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Money talks? Obstacles to innovation in the Colombian manufacturing sector

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ABSTRACT

Background and objectives: Around the world, innovation has become a central issue on the agenda of policymakers given that innovation activities are critical as a generator of competitiveness. This work adds to the literature on the elements that hinder firms' ability to innovate. Therefore, this work analyzes the relationship between innovation propensity and innovation barriers in the Colombian manufacturing sector.

Methods: This relationship was estimated through a Probit model using cross-sectional data provided by the National Administrative Department of Statistics (DANE). In addition, we performed the correction of the sample selection bias present in many studies on barriers to innovation as proposed in recent literature (Pellegrino and Savona, 2017). Explanatory variables were included to understand firms' characteristics, such as firms' size, technological intensity of the industries, among others.

Findings: Among the relevant results is that obstacles to innovation have negative effects on innovation. More precisely, financial barriers have the greatest effect on the firms' propensity to innovate, followed by explanatory variables, such as firms' size, expenditures on innovation activities, and their technological intensity.

Conclusion: We test the effect of potential innovators' perception of the importance of diverse obstacles to innovation on their ability to produce innovative goods (or services). More precisely, we tested the assumption of non-financial and financial barriers affected firms' innovation propensity. We found evidence of our main conjecture that financial related barriers are the most relevant and important obstacle for innovation.

Keywords: Barriers to innovation; Innovation; Innovation propensity; Obstacles to innovation.

JEL: O30; 031; 032

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ARTICULO ORIGINAL

¿El dinero lo es todo? Obstáculos a la innovación en el sector manufacturero colombiano

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RESUMEN

Objetivos: En todo el mundo, la innovación se ha convertido en un tema central en la agenda de los responsables de la formulación de políticas, dado que las actividades de innovación son fundamentales como generadoras de competitividad. Este trabajo se suma a la literatura sobre los elementos que obstaculizan la capacidad de las empresas para innovar. Por lo tanto, este trabajo analiza la relación entre la propensión a la innovación y las barreras a la innovación en el sector manufacturero colombiano.
Métodos: Esta relación se estimó mediante un modelo Probit utilizando datos transversales proporcionados por el Departamento Administrativo Nacional de Estadística (DANE). Además, realizamos la corrección del sesgo de selección de la muestra, presente en muchos estudios sobre barreras a la innovación, como se propone en la literatura reciente (Pellegrino y Savona, 2017). Se incluyeron variables explicativas para comprender las características de las empresas, como el tamaño de las empresas, la intensidad tecnológica de las industrias, entre otras.
Resultados: Entre los resultados relevantes se encuentran que los obstáculos a la innovación tienen efectos negativos sobre la innovación. Más precisamente, las barreras financieras tienen el mayor efecto sobre la propensión de las empresas a innovar, seguidas de variables explicativas, como el tamaño de las empresas, el gasto en actividades de innovación y su intensidad tecnológica.
Conclusión: Verificamos el efecto de la percepción de los innovadores potenciales sobre la importancia de diversos obstáculos a la innovación sobre su capacidad para producir bienes (o servicios) innovadores. Más precisamente, probamos el supuesto de que las barreras financieras y no financieras afectaban la propensión a la innovación de las empresas. Encontramos evidencia empírica de que las barreras financieras son el obstáculo más relevante e importante para la innovación de las empresas industriales colombianas.

Palabras clave: Barreras a la innovación; Innovación; Propensión a la innovación; Obstáculos a la innovación.

Clasificación JEL: O30; 031; 032

INTRODUCTION

Innovation is an important source of economic growth. Various theoretical approaches such as those of Aghion and Howitt (1992) and Romer (1990) have highlighted the importance of ideas as an engine of economic growth and the capacity of innovation to destroy and create new markets. Despite its importance, the process of innovation is not a linear path that ensures success for all companies linked to this activity. This is because firms constantly face factors that have the capacity to slow down or inhibit their innovative activities. These factors can be explained by the non-availability of own resources to finance innovation, the impossibility of obtaining external resources (e.g. credit access), the lack of knowledge that prevents its development, among others. Nevertheless, most literature analyzed obstacles to innovation largely focused on financial or financial resource limitations (Canepa and Stoneman, 2008; Crespi and Álvarez, 2015; Escobar et al., 2023; Hall, 2002; Savignac, 2008).

A new stream of empirical research show that not only financial barriers affect the innovative performance of companies, but other non-financial aspects such as knowledge, market and institutional obstacles, can inhibit innovation performance (Arza and Lopez, 2018; García-Quevedo et al., 2017; Madeira et al., 2017; Oudgou, 2021; Pellegrino and Savona, 2017; Bukstein et al., 2019). These aspects require considering barriers to innovation in a perspective where firms' internal and external aspects such as market structures and demand are important elements that explain the innovative success or failure of companies. In the Colombian case, there is no abundant literature that addresses the effects of innovation obstacles on the innovative performance of firms. In fact, the vast majority focus from a managerial perspective (Padilla, 2014), leaving aside intra-industrial dynamics that are important for the development of public policies.

Despite this, the first approximation to understand the relationship between innovative performance and barriers to innovation focuses on the financial aspects of innovation (Barona Zuluaga et al.; 2015). While Langebaek and Vásquez (2007) and Villarreal et al. (2014) analyze the determinants of innovative performance and R&D investment and their subsequent impact on the productivity of manufacturing firms. However, it is necessary to highlight that, although these works constitute an important advance in the understanding of firms' innovative dynamics, none of them delves into the relationship between innovative performance and barriers to innovation (or obstacles).

The understanding of barriers to innovation has not been fully addressed in Latin America. In particular, research on different types of barriers (eg. demand or knowledge barriers) that affect more the innovative performance of firms. Therefore, it is not clear if barriers are equally important to explain the innovative performance. This paper aims to examine the impact of innovation barriers that

face Colombian manufacturing firms. The understanding of these barriers and their effects on the innovative activity is vital for public policy.

The paper is structured as follows. The related literature on innovation obstacles are presented in section 2. Section 3 discusses the methodology, describes the data and the empirical approach. Section 4 presents the main results. Section 5 presents the conclusions and discusses implications for public policy.

Literature review: Obstacles to innovation

The intensity and level of innovation of firms is influenced by their environment in which they operate, and is known as the Innovation System (Lundvall, 2007), and also by firms' internal conditions, such as the availability of knowledge and internal financing (Canales and Álvarez, 2017; Hall, 2002, Luna et. al., 2022). Those factors that have the capacity to inhibit or slow down the innovative activity of firms are commonly known as barriers or obstacles to innovation (Escobar et al., 2023; Luna et al., 2023; OCDE & EUROSTAT, 2005).

These obstacles to innovation are grouped differently depending on the objective of the study and the availability of information. Commonly, to explore the effects of the different barriers and make them comparable, they are divided in knowledge, market, financial and institutional (or regulatory) barriers (Arza and López, 2018; Bukstein et al., 2019; Pellegrino and Savona, 2013, 2017; Zahler et al., 2018). However, a small set of studies group them into a single large set of obstacles (Blanchard et al., 2012), or simply do not group them at all (Madeira et al., 2017). Among all these groups of barriers, those that received most attention in the literature are those related to financial aspects. From a classical perspective, innovation is understood as the reorganization of the productive factors to achieve new goods or services, or others with new characteristics. Given that by assumption in an economy without innovation there is no savings, the only source to finance innovation is the creation of money through credit (Schumpeter, 1944).

This would be presented as a strong theoretical reason that would explain the focus on financing sources and credit availability as the main obstacle to innovation, represented in the works Savignac (2008), Hall (2002, 2010), Canepa and Stoneman (2008) and Crespi and Álvarez (2015).

Nevertheless, a new stream of empirical research has shown that not only financial barriers affect the innovative performance of firms. Non-financial aspects such as the demand for goods (those innovative), knowledge and the institutional environment also influence the entire innovative cycle. This cycle corresponds to the process that begins with the decision to innovate and ends with the successful launch of the innovation developed (Arza and López, 2018; Bukstein et al., 2019; García-Quevedo et al., 2017; Madeira et al., 2017; Oudgou, 2021; Pellegrino and Savona, 2013, 2017). Furthermore, some research show that, depending on the

characteristics of the firms, size effects of non-financial barriers can be similar to those financial obstacles (Bukstein et al., 2019; Pellegrino and Savona, 2017). Another way of understanding these barriers distinguishes between *deterrent barriers* and *revealed barriers* (D'Este et al., 2012). The former are those barriers perceived as insuperable by firms therefore inhibit or stop innovative activity. On the contrary, the latter are those barriers perceived as discovered by firms while they participate in innovation activities and do not necessarily affect their innovative performance. In both cases, innovation strategies to stimulate innovation would be different by each type of barrier.

This discussion between *revealed* and *deterrent* barriers was even more important in explaining a variety of counterintuitive results that showed a positive relationship between innovative performance and innovation obstacles (Pellegrino and Savona, 2017). These results are due to the high correlation between barriers' perception to innovation (or *revealed* barriers) and the amount of innovative activity within firms (D'Este et al., 2008; 2012). That is, the more innovative activities a company carries out, increases its exposure to the effects of barriers on innovation. However, there may be groups of non-innovative firms that perceive the effects of barriers to greater or equal intensity (D'Este et al., 2008; Savignac, 2008). Blanchard et al. (2012) and more recently Pellegrino and Savona (2017), have argued and demonstrated that this positive relationship between barriers to innovation and innovative performance is due to an incorrect sample selection and not to intrinsic characteristics of the data. Thus, to analyze correctly the effect of barriers on innovative performance, only firms with intention to innovate (potential innovators) should be considered and exclude those firms without any intention to innovate (non-innovation oriented firms).

Finally, it is known that the perception of barriers to innovation not only affects the innovative performance of organizations, but also indirectly affects other aspects of firms and their interactions with other actors in the economic system. Antonioli et al. (2017) provides evidence on how firms' cooperation increases with their strong perceptions on obstacles to innovation. This explains the risk sharing behavior from innovative activities that increases with the perception of barriers to innovation.

Financial barriers

Financial barriers are associated with the perception of high costs of innovation, excessive risks and shortage of sources of financing, both external and internal (OCDE and EUROSTAT, 2005). These elements are affected by the asymmetry of information and the risks inherent to R&D activities. As explained in Hall (2010), due to the difference in information between investors and entrepreneurs regarding the probabilities of success of an innovation, it is normal for the expected returns on investors to increase. This translates into an increase in the interests that entrepreneurs must pay for funding, increasing their cost of

financing. On the other hand, the literature is clear regarding the negative effects of financial barriers on innovative activity (Savignac, 2008; Hall, 2010). However, although financial barriers have the capacity to affect a wide range of organizations, evidence indicates that their effect on innovative performance is greater in small and young companies, both in developed and developing countries (Arza and López, 2018; Canepa and Stoneman, 2008; Crespi and Álvarez, 2015; Hall, 2010; Pellegrino, 2016, 2017). This would explain the fact that smaller firms generally face insufficient or lack internal resources to perform R&D activities that may lead to successful innovations.

Evidence also suggests that the perception of financial barriers depends on the type of innovation to be developed within a company or the industry in which a firm operates. In particular, firms that develop incremental innovations tend to perceive financial barriers with greater intensity (Radicic, 2021), and this pattern is further evident in hi-tech firms (Canepa and Stoneman, 2008).

Non-financial barriers

Non-financial barriers considers knowledge, market and regulatory barriers (OCDE and EUROSTAT, 2005). A considerable number of studies show an important effect of these type of barriers on innovative performance. Within the group of firms with the intention to innovate (or potential innovators), market barriers have negative and significant effects on the propensity to innovate (Pellegrino and Savona, 2013, 2017). In Latin America, demand and knowledge barriers have significant effects on the probability to innovate and on R&D investment intensity (Bukstein et al., 2019; Zahler et al., 2018). Evidence suggests that some intrinsic characteristics of firms affect their perception of non-financial barriers. Firms' age has no effect on the perception of knowledge and market obstacles (Pellegrino, 2017). However, insufficient qualified labor decreases the probability of innovating in mature firms (Pellegrino, 2016). In turn, the perception of non-financial barriers is greater in firms that carry out radical innovations than those that carry out incremental innovations (Radicic, 2021).

Unlike financial barriers, few documents analyze non-financial barriers individually. Although scarce, Canales and Alvarez (2017) study the relationship between the obstacles to knowledge innovation and the innovation propensity of Chilean firms, with the former having a negative and significant relationship with the latter. This relationship may be even closer in manufacturing companies (Zahler et al., 2018). On the other hand, García-Quevedo et al. (2017) determine whether the lack of market demand and uncertainty have negative effects on R&D activity in Spanish firms.

Materials and methods

Sample design and data collection

The research is based on data of the Colombian Technical Development and Innovation in the Manufacturing Industry Survey (EDIT8) for the period 2015-2016 at the firm level. Its purpose is to investigate the products, activities, resources and support instruments associated with technological development and innovation of manufacturing firms. For this purpose, biennial information is available and the data structure is cross-sectional.

The EDIT8 includes Colombian manufacturing firms with more than 10 employees, and/or with a yearly production value greater than 500 million of Colombian pesos (COP). The survey sampled 7,947 Colombian manufacturing firms, distributed among 22 industries and 55 subsectors. The industries with the greatest share of firms are food products and clothing industry, which together represent 28.1% of the total. On the other hand, the industry that has the lowest share is the manufacturing of computers, electronics and optical products with 0.3%.

On the other hand, we exclude companies that are not disposed to innovate, and focus on potential innovators. They correspond to firms that introduced, abandoned or had in process at least one new product, service, process, organizational or commercial method significantly improved during the period. An important condition is that these companies must perceive at least one obstacle to innovation and have been associated to any innovative activity. By this, we exclude non-innovation oriented firms, which by choice had not introduced an innovation and neither were in process of doing so (Pellegrino and Savona, 2017). By this, we take a final relevant sample of 2,007 of innovators (potential), that managed to innovate or not.

Empirical strategy and variables

In order to analyze the effect of different types of innovation barriers on companies, we consider the following equation:

Equation 1. Latent variable equation

$$Y_i = I[\alpha + \boldsymbol{X}_i\beta + \boldsymbol{Z}_i\gamma + e > 0]$$

And,

$$y^* = \alpha + \boldsymbol{X}_j\beta + \boldsymbol{Z}_j\gamma + e$$

Then,

$$Y_i = 1[y^* > 0]$$

Where $\boldsymbol{I}[\cdot]$ is afunction that takes the value 1 if it is true that $\boldsymbol{\alpha + X_j\beta + Z_j\gamma + e > 0}$ (and takes the value of zero otherwise). $\boldsymbol{X_j}$ represents the set of barriers to

innovation and $\boldsymbol{Z_j}$ represents the set of explanatory variables In contrast, $\boldsymbol{Y_i}$ takes the value 1 if company i is an innovator. This relationship is given through the function $\boldsymbol{I[\cdot]}$, and $\boldsymbol{y^*}$ which is called the latent variable (Wooldridge, 2010).

Finally, $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ represent the coefficients that measure the indirect effect that the barriers to innovation and the explanatory variables have on the probability that a firm is innovative, respectively. In this sense, the estimated model takes the following form:

Equation 2. Conditional probability equation (Probit model)

$$P(Y = 1|\boldsymbol{X}, \boldsymbol{Z}) = \boldsymbol{F}(\alpha + \boldsymbol{X}\beta + \boldsymbol{Z}\gamma)$$

Where $\boldsymbol{P(Y = 1|X, Z)}$ represents the probability that firms have successfully developed at least one innovation during that period given the barriers and the explanatory variables. On the other hand, $\boldsymbol{F(\cdot)}$ represents the cumulative density function of a standard normal distribution that depends on the values of $\boldsymbol{X}$ and $\boldsymbol{Z}$. A common strategy to address this equation is to replace $\boldsymbol{\alpha + X\beta + Z\gamma}$ by $\boldsymbol{S}$, with $\boldsymbol{S}$ being a normal random variable, expressed as follows:

Equation 3. Normal standard equation

$$\boldsymbol{F}(\cdot) = \int_{-\infty}^{S}\left((2\pi)^{-1/2}e^{-S^2/2}\right)dz;\ where\ \boldsymbol{S} = \alpha + \boldsymbol{X}\beta + \boldsymbol{Z}\gamma$$

Finally, $\boldsymbol{F(\cdot)}$ is maximized based on the coefficients $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$, with simple data to obtain the estimates for parameters $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$. This is known as the Maximum Likelihood (MV) estimation method. The use of a Probit model is employed, which is frequently found in applied empirical works that deal with barriers to innovation. This model also allows treating some specification issues due to the properties of the normal distribution (Wooldridge, 2010).

Marginal effects and goodness-of-fit for Probit models

The partial effects of the independent variables on $\boldsymbol{P(Y = 1|X, Z)}$ are represented as follows:

Equation 4. Partial effects of independent variables.

$$\frac{\partial P(Y = 1|\boldsymbol{X})}{\partial \boldsymbol{X}} = \frac{\partial \boldsymbol{F}(\cdot)}{\partial \boldsymbol{X}} \cdot \beta \quad \text{ó} \quad \frac{\partial P(Y = 1|\boldsymbol{Z})}{\partial \boldsymbol{Z}} = \frac{\partial \boldsymbol{F}(\cdot)}{\partial \boldsymbol{Z}}\gamma$$

The partial effects are a function of the probability and the estimated coefficients. It also becomes evident that, with $\frac{\partial \boldsymbol{F}(\cdot)}{\partial \boldsymbol{X}}$ being a strictly increasing function, the signs of the partial effects will be equal to the signs of the estimated coefficients $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$. For binary independent variables, only changes in probabilities should

be considered when they take the value of one or zero. The usual goodness-of-fit for Probit models are two, namely, the McFadden R-square (McFadden, 1974) and the Count R-square. The former is based on the log-likelihood function, and the latter consists of providing values of 1 to any observation whose probability of occurrence is greater than or equal to 0.5 and a value of 0 if the probability of occurrence is less than 0.5. To the extent that these predictions are equal to the real values of the dependent variable, they are correctly predicted.

With respect to the determinants of innovation ($\boldsymbol{Z}_j$), we consider the total number of firm's employees as firm size (which is measured as the logarithm of employees) given that larger firms are less affected by liquidity constraints (Mairesse and Mohnen, 2002; Pellegrino and Savona, 2017). In addition, the ability of firms to innovate is influenced by market dynamics (concentration and structure) so firms engaged in international markets can engage in innovation activities due to the high level of competition (Narula and Zanfei, 2003). In this sense, we consider being an exporter an important determinant of innovation. We consider a variable to proxy for the share of fims' highly qualified workers as an important aspect to deal with complex environments and exploit innovative ideas (Piva and Vivarelli, 2009). Finally, we consider the total innovation expenditure of firms and also control for technological factors that influence the ability to innovate of firms. The vector ($\boldsymbol{X}_j$) includes dummy variables for companies facing at least one obstacle: financial, knowledge, market, and institutional/regulatory barriers (see Appendix A for variables' description).

Results and discussion

Descriptive statistics

Descriptive statistics for the variables according to firms' categories divided by innovative, non-innovative companies and total sample are shown in Table 1. In this sense, following the criteria outlined previously, 86% of firms included in the total sample are innovative companies, while the rest are non-innovative (14%). Descriptive statistics show that average values of explanatory variables are higher in the group of innovative firms when compared to the total sample. On the contrary, the average values of explanatory variables are lower in the group of non-innovative firms. In addition, the explanatory variable that presents the greatest dispersion (standard deviation) between non-innovative and innovative companies is the intensity of investment in innovation.

The most frequently perceived obstacle is the knowledge barrier. However, non-innovative firms perceive mostly financial barriers. On the contrary, the institutional barrier is the least perceived by firms (both non-innovative and innovative). In general, non-innovative companies perceive each of the barriers to innovation more frequently compared to those innovative.

Table 1. Descriptive statistics: standard deviation and mean of selected variables

Variables	Total sample		Innovative firms		Non-innovative firms	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Innovator	0.86	0.35	1.00	0.00	0.00	0.00
High education	9.10	11.60	9.16	11.19	8.77	13.83
Exporter	8.05	16.48	8.37	16.71	6.12	14.88
Size	4.35	1.35	4.43	1.36	3.86	1.19
Technological intensity	0.25	0.43	0.26	0.44	0.20	0.40
Innovation expenditures	2.84	11.11	2.99	11.85	1.97	4.49
Financial barriers	0.67	0.47	0.66	0.47	0.76	0.42
Knowledge barriers	0.69	0.46	0.68	0.47	0.74	0.44
Market barriers	0.63	0.48	0.62	0.48	0.68	0.47
Institutional barriers	0.57	0.49	0.56	0.50	0.64	0.48

The potential relationships between variables are shown in table 2. Being an innovative firm is positively associated with all the explanatory variables and negatively associated with all the barriers to innovation. The strongest correlation occurs with firms' size (Size). On the contrary, the weakest correlation occurs with high-skilled workers (High Education). Focusing on the barriers to innovation, a high correlation is observed between them. Financial and knowledge barriers present higher correlation with firms' size (Size). On the other hand, market and institutional barriers present higher correlation with industries' technological intensity in which firms operate (technological intensity). Despite this, these correlations are not significant in economic terms since they tend to be close to zero.

Model estimations

We estimate a Probit model as outlined previously. In this sense, the estimated model includes four barriers variables (column 1). Later, we consider additional estimations (columns 2 and 3) with explanatory variables. The explanatory variables are included in the model to observe changes in the estimated coefficients of barriers to innovation. The last model (column 3) considers a new specification of high-skilled workers[1]. This new specification consider only personnel with a master's degree and doctorate. Although this does not make the variable significant, it does correct the negative sign of the first specification as shown in table 3.

[1] The variable Higher Education (Spec. 1) is presented in detail in Appendix A (table A1). The variable Higher Education (Spec. 2) only considers graduate studies of firms' employees such as masters and doctorates degrees.

Table 2. Descriptive statistics: correlation coefficients

	Innovator	High Education	Exporter	Size	Technological intensity	Innovation expenditures	Financial barrier	Knowledge barrier	Market barrier	Institutional barrier
Innovator	1.00									
High Education	0.01	1.00								
Exporter	0.05	0.10	1.00							
Size	0.15	0.09	0.24	1.00						
Technological intensity	0.05	0.08	0.13	0.03	1.00					
Innovation expenditures	0.03	0.03	-0.03	-0.05	-0.02	1.00				
Financial barriers	-0.08	0.03	-0.05	-0.11	-0.01	-0.03	1.00			
Knowledge barriers	-0.05	0.03	-0.02	-0.06	0.02	-0.02	0.46	1.00		
Market barriers	-0.04	0.04	-0.01	0.03	0.05	0.01	0.40	0.43	1.00	
Institutional barriers	-0.06	0.06	0.01	-0.06	0.08	-0.01	0.41	0.47	0.41	1.00

In the first specification (column 1), all barrier variables have negative effects on the probability of being innovative, except market barriers. Financial barriers effect is significant at the 5% level. When explanatory variables are included, all barrier variables have negative effect on the probability of being innovative. In contrast, the financial barrier is no longer significant at 5% but remains significant at 10%. It is important to highlight that financial barriers are the only statistically significant group of barriers in all three specifications. In this second specification, knowledge barriers present the smallest absolute effect and financial barriers present the largest effect. The joint hypothesis test at a 5% significance level reveals that at least one of the four barriers has significant effects on the probability of being innovative (see Appendix A-table A3).

However, the results suggest that financial obstacles significantly shrinks the company's probability to become an innovator by 4,9%. These results also suggests for more applied research of the importance of other obstacles since shortage of funding does not appear to be the only challenge for unsuccessful innovators. Nevertheless, other systemic obstacles appear for affecting firm innovation performance, although require more available information and data at the firm level.

With respect to explanatory variables, they indicate the expected signs for the determinants of being an innovator. More precisely, firms trading in global markets and larger firms are more likely to develop new products and/or services for the market. In addition, as expected, innovation expenditures and differences in technological intensities play a significant role at the time to develop innovative outputs (see Appendix A–table A3). In general, our third model suggest that

manufacturing firms that face financial barriers see their probability of being innovative decreased by 3.5 percentage points compared to those firms do not perceive them. The smallest effect, although not significant, is observed in knowledge barriers, which is predicted between 0.24 and 0.26 percentage points of less probability of being innovative by firms that perceive that barrier.

Table 3. Probit estimations of the likelihood of being an innovator

	Dependent variable		
	Likelihood of being an innovator		
	(1)	(2)	(3)
Financial barriers	-0.233**	-0.169*	-0.171*
	(0.092)	(0.094)	(0.094)
Knowledge barriers	-0.020	-0.012	-0.011
	(0.094)	(0.096)	(0.096)
Market barriers	0.007	-0.054	-0.055
	(0.085)	(0.087)	(0.087)
Institutional barriers	-0.091	-0.075	-0.076
	(0.085)	(0.087)	(0.087)
High Education (Spec. 1)		-0.001	
		(0.003)	
High Education (Spec. 2)			0.002
			(0.008)
Exporter		0.001	0.001
		(0.002)	(0.002)
Ln(Size)		0.184***	0.183***
		(0.029)	(0.029)
Technological Intensity		0.196**	0.194**
		(0.086)	(0.086)
Innovation Expenditures		0.021**	0.021**
		(0.009)	(0.009)
Constant	1.300***	0.418***	0.416***
	(0.077)	(0.147)	(0.147)
Observations	2,007	2,007	2,007
Log Likelihood	-812.638	-785.024	-785.023
Akaike Inf. Crit.	1,635.275	1,500.048	1,500.046

Note: The dependent variable takes the value of 1 if the firm is an innovator (dummy variable). ***, **, *: significance levels at 1%, 5% and 10% respectively. Robust standard errors in parenthesis.

These results complement to the work done on developed countries by identifying a relevant sample of firms of potential innovators depending on their willingness to innovate (Pellegrino and Savona, 2017; D'Este et al., 2008, 2012; Savignac, 2008). This evidence adds to the empirical work, both in the Latin American context (Crespi and Álvarez, 2015; Zahler et al., 2018) and in the context of developed countries (Pellegrino & Savona, 2017; Savignac, 2008). This empirical results are consistent with the evidence on innovation and finance, which suggest that innovators use venture capital as external financial resources (Bertoni and Tykvová, 2015; Arqué-Castells, 2012). These results can be associated to an inability of financial markets to allocate necessary resources for innovative projects. Nevertheless, Barona-Zuluaga et al. (2015) argues that it is not enough

to allocate public funds for these purposes, while strengthening the stock market in Colombia will enable greater flow of financial resources in an efficient manner.

CONCLUSIÓN

The results of this work add to the empirical evidence on innovation obstacles that is highly relevant for public policy in Colombia by presenting an analysis of the obstacles to companies' abilities to translate their internal efforts into market innovations (products or services). We complement to the work done on developing countries by identifying a relevant sample of firms of potential innovators known as innovation-oriented and non-innovation oriented companies. We test the effect of potential innovators' perception of the importance of diverse obstacles to innovation on their ability to produce innovative goods (or services). More precisely, we tested the assumption of non-financial and financial barriers affected firms' innovation propensity. We found evidence of our main conjecture that financial related barriers are the most relevant and important obstacle for innovation.

Some limitations regarding firm level data are worth to highlight. Firstly, Colombia's specific data does not include relevant information of perceptions on market functioning and entry barriers due to monopolized markets that may limit innovations. In the Colombian case, the manufacturing sector has a large share of smaller companies with smaller market shares, therefore market concentration becomes relevant in the analysis. Another important limitation is the non-availability of firms' age, which is important in empirical analysis between mature and younger firms (Pellegrino and Savona, 2017). Nevertheless, estimation results are consistent with the expected effects.

The main policy recommendation derived from this research is the need to guarantee financial resources for innovation projects. Indeed, promising innovative ideas require efficient allocation of resources. Innovation in Colombia is mainly financed by firms' internal resources (Barona-Zuluaga et al., 2015), therefore efforts should be largely focused on ensuring financing options. In the short-term, public financing to increase liquidity can create crowding-in effects (Gómez and Mitchell, 2014), but these initiatives require long-term solutions where investors and entrepreneurs interact freely such as a dynamic stock market. Future research should focus on exploring the role of non-financial barriers on the ability of firms to introduce innovations, both in manufacturing and in services sectors. For the Colombian case, the analysis can be improved using longitudinal data.

APPENDIX

Table A1. Explanatory variables: acronyms and definitions

Explanatory Variable	Name	Definition	Authors	Expected Effect
Highly Skilled Workers	High Education	Average share of skilled workers with graduate education (specialization degree, masters and doctorates), with respect to the total of employees during the period.	(Bukstein et al., 2019; Canales & Álvarez, 2017; Pellegrino & Savona, 2013, 2017)	(+)
Exports	Exporter	Share of export sales in total sales during the period	(Canales & Álvarez, 2017; Fuentes & Soto, 2015; Pellegrino & Savona, 2013, 2017)	(+)
Firm size	Size	Log of the total number of firms' employees during the period	(Blanchard et al., 2012; Bukstein et al., 2019; Canales & Álvarez, 2017; Fuentes & Soto, 2015; Pellegrino & Savona, 2013, 2016)	(+)
Industrial sector	Technological intensity	Subsector industrial classification as a function of the level of technological intensity following Hatzichronoglou (1997) and ISIC Rev. 4: Hi-tech industries: 21, 26, 27. Mid Hi-tech industries: 20, 28, 29, 30, 33. Mid Low tech industries: 19, 22, 23, 24, 25, 32. Low-tech industries: 10, 11, 12, 13, 14, 15, 16, 17, 18, 31.	Villarreal et al.(2014).	(+/-)
Investment performance on innovation	Innovation expenditures	Share of total amount of investment in innovation activities in total sales	(Pellegrino & Savona, 2013, 2016)	(+)

Table A2. *Barriers to innovation variables*

Barriers to innovation	Definition	Expected effect
Financial barriers	Dummy = 1 if firm faced at least one of the following obstacles: 1) Non-availability of finance; 2) Deterred by the access to external funding, and zero otherwise.	(-)
Knowledge barriers	Dummy = 1 if firm faced at least one of the following obstacles: 1) lack of qualified personnel; 2) lack of information on markets; 3) lack of information on technology, and zero otherwise.	(-)
Markets barriers	Dummy = 1 if firm faced at least one of the following obstacles: 1) uncertain demand for innovative goods or services, and zero otherwise.	(-)
Institutional barriers	Dummy = 1 if firm faced at least one of the following obstacles: 1) lack of institutional capacity to protect intellectual property rights; 2) Difficulties on regulations, and zero otherwise.	(-)

Table A3. *Hypothesis test, Goodness-of-fit statistics and Marginal effects at Mean.*

Hypothesis test:

Ho: Financial barriers = 0; Knowledge barriers = 0; Market barriers = 0; Institutional barriers = 0

H1: The effect of at least one barrier is different from zero.

Res.Df.	*Df*	*F*	*Pr(>F)*
2001	NA	NA	NA
1997	4	2.593	0.03491

Goodness-of-fit statistics:

$$\text{McFadden } R^2 = 1 - \frac{\log\left(f^{max}_{probit\ UR}\right)}{\log\left(f^{max}_{probit\ R}\right)}$$

$$Where\ f_j^{max}\ is\ the \log - likelihood\ of\ model\ \ j.$$

Statistic	*Model 1 (1)*	*Model 2 (2)*	*Model 3 (3)*
$\text{McFadden } R^2$	0,009	0,0427	0,0427
% Classified (Cut-off=0.5)	0,86	0,86	0,86
% Classified (Cut-off=proportion of innovators)	0.42	0.58	0.58

Marginal effects at Mean:

Variables	*Model 1 (1)*	*Model 2 (2)*	*Model 3 (3)*
Financial barriers	-0.0496	-0.0346	-0.0349
Knowledge barriers	-0.0496	-0.0026	-0.0024
Market barriers	0.0015	-0.0113	-0.0115
Institutional barriers	-0.0201	-0.0157	-0.0159
High Education (Spec. 1)		-0.0002	
High Education (Spec. 2)			0.0005
Exporter		0.0001	0.0001
Ln(Size)		0.0388	0.0386
Technological Intensity		0.0391	0.0387
Innovation Expenditures		0.0045	0.0045

AUTHOR CONTRIBUTIONS

A. Escobar performed the literature review and research design, analyzed, interpreted the data, and prepared the manuscript text and manuscript edition. N. López conducted the literature review and research design and analyzed and interpreted the data, prepared the manuscript text and manuscript edition. R. Castro helped in the literature review and manuscript preparation.

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CONFLICT OF INTEREST

The authors declare no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, were observed by the authors.

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