418)
$B_{(2)}$	0.273**	0.318***	0.078	0.186*	0.397	0.482*	0.314*	0.100	0.252	0.292	0.192	0.095
	(0.1278)	(0.1129)	(0.1172)	(0.1067)	(0.2496)	(0.2753)	(0.1784)	(0.1991)	(0.1980)	(0.2184)	(0.1477)	(0.1440)
$B_{(3)}$	0.111	0.136	0.463***	0.279***	0.150	-0.149	0.357*	0.242	-0.226	0.282	0.087	-0.024
	(0.1038)	(0.0991)	(0.1113)	(0.1007)	(0.2487)	(0.2683)	(0.1830)	(0.1863)	(0.1900)	(0.1953)	(0.1462)	(0.1545)
GROUP	0.458***	0.287***	0.370**	0.033	0.306	-0.219	0.555**	0.417	0.223	0.628***	0.393***	0.271*
	(0.1070)	(0.0981)	(0.1646)	(0.1300)	(0.2436)	(0.2081)	(0.2436)	(0.2662)	(0.2138)	(0.2414)	(0.1501)	(0.1426)
AGE	0.003	0.005***	-0.005*	-0.000	0.008	0.012*	-0.001	0.005	-0.001	0.009	0.001	0.002
	(0.0021)	(0.0020)	(0.0032)	(0.0029)	(0.0059)	(0.0066)	(0.0053)	(0.0053)	(0.0069)	(0.0065)	(0.0029)	(0.0030)
FOREIGN	0.107	0.122	0.287	0.074	0.153	0.295	0.328	-0.063	0.312	0.130	0.034	-0.494***
	(0.1326)	(0.1248)	(0.1958)	(0.1780)	(0.2392)	(0.2338)	(0.3736)	(0.3199)	(0.2390)	(0.2793)	(0.2025)	(0.1346)
SIZE	0.092**	0.142***	0.126**	0.121***	0.043	0.070	0.265***	0.252***	0.166**	0.104	0.131**	0.233***
	(0.0371)	(0.0379)	(0.0566)	(0.0442)	(0.0845)	(0.0923)	(0.0767)	(0.0903)	(0.0802)	(0.0747)	(0.0557)	(0.0565)
EXPORT	0.424***	0.365***	-0.023	0.271**	0.607***	0.226	0.086	0.035	-0.288	0.180	0.117	0.196
	(0.1188)	(0.1054)	(0.1482)	(0.1167)	(0.2171)	(0.2381)	(0.2139)	(0.2439)	(0.2543)	(0.2420)	(0.1575)	(0.1195)
Model	Bivariate probit		Bivariate probit		Bivariate probit		Bivariate probit		Bivariate probit		Bivariate probit	
ρ_{FR}	0.909*** (0.0191)		0.580*** (0.0587)		0.662*** (0.0828)		0.519*** (0.0881)		0.179 (0.1210)		0.056 (0.0813)	
Country effects	NO		NO		NO		NO		NO		NO	
Sector effects	YES		YES		YES		YES		YES		YES	
Year effects	YES		YES		YES		YES		YES		YES	
Survey effects	NO		NO		NO		NO		NO		NO	
Firm effects	NO		NO		NO		NO		NO		NO	
Observa-tions	1,894		1,585		279		438		1,829		1,514	

Source: Authors' elaboration.

Notes: All parameters were estimated by SML with 150 random draws and sample weights. All models also include constants and several fixed effects (omitted for convenience). Robust standard errors in parenthesis. Symbols *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

6. Concluding Remarks

The interplay between innovation barriers and cooperation is still an under-explored research topic in developing countries. This paper used firm-level data from six different Latin American countries to examine this issue and shed light on how innovation barriers might promote (or hamper) more cooperation.

Our findings robustly suggest that cooperation is a coping strategy for innovation obstacles, which means that firms perceiving obstacles tend to cooperate more. Particularly, there is a positive and statistically significant relationship between knowledge obstacles and cooperation both with firms and RIs. Similar results were found for Brazilian (Cânedo-Pinheiro et al., 2018; Moraes Silva, Lucas, and Vonortas, 2020) and Colombian firms (Salazar-Elena, Castillo, and Alvarez, 2023), which may suggest that this is a pattern common to developing countries, or at least to Latin America countries. From a public policy perspective, it means that promoting and facilitating cooperation between firms and research institutions may be a cheaper way to reduce knowledge innovation barriers compared with public funding to private innovation. This is particularly relevant in developing countries, where public funds are relatively scarcer and more expensive than in developed countries. For smaller companies there is also a positive and statistically significant correlation between financial barriers and cooperation with firms, as well as between market obstacles and cooperation with research institutions.

Our results also suggest that barriers promote cooperation mostly for innovators. This means that strategies to promote more cooperation between failed innovators and other economic agents might not work if they focus on tackling their economic obstacles in the context of a developing country. At this point, we do not know if cooperation is less relevant as a coping strategy for failed innovators or if those companies do not have sufficient capabilities and skills to engage in such cooperation efforts. Thus, more specific lessons in terms of public policy may require more detailed information about this issue. This is beyond the scope of this paper, but these details would probably require qualitative data from firms, as in Pereira Cabral et al. (2020).

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