THE RELATIONSHIP BETWEEN FINANCIAL CONSTRAINTS AND INNOVATION, WITH A SUPPORTIVE ANALYSIS ON A SAMPLE OF FIRMS

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Abstract

The purpose of this study is to investigate the impact of financial constraints on firms' innovative activities. While this topic has been extensively studied in the economic literature, research, and development (R&D) activities present peculiarities that tend to discourage investment due to the uncertainty of outcomes. As a consequence, a firm may have little or no incentive to invest in research, despite the fact that it has the potential to increase the social surplus. To answer this research question, a probit regression analysis was conducted on a heterogeneous sample of European and Asian firms to examine how the presence of financial constraints affects the probability of innovation success.

Keywords: Research and Development, Technological Innovation, Technological Change, Industrial Research, Innovation Management.

JEL classification: G3; O16; O3.

1. INTRODUCTION

The role of innovation in the economic system has consistently held significant importance, as knowledge creation emerges from the research and innovation endeavors pursued by firms, ultimately contributing to the overall welfare of society (Romer, 1986; Levine, 2005). Consequently, the economic literature has displayed substantial interest in examining the impact of financial constraints on firms' research and development (R&D) activities, as these constraints have the potential to delay or even terminate innovation projects.

One possible definition of R&D, as stated in the Frascati Manual (OECD, 2015), which is regularly updated by the OECD, is the creative work carried out systematically to increase the existing knowledge base and use it to develop new practical applications. There is empirical evidence to support this definition, showing a positive relationship between innovation and product quality (Galia and Pekovic, 2008). Academics have emphasized that research activities, and in particular the development of new technologies, are key elements in achieving a competitive advantage for firms, in some cases even determining their survival (Suarez and

Utterback, 1995; Iansiti, 2000). Innovative firms that successfully introduce new products, services, processes, or business models are significantly more likely to create new market niches and experience accelerated growth (Lee et al., 2015). However, the presence of financial constraints in the context of research and development (R&D) activities is a common challenge faced by innovative firms, primarily due to market failures and the unique characteristics of knowledge (Arrow, 1962). These constraints arise from a combination of factors, including issues related to appropriability, spillovers, and information asymmetries.

The characteristics of knowledge, such as its non-rivalrous and non-excludable nature, contribute to a lack of reliability on the part of financiers when considering investments in R&D activities. The difficulty in appropriating the full benefits of innovation discourages external sources of funding from fully embracing such ventures. Furthermore, information asymmetries create challenges for innovative firms in accessing credit, as moral hazard and adverse selection problems emerge (Akerlof, 1970). The inherent uncertainty and information gaps associated with R&D make it challenging for financial institutions to accurately assess the risks and potential returns of supporting innovative projects. Moreover, firms engaged in R&D face the risk of benefiting competitors, as their pioneering efforts may pave the way for subsequent entrants to reap the rewards at a lower cost and with reduced associated risks (Mansfield et al., 1981). This dynamic further deters external financing, as firms may be reluctant to invest substantial resources in innovation without adequate protection or guarantees of capturing the full benefits.

Consequently, firms encounter difficulties in obtaining external sources of finance, which often come with high-risk premiums due to the uncertain nature of innovation. As a result, firms predominantly rely on internal resources to finance their innovation activities. However, internal resources, such as retained earnings, may not always generate sufficient and stable cash flows to support continuous innovation (Schumpeter, 1942). Consequently, many promising innovation projects are abandoned or delayed due to the lack of internal funds and the unavailability of affordable external financing options. In summary, the presence of financial constraints in R&D activities poses significant challenges for innovative firms. Market failures, information asymmetries, and the inherent risks and uncertainties associated with innovation contribute to limited access to external financing. This reliance on internal resources can hamper firms' ability to sustain and expand their innovative efforts, ultimately hindering overall economic growth and societal welfare.

However, the question of whether financial constraints affect the likelihood of an R&D project is becoming increasingly important in the economics literature. Thus, the studying of financial constraints is fundamental for its potential impact on economic growth, as it could potentially cause a reduction in new knowledge. Therefore, it is not trivial to study the financial barriers that innovative projects face, such as financial constraints, as their potential impact on economic growth could be significant. This paper aims to investigate whether the presence of financial constraints has an impact on firms' chances of successful innovation, and it is

organized as follows. Section 2 reports the literature review on the relationship between financial constraints and innovation. Section 3 reports data and some statistics on a sample of firms in emerging economies used to study the impact of financial constraints on innovation performance. Section 4 applies a probit regression model to the sample of firms to test the research hypothesis, a method widely used in the literature. Section 5 summarizes the results of this work and discusses some policy implications.

2. THEORICAL BACKGROUND

The review of the economic literature emphasizes the considerable importance of enabling conditions for innovation, with particular attention to the financial constraints affecting firms' R&D investment. Innovative firms often struggle to attract external financing due to the associated higher risk and information problems, as noted by Hall (2002), and oftentimes the complexity of the R&D process leads to project failure, as shown by Mazzucato (2013). Therefore, access to finance is regarded as a major factor in innovation success, as pointed out by D'Este et al. (2012) and Hölzl and Janger (2014).

Utilizing a direct method, one line of the literature suggests that the presence of financial constraints is a significant determinant of the probability of success of a research project. Using the CIS survey, Mohnen et al. (2008) analyzed the impact of financial constraints as a barrier to innovation and found that financial constraints can affect the likelihood of prematurely stopping or not starting a research project. Similarly, Savignac (2008) found for a sample of French firms that the presence of financial constraints reduces the likelihood of innovating. Garcia-Vega and Lopez (2010) tested a sample of more than 8,300 Spanish firms for the period 2005-2007 and found evidence for a lack of funds has a significant impact on the likelihood of abandoning research projects. Lastly, using CIS data for 11 countries for the period 2002-2004, Efthyvoulou and Vahter (2015) prove, in line with previous analyses, that financial constraints have a negative impact on innovation outcomes.

Previous empirical studies have investigated the influence of financial constraints on the dropout of R&D initiatives (Gorodnichenko and Schnitzer, 2013; Pellegrino and Savona, 2017; Mateut, 2018; García-Quevedo et al., 2018). Using probit regression, these authors studied whether financial constraints shaped the propensity of a firm to discontinue an innovation blueprint. Hall and Lerner (2010) argue that financial constraints have a bigger effect on the likelihood of abandoning an innovation project due to the knowledge nature. To address this issue, public policy measures that subsidize R&D would be suggested as a possible solution, as an intervention of this kind would benefit businesses and consumers, given the positive relationship between innovation and long-term economic growth (Schneider and Veugelers, 2010; Arqué-Castells and Mohnen, 2015).

Gorodnichenko and Schnitzer (2013) were among the first to study the impact of financial constraints on innovation success. Using a sample of firms from the Business Environment and Enterprise Performance Surveys (BEEPS) including 6500 and 7900 firms in 27 countries in 2002 and 2005, respectively, the authors

conducted a probit regression to test how financial constraints affect innovative activities. The dependent variable was a dummy equal to 1 if the firm had successfully innovated and 0 otherwise. The authors tested financial constraints using a measure based on the difficulty of access to credit and cost of financing as their primary independent variable, controlling for firm size, seniority, and location.

In this study, control variables were included to examine whether R&D activity varies among firms due to different drivers other than financial constraints. As widely discussed in the literature, some firm-specific characteristics may or may not foster both research activity and the attraction of finance (Savignac, 2008; Blanchard et al., 2012; Hottenrott et al., 2017). Based on the results of Gorodnichenko and Schnitzer's (2013) paper, small and young firms, as argued in the literature (Hottenrott et al., 2017; Cucculelli and Bettinelli, 2016), appear to be especially affected by funding constraints, thereby proving their research hypothesis. The study highlights how financing constraints originate from high financing costs, emphasizing the significance of financial markets in mitigating the problem of funding restrictions (Chan, 2001; Blass and Yosha, 2003; Hall and Oriani, 2006; Ughetto, 2008).

Analogously, Mateut (2018) employs the 2009 BEEPS sample of 11,998 firms from 30 countries in Eastern Europe and Central Asia to estimate a linkage between government subsidies and innovation for financially constrained firms. The results of the regression show a positive correlation between subsidies received and R&D activities, which became more significant the more financially constrained the firms are. This result underlines how public research grant policies could help not only firms that already perform R&D, but also those that abandon innovative projects due to a lack of available resources (Schneider and Veugelers, 2010; Arqué-Castells and Mohnen, 2015). García-Quevedo et al. (2018) performed a similar investigation on a sample of 4600 Spanish firms from the Panel of Technological Innovation (PITEC), derived from the Community Innovation Survey (CIS) for the period 2005-2013. In their study, the authors considered the impact of financial constraints on the likelihood of firms exiting an R&D venture and at what stage of the process the dropout occurs. The authors point out that the abandonment occurs in the early stages of the project due to the complex nature of research activities (Mazzucatto, 2013) and difficulties in credit access (Mohnen et al., 2008). Lastly, Pellegrino and Savona (2017) conducted a probit regression on a sample of over 37,000 UK firms covering the period 2002-2010. Results of their research show that financial constraints and market structure are important barriers to innovation and influence firms' propensity to innovate (Arqué-Castells, 2012; Bertoni et al., 2015).

Drawing on the existing body of literature, a probit regression will be conducted in this paper to estimate how financial constraints affect firms' innovation success by directly measuring both financial restrictions and other relevant firm characteristics that may influence R&D propensity.

3. RESEARCH METHODOLOGY

In order to examine the impact of financial constraints on the likelihood of successful innovation, this study employs a probit regression model. The analysis is conducted using a sample of 3914 firms extracted from the BEEPS 2009 dataset, which provides more recent data compared to previous studies and encompasses firms from 26 European and Asian countries. This particular model distinguishes itself from earlier research by employing binary variables to capture innovation outcomes (1 for firms that innovate and 0 for firms that do not innovate) and financial constraints (1 for constrained firms and 0 for unconstrained firms) as explanatory variables. Moreover, additional control variables such as firm seniority and the number of employees is included in the model to account for the effects of experience and firm size, following the methodology established by Gorodnichenko and Schnitzer (2013). By adopting this approach, the study aims to provide novel insights into the relationship between financial constraints and firms' innovation behavior while controlling for relevant firm characteristics and contextual factors.

To account for the specific context in which firms operate, dummy variables are used for the country and sector they belong to. These variables help to consider the influence of a variety of characteristics, such as infrastructure, legal system, and markets, on the likelihood of innovation success for firms. The evidence for the significance of resource constraints was conducted on a sample of the BEEPS (World Bank, 2013), which includes a wide range of countries in Europe and Asia. The surveys, which are part of the Business Environment and Enterprise Performance Surveys initiative of the European Bank for Reconstruction and Development (EBRD) and the World Bank Group, use the same questionnaires in all countries and employ stratified random sampling to ensure that the samples are representative of the large population of enterprises. The BEEPS measures a broad spectrum of R&D activities, either the development of a new product line or the improvement of an existing line of products over the past three years. These innovation measures are aligned with the guidance in the Oslo Manual (OECD, 2018), developed by the OECD and Eurostat for innovation surveys. The manual assumes that innovative measures that are "new to firms," even if they are not new technologies or processes, are still considered innovations for firms that have not previously adopted them. In addition, BEEPS collects not only data on innovative activities but also information on access to credit, including whether firms have applied for a loan and the outcome of that application, in order to examine the difficulties firms, face in obtaining financing. However, although these self-reported measures of financial constraints may be subject to measuring errors compared to more objective measures like patents or R&D expenditures, they do allow direct identification of barriers to financing as they were reported by the firm, avoiding indirect measures.

The sample for hypothesis testing consists of 3914 BEEPS-observed enterprises in 2009 across 26 European and Asian countries. The descriptive statistics of the variables used in the analysis, broken down by country, age, size, and sector, are presented in the appendix to illustrate any differences due to firms'

characteristics. Hence, the survey questionnaire is split into two parts: the central part gives information on business activities and the environment, including indicators related to innovation, in the form of new products or services; the second part reports on transactions, like financing and labor purchases, and specific questions on loan refusal and reason for refusal are applied to measure financial constraints. The study sample included firms with at least five employees that applied for a loan in the previous year, divided into two macro-categories: services and manufacturing. Also, companies operate in heterogeneous contexts, with different legal regimes, infrastructures, and financial markets. The paper reports on the variables used and presents descriptive statistics and correlation analysis to explore the possible relationships between them. However, even if the self-reported variables are subject to measurement error, although they provide a valuable tool for determining whether R&D spending has led to innovation and how financial constraints affect R&D outcomes. Table 1 illustrates the variables employed in the study.

Table 1 Variables description

Variable	Description
Age	*Age of the enterprise at the time of the survey (Continues)*
Cert	*Whether or not the enterprise holds a quality certification (Dummy)*
UoInt	*If the enterprise uses a website to make sales (Dummy)*
Exp	*Whether the enterprise exports, considering both direct and indirect exports (Dummy)*
Pdom_Prod	*Pressure from domestic competitors in affecting decisions to develop new products or services (Dummy)*
Pfor_prod	*Pressure from foreign competitors in affecting decisions to develop new products or services (Dummy)*
Pcust_prod	*Pressure from customers in affecting decisions to develop new products or services (Dummy)*
Pdom_cost	*Pressure from domestic competitors in affecting decisions with respect to reducing the production costs of existing products or services (Dummy)*
Pfor_cost	*Pressure from foreign competitors in affecting decisions with respect to reducing the production costs of existing products or services (Dummy)*
Pcust_cost	*Pressure from customers in affecting decisions with respect to reducing the production costs of existing products or services (Dummy)*
Subs	*If firm received any subsidies from the national, regional or local governments or European Union sources (Dummy)*
Innov	*Measures whether the enterprise has introduced new products, services, or processes in the last 3 years (Dummy)*
R_D	*If firm spend on research and development activities, either inhouse or contracted with other companies in last 3 years (Dummy)*
Cred_Cons	*Measures whether the enterprise did not apply for a loan because it believed it could not get one, or applied for a loan and was rejected (Dummy)*
Obs_fin	*Obstacle for access to finance (Dummy)*
Obs_tax	*Obstacle for Tax rates (Dummy)*

Obs_Lic	Obstacle for Business licensing and permits (Dummy)
Obs_Corr	Obstacle for Corruption (Dummy)
Obs_Cour	Obstacle for Courts (Dummy)
lnEmpl	Number of employees in log (Continues)
NewPS	Introduction of new product or services (Dummy)
Upgr	Upgraded an existing product line or service (Dummy)
Ref_loan	Apply for any new loans or new lines of credit that were rejected (Dummy)
Appl	Apply for any loans or lines of credit (Dummy)

Notes: The table shows the variables considered to conduct the analysis and used for descriptive statistics and correlations. The table shows the name of the variables in the first column and a description of the variable in the second column.

Some descriptive statistics of the sample are presented in Table 2, including the variable *Innovation*, which takes a value of 1 if the firm achieves a product or service innovation and a value of 0 if not. This variable has a mean of 62% and both the median and the mode are equal to 1, indicating that the sample consists mainly of innovative firms. The variable *Denial*, which will be the main explanatory variable in the regression, reports that about 15% of the firms receive a loan rejection, which is a good measure of the presence of financial constraints.

Table 2 *Descriptive statistics*

	Variable	N	Mean	Std. Dev.	Min	Pctl. 25	Pctl. 75	Max
1	Age	3914	18	19	1	8	18	184
2	Cert	3914	0.28	0.45	0	0	1	1
3	UoInt	3914	0.86	0.35	0	1	1	1
4	Exp	3914	0.33	0.47	0	0	1	1
5	Pdom_Prod	3914	0.84	0.37	0	1	1	1
6	Pfor_prod	3914	0.57	0.49	0	0	1	1
7	Pcust_prod	3914	0.8	0.4	0	1	1	1
8	Pdom_cost	3914	0.82	0.39	0	1	1	1
9	Pfor_cost	3914	0.56	0.5	0	0	1	1
10	Pcust_cost	3914	0.78	0.41	0	1	1	1
11	Subs	3914	0.12	0.32	0	0	0	1
12	Innov	3914	0.84	0.36	0	1	1	1
13	R_D	3914	0.31	0.46	0	0	1	1
14	Cred_Cons	3914	0.18	0.39	0	0	0	1
15	Obs_fin	3914	1.8	1.3	0	0	3	4
16	Obs_tax	3914	0.87	0.34	0	1	1	1
17	Obs_Lic	3914	0.63	0.48	0	0	1	1
18	Obs_Corr	3914	0.69	0.46	0	0	1	1
19	Obs_Cour	3914	0.62	0.49	0	0	1	1
20	lnEmpl	3914	3.9	1.5	0	2.8	5	9.8
21	NewPS	3914	0.63	0.48	0	0	1	1
22	Upgr	3914	0.79	0.41	0	1	1	1
23	Ref_loan	3914	0.14	0.35	0	0	0	1
24	Appl	3914	0.96	0.2	0	1	1	1

Notes: The table shows the descriptive statistics conducted on the sample of enterprises,

these include the mean, standard deviation, minimum,maximum and 25th and 75th percentiles.

The variables utilized in this study have been chosen with the aim of capturing the principal determinants of innovation in firms, as identified by the existing economic literature. These variables have been carefully selected based on their theoretical and empirical significance in comprehending the factors that drive innovation. Specifically, the variable "Subs" demonstrates a mean value of 0.12, indicating that a majority of the firms included in the sample did not receive any form of public subsidies targeted specifically for research purposes. This finding is of particular importance in evaluating the research hypothesis as it suggests that companies without such subsidies must actively seek alternative sources of financing for their research and development endeavors. Additionally, the relatively low average proportion of enterprises involved in research and development activities, as represented by the variable "R_D" which amounts to 31%, further indicates the presence of financial constraints within the sample. These observations shed light on the financial challenges faced by firms in their pursuit of innovation, emphasizing the significance of investigating the impact of such constraints on firms' innovation outcomes. It represents the financial resources allocated specifically towards research and development activities, which are fundamental for generating new knowledge and technological advancements. This finding aligns with the variable *Obs_fin*, which ranges from 1 to 4 and represents the degree of difficulty faced by firms when attempting to obtain new financial resources. A rating of 1 indicates a 'Minor obstacle', while 5 represents a 'Very severe constraint'. With an average value of 1.8, the variable *Obs_fin* indicates that, on average, enterprises encounter notable challenges when attempting to secure external funding.

The variable *UoInt* exhibits significantly high average values, slightly surpassing 85%. Furthermore, the 25th percentile value is recorded as 1, which suggests that the majority of firms within the sample predominantly employ online activities as a means of establishing their online presence, primarily through the utilization of websites. Moreover, it is noteworthy that approximately one-third of the firms included in the study engaged in export activities, as indicated by the mean value of the variable *Exp* which stands at 33%.

Table 3 *Correlations*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1,00																						
2	0.167	1,00																					
3	0.249	0.214	1,00																				
4	-0.025	0.067	-0.069	1,00																			
5	0.161	0.181	0.286	0.231	1,00																		
6	0.047	0.104	0.068	0.36	0.298	1,00																	
7	-0.009	0.054	-0.029	0.623	0.203	0.325	1,00																

#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
8	0.165	0.166	0.274	0.191	0.784	0.276	0.304	1,00															
9	0.06	0.105	0.1	0.31	0.293	0.68	0.481	0.38	1,00														
10	0.165	0.091	0.162	0.003	0.072	0.064	0.017	0.08	0.07	1,0													
11	0.072	0.142	0.107	0.028	0.078	0.046	0.04	0.083	0.039	0.041	1,0												
12	0.201	0.192	0.225	0.005	0.162	0.079	0.012	0.159	0.069	0.097	0.226	1,00											
13	-0.081	-0.059	-0.016	-0.015	0.015	-0.023	-0.007	-0.009	-0.009	0.028	0.005	0.015	1,00										
14	-0.059	-0.017	-0.036	0.087	0.062	0.071	0.111	0.08	0.086	-0.03	0.015	-0.022	0.124	1,0									
15	0.001	0.009	0.011	0.082	0.065	0.105	0.082	0.069	0.119	0.015	0.045	-0.014	-0.017	0.184	1,0								
16	0.015	0.03	0.026	0.107	0.112	0.153	0.122	0.102	0.146	-	0.026	0.022	0.003	0.197	0.271	1,0							
17	-0.004	0.061	-0.016	0.122	0.124	0.143	0.126	0.132	0.128	-0.03	0.047	0.014	0.013	0.213	0.265	0.347	1,00						
18	0.02	0.088	0.052	0.087	0.128	0.136	0.089	0.141	0.141	0.027	0.07	0.057	0.036	0.212	0.245	0.359	0.495	1,00					
19	0.319	0.267	0.27	-0.013	0.147	0.041	-0.002	0.147	0.06	0.127	0.116	0.022	-0.086	0.012	0.051	0.066	0.05	0.094	1,0				
20	0.085	0.193	0.141	0.052	0.095	0.084	0.055	0.087	0.07	0.062	0.563	0.286	-0.045	0.044	0.034	0.05	0.054	0.01	0.125	1,0			
21	0.072	0.122	0.108	0.021	0.074	0.034	0.031	0.087	0.032	0.048	0.832	0.228	-0.051	0.001	0.03	0.009	0.039	0.008	0.135	0.398	1,00		
22	-0.063	-0.046	-0.026	-0.023	-0.025	-0.043	-0.015	-0.019	-0.029	-0.016	-0.003	-0.029	0.863	0.174	-0.013	-0.011	0.025	0.031	-0.064	-0.014	-	1,00	
23	-0.046	-0.034	-0.015	-0.012	-0.015	-0.031	-0.013	-0.016	-0.035	-0.027	-0.094	-0.022	0.433	-0.067	-0.001	-0.014	0.019	0.015	-0.055	-0.065	0.101	0.083	1,00

Notes: The table shows the correlations conducted on the sample of firms using Pearson's linear correlation coefficient

Table 3 shows the correlations between the variables examined. In some cases, the correlation cannot be calculated, and missing data are replaced by NA. Overall, the variables show a positive correlation with each other, although in most cases the correlation is weak. The highest correlation is between *Employees* and *Specialized* at 0.933, indicating that enterprises with more employees tend to have more specialized ones. This finding suggests that the sample enterprises have an innovation-oriented approach. Other significant correlations are between *R&D* and *Innovation* at 0.235, indicating that investment in research is associated with the introduction of innovations, in line with theory. In addition, the correlations between *Age* and *Specialized* at 0.264 and between *Age* and *Employees* at 0.168 show that more established firms tend to be larger and have more specialized employees. The correlation between *Specialised* and *R&D* of 0.151 highlights the relationship between investment in research and investment in human capital.

Table 4 *Sample split*

	High Employees			Low Employees			High Age			Low Age	
Variable	N	Mean	Variable	N	Mean	Variable	N	Mean	Variable	N	Mean
Age	1957	23	Age	1957	13	Age	1957	28	Age	1957	8.4
Cert	1957	0.4	Cert	1957	0.16	Cert	1957	0.34	Cert	1957	0.23
UoInt	1957	0.94	UoInt	1957	0.78	UoInt	1957	0.88	UoInt	1957	0.83
Exp	1957	0.44	Exp	1957	0.22	Exp	1957	0.38	Exp	1957	0.27
Pdom_Prod	1957	0.84	Pdom_Prod	1957	0.84	Pdom_Prod	1957	0.86	Pdom_Prod	1957	0.82
Pfor_prod	1957	0.64	Pfor_prod	1957	0.5	Pfor_prod	1957	0.63	Pfor_prod	1957	0.52
Pcust_prod	1957	0.81	Pcust_prod	1957	0.78	Pcust_prod	1957	0.83	Pcust_prod	1957	0.77
Pdom_cost	1957	0.82	Pdom_cost	1957	0.82	Pdom_cost	1957	0.84	Pdom_cost	1957	0.79
Pfor_cost	1957	0.63	Pfor_cost	1957	0.49	Pfor_cost	1957	0.61	Pfor_cost	1957	0.51
Pcust_cost	1957	0.81	Pcust_cost	1957	0.76	Pcust_cost	1957	0.81	Pcust_cost	1957	0.75
Subs	1957	0.15	Subs	1957	0.084	Subs	1957	0.15	Subs	1957	0.095
Innov	1957	0.87	Innov	1957	0.82	Innov	1957	0.86	Innov	1957	0.83
R_D	1957	0.4	R_D	1957	0.23	R_D	1957	0.36	R_D	1957	0.27
Cred_Cons	1957	0.16	Cred_Cons	1957	0.2	Cred_Cons	1957	0.16	Cred_Cons	1957	0.2
Obs_fin	1957	1.8	Obs_fin	1957	1.8	Obs_fin	1957	1.8	Obs_fin	1957	1.8
Obs_tax	1957	0.89	Obs_tax	1957	0.85	Obs_tax	1957	0.87	Obs_tax	1957	0.87
Obs_Lic	1957	0.65	Obs_Lic	1957	0.61	Obs_Lic	1957	0.63	Obs_Lic	1957	0.63
Obs_Corr	1957	0.71	Obs_Corr	1957	0.67	Obs_Corr	1957	0.68	Obs_Corr	1957	0.7
Obs_Cour	1957	0.66	Obs_Cour	1957	0.58	Obs_Cour	1957	0.63	Obs_Cour	1957	0.61
lnEmpl	1957	5.1	lnEmpl	1957	2.7	lnEmpl	1957	4.3	lnEmpl	1957	3.6
NewPS	1957	0.67	NewPS	1957	0.59	NewPS	1957	0.66	NewPS	1957	0.6
Upgr	1957	0.82	Upgr	1957	0.75	Upgr	1957	0.8	Upgr	1957	0.77
Ref_loan	1957	0.12	Ref_loan	1957	0.16	Ref_loan	1957	0.13	Ref_loan	1957	0.15
Appl	1957	0.97	Appl	1957	0.95	Appl	1957	0.97	Appl	1957	0.95

Notes: The table shows the mean and the number of observations for the variables that were split into sample divisions, which were carried out on two variables, namely age and ln(empl). These divisions are based on whether the values are above or below the median.

Table 4 provides statistical measures for firms with employee counts above the median, while Table 5 presents corresponding statistics for firms with employee counts below the median. The aim is to examine potential variations in various key indicators and gain insights into the characteristics and dynamics of firms operating in different workforce size categories.

Specifically, the group with higher employee counts exhibited a 5% higher average Innov score compared to the group with lower employee counts. This finding suggests that firms with larger workforces tend to engage in more innovative activities. Additionally, the variable Cred_Cons exhibited a 4% difference between the two groups. Firms with lower employee counts experienced a slightly higher average Cred_Cons score compared to their counterparts with higher employee counts. This discrepancy implies that smaller firms face relatively greater credit constraints compared to their larger counterparts.

The findings suggest that larger firms, with their increased resources and capabilities, tend to have a higher propensity for innovation. Conversely, smaller firms face relatively greater challenges in accessing credit, indicating the presence of significant credit constraints within this subgroup.

Table 6 presents a comprehensive overview of descriptive statistics pertaining to firms categorized based on their age counts surpassing the median, while Table 7 showcases corresponding statistical measures for firms with age counts falling below the median. The primary objective of this analysis is to explore potential disparities across various pivotal indicators and acquire valuable insights into the unique traits and dynamics of firms operating within distinct age groups.

Specifically, the findings reveal that firms with greater age exhibit a 3% lower average Innov score compared to their younger counterparts. This finding suggests that older firms tend to engage in relatively less innovative activities. Moreover, the variable Cred_Cons demonstrates a 4% difference across different firm age categories. Younger firms experience a slightly higher average Cred_Cons score in comparison to their older counterparts. This discrepancy implies that younger firms encounter relatively greater credit constraints compared to more established firms.

The observed disparities in the variables Innov and Cred_Cons based on firm age provide valuable insights into the innovation practices and credit limitations experienced by firms. The findings suggest that older firms, with their accumulated experience and resources, encounter fewer challenges in accessing credit. Conversely, younger firms face relatively greater obstacles in securing credit, indicating the presence of significant credit constraints within this age group. Nevertheless, younger firms tend to exhibit a higher propensity for innovation.

4. FINDINGS

The econometric approach employed in this analysis to investigate the likelihood of firm innovation under financial constraints is the probit model. This model is specifically designed to predict a binary dependent variable, where the dependent variable in this case represents whether the firm has successfully innovated or not. The regression function in the probit model is interpreted as the predicted probability or odds of the dependent variable being equal to one, indicating a successful innovation outcome. In this context, the explanatory variables in the model, measuring credit constraints, play a significant role in impacting the

probability of the dependent variable being equal to one. The influence of these variables can be either positive or negative, indicating their potential effects on the likelihood of successful innovation.

The primary focus of the estimated model revolves around incorporating only those variables that are highly relevant to the innovation process. By considering these specific variables, the model aims to capture the key determinants that contribute significantly to firm innovation. However, it is worth noting that an alternative model is also estimated, which includes all available variables. This allows for a comprehensive analysis, encompassing a broader set of factors that might influence the innovation process within firms. By employing the probit model and carefully selecting the relevant variables, this analysis aims to provide valuable insights into the relationship between financial constraints and firm innovation. The estimated model allows for the identification of significant factors that either facilitate or hinder the likelihood of successful innovation.

The estimated model used to test the hypothesis is as follows:

$$\Pr(\mathrm{Innov}_{ics} = 1 \mid \mathrm{Cred\_Cons}_{ics}, \mathrm{Cert}_{ics}, \mathrm{UoInt}_{ics}, \mathrm{Exp}_{ics}, \mathrm{R\_D}_{ics}, \ln(\mathrm{Empl})_{ics} = \Phi(\beta 0 + \beta 1\,\mathrm{Cred\_Cons}_{ics} + \beta 2\,\mathrm{Cert}_{ics} + \beta 3\,\mathrm{UoInt}_{ics} + \beta 4\,\mathrm{Exp}_{ics} + \beta 5\,\mathrm{R\_D}_{ics} + \beta 6\ln(\mathrm{Empl})_{ics} + \mathrm{D}_{ic} + \mathrm{D}_{is} + u_{ips})$$
(1)

The regression takes into account firm characteristics and controls for the effects of country and industry. The dependent variable is the Innov variable, which measures the probability of a firm successfully implementing an innovation. The main explanatory variable is Cred_Cons, which measures financial constraints by indicating whether the firm has been denied financing. Following the research hypothesis, if a firm is rejected for a loan, it will likely lack the financial resources to carry out R&D, affecting its probability of innovating. As expected from the literature, the regression shows that Rejection has a negative effect on the firm's likelihood to innovate and thus represents a measure of financial constraints. The regression analysis conducted in this study aimed to explore the relationship between innovation probability and a set of additional explanatory variables, namely Cert, UoIn, Exp, R_D, and ln(Empl). These variables were included in the regression model due to their potential impact on facilitating the innovation process, as documented in previous studies (Gorodnichenko and Schnitzer, 2013; Pellegrino and Savona, 2017; Mateut, 2018). The variable Cert represents if the firm have a quality certification, which may contribute to enhancing its innovative capabilities. Certifications can provide firms with credibility and recognition, enabling them to access resources and collaborate with other innovative entities. Consequently, it is hypothesized that firms with higher certification levels are more likely to engage in innovative activities.

UoIn denotes the utilization of online activities by the firm, such as having a dedicated website. Online platforms and digital technologies have become vital channels for information exchange, market outreach, and collaboration, all of which can facilitate the innovation process. Therefore, firms actively utilizing online

activities are expected to exhibit a higher likelihood of innovation compared to those with limited or no online presence. The variable Exp represents the extent of export activities undertaken by the firm. Engaging in export markets exposes firms to diverse market conditions, competition, and customer demands, thereby encouraging innovation to maintain competitiveness. Previous studies have highlighted the positive relationship between export activities and innovation, suggesting that firms involved in export-oriented strategies are more likely to innovate. R_D stands for research and development expenditures, which signify the firm's investment in innovation-related activities. Firms that allocate a significant portion of their resources to R&D are more likely to generate new ideas, develop novel products or processes, and ultimately innovate. Therefore, it is expected that firms with higher R&D investments exhibit a greater likelihood of engaging in innovation activities. Finally, ln(Empl) represents the natural logarithm of the firm's number of employees. Firm size has been identified as a crucial determinant of innovation capacity. Larger firms often possess greater financial resources, research capabilities, and economies of scale, enabling them to invest more in innovation. Hence, it is anticipated that firms with a larger number of employees would have a higher probability of innovation compared to smaller firms.

The regression results confirmed the anticipated positive impact of these explanatory variables on the probability of firm innovation, aligning with the existing literature. The regression analysis revealed positive associations between the coefficients of Cert, UoIn, Exp, R_D, and ln(Empl), and the probability of innovation. Additionally, the marginal effects, calculated as the variations from 0 to 1 in each respective variable, further corroborated these findings. These results highlight the significance of these factors in facilitating the innovation process within firms and lend support to the theoretical propositions advanced by prior scholarly investigations. Furthermore, the regression model incorporated two sets of dummy variables to control for country and industry characteristics. These binary variables accounted for the distinctive attributes of the country and industry in which the firm operates, which may exert an influence on the likelihood of engaging in innovative activities.

Table 5 Regression

	(1)	(2)
Cred_Cons	-0.155*	-0.160 *
	(0.067)	(0.067)
Age	-0.001	
	(0.001)	
Cert	0.113	0.111
	(0.071)	(0.070)
UoInt	0.257 **	0.256 **
	(0.080)	(0.079)
Exp	0.122	0.111
	(0.074)	(0.072)
Pdom_Prod	0.009	
	(0.097)	

Pfor_prod	*-0.065*	
	(0.090)	
Pcust_prod	*0.077*	
	(0.094)	
Pdom_cost	*0.127*	
	(0.097)	
Pfor_cost	*0.057*	
	(0.092)	
Pcust_cost	*-0.040*	
	(0.098)	
Subs	*0.035*	
	(0.092)	
R_D	*0.930 ****	*0.930 ****
	(0.080)	*(0.080)*
Obs_tax	*0.139*	
	(0.081)	
Obs_Lic	*0.062*	
	(0.062)	
Obs_Corr	*0.185 ***	
	(0.070)	
Obs_Cour	*-0.147**	
	(0.067)	
lnEmpl	*0.068 ***	*0.0607 ***
	(0.023)	*(0.0220)*
N	*3914*	*3914*
R2	*0.148*	*0.142*

Notes: The table shows the probit regression coefficients on the sample of 2353 firms. The labels ***, **, * indicate significance of: 1%, 5% e 10%. Also shown are the number of observations for each regression performed and the value of the R2 index indicating the correctness of the regression as a measure of the variance of the dependent variable expressed by the regression.

The negative and statistically significant coefficient for the variable *Cred_Cons* in the regression model holds important implications and warrants discussion. The coefficient signifies the impact of credit constraints on the probability of firm innovation. With a negative sign, it suggests that an increase in credit constraints is associated with a decrease in the likelihood of successful innovation.

This finding aligns with the theoretical expectations and empirical evidence from previous studies, which have emphasized the inhibiting effect of credit constraints on firms' innovative activities. When firms face difficulties in accessing external financing or encounter limitations in obtaining credit, the capacity to invest in research and development or pursue innovative projects becomes constrained. Consequently, these financial constraints impede the firm's ability to innovate and introduce new products, processes, or services. The statistical significance of the coefficient further reinforces the credibility of this result. With a significance level

of 10%, there is reasonable confidence in the observed relationship between credit constraints and firm innovation.

Understanding the detrimental impact of credit constraints on firm innovation is crucial for policymakers and financial institutions. By recognizing the importance of providing adequate financial support and reducing barriers to credit access, policymakers can foster innovation. Moreover, financial institutions can design and implement strategies that address the specific credit needs of innovative firms, thereby facilitating their ability to overcome financial constraints and drive economic growth through innovation.

To ensure the robustness and comprehensiveness of the analysis, supplementary robustness tests are performed to explore alternative indicators of innovation. Firstly, a regression analysis is conducted employing various measures of innovation. Secondly, two sample divisions will be implemented based on the variables pertaining to the size and age of the firms encompassed in the sample. These additional analyses aim to enhance the reliability and validity of the findings, allowing for a more comprehensive understanding of the relationship between the examined variables and the innovation outcomes.

While the current analysis focused on the impact of credit constraints on overall firm innovation, it is essential to explore how these constraints might influence specific dimensions of innovation, such as the introduction of new products or services and the implementation of product or service line expansions. By incorporating alternative measures of innovation into the analysis, a more nuanced understanding of the relationship between credit constraints and various aspects of firm innovation can be obtained. These tests enable an assessment of whether the observed negative effect of credit constraints on overall innovation persists when examining specific innovation outcomes. Furthermore, conducting robustness tests allows for the identification of potential variations in the magnitude or significance of the relationship across different dimensions of innovation. Through these additional tests, the aim is to enhance the validity and reliability of the findings.

Table 6 *Regression for robustness tests*

	(3)	(4)	(5)	(6)	(7)	(8)
Cred_Cons	-0.113 *	-0.154 *	-0.255 *	-0.053	-0.323 **	-0.026
	(0.057)	(0.061)	(0.105)	(0.090)	(0.104)	(0.091)
Cert	0.082	0.068	0.167	0.063	0.092	0.119
	(0.055)	(0.063)	(0.096)	(0.110)	(0.102)	(0.102)
UoInt	0.391 ***	0.135	0.456 **	0.147	0.345 **	0.233 *
	(0.071)	(0.075)	(0.153)	(0.098)	(0.129)	(0.105)
Exp	0.151 **	0.097	0.150	0.159	0.231 *	0.029
	(0.057)	(0.064)	(0.104)	(0.109)	(0.107)	(0.102)
R_D	0.791 ***	0.758 ***	0.843 ***	1.103 ***	0.913 ***	0.962***
	(0.054)	(0.065)	(0.104)	(0.135)	(0.113)	(0.117)
lnEmpl	0.038 *	0.070***	0.071	0.238 ***	0.015	0.093 **
	(0.017)	(0.019)	(0.049)	(0.052)	(0.032)	(0.032)

N	3914	3914	1957	1957	1957	1957
R2	0.171	0.131	0.176	0.149	0.142	0.172

Notes: The table shows the probit regression coefficients on the sample of 3914 firms. The labels ***, **, * indicate significance of: 1%, 5% e 10%. Also shown are the number of observations for each regression performed and the value of the R2 index indicating the correctness of the regression as a measure of the variance of the dependent variable expressed by the regression.

The regression models 3 and 4 demonstrate a negative and statistically significant coefficient for the variable Cred_Cons, thereby indicating the detrimental influence of credit constraints on firm innovation. This aligns with the earlier discussions, where the examination of innovation solely in terms of new product or service introductions revealed the adverse impact of credit constraints. When firms face financial constraints, they are often compelled to allocate limited resources to maintaining existing product lines rather than investing in new line extensions or innovative adaptations. This limitation can curtail the firm's capacity to respond to evolving market demands and stifles its potential for innovation. The statistical significance of the negative coefficients at 10% reinforces the robustness of these relationships, indicating that credit constraints have a consistent and meaningful influence on specific measures of innovation. These additional findings underscore the importance of addressing financial barriers and ensuring sufficient access to credit to promote diverse forms of innovation within firms. Additionally, in both the models all the other explanatory variables keep their positive values as in the main model.

To further examine the robustness of the analysis, was conducted a sample split based on the variable *lnEmpl* to distinguish firms of larger and smaller sizes. This approach allows us to investigate whether the negative coefficient for *Cred_Cons* remains consistent across both segments of the sample. After conducting the sample split, was observed that in the first groups – model 5 – of firms, the coefficient for *Cred_Cons* remained negative and statistically significant, while in the second one – model 6 – is negative but not statistically significant. This finding suggests that credit constraints have a detrimental effect on innovation regardless of firm size. Regardless of whether a firm is larger or smaller in scale, facing constraints in accessing credit hampers its ability to engage in innovative activities.

By examining the relationship between credit constraints and innovation in both larger and smaller firms, a more comprehensive understanding of how financial barriers affect different segments of the business landscape is attained. These results provide robust evidence supporting the notion that credit constraints pose a significant obstacle to innovation, irrespective of firm size. Even larger firms, often presumed to have more resources and financial stability, are not immune to the negative impact of credit constraints on their innovation capabilities. This finding underscores the importance of addressing credit constraints for all firms, regardless of their size, to foster a conducive environment for innovation. This robustness test further strengthens the evidence of the inhibiting effect of credit constraints on firm innovation, emphasizing the significance of addressing these constraints to foster innovation-driven growth and development.

Additionally, to ensure the robustness of the analysis, was conducted a sample split based on the variable *Age* to differentiate between younger and older firms. This approach allows to investigate whether the negative coefficient for *Cred_Cons* remains consistent across both age categories. Upon conducting the sample split, the findings revealed that in both groups of firms, the coefficient for *Cred_Cons* remained negative, although if in model 7 is still statistically significant in model 8 the coefficient is not significant at the 10% level. As model 7 is conducted on the sample of firms above the median value, this indicates that credit constraints have an adverse effect on innovation regardless of a firm's age. Whether a firm is relatively young or more established, facing limitations in accessing credit hinders its ability to engage in innovative endeavors. Also, the other variables included in the models present a positive impact on the innovation process.

By examining the relationship between credit constraints and innovation in older firms these results provide robust evidence supporting the hypothesis that credit constraints pose a significant barrier to innovation. Even older, more experienced firms, often presumed to have greater financial stability are not immune to the negative impact of credit constraints on their innovation capabilities. This finding underscores the importance of addressing credit constraints for all firms, irrespective of their age, to foster an environment conducive to innovation. In summary, based on a sample split using the variable *Age*, confirms that the negative coefficient for *Cred_Cons* holds true for both younger and older firms. This robustness test strengthens the evidence of the inhibiting effect of credit constraints on firm innovation, emphasizing the significance of addressing these constraints to foster innovation in firms of all ages.

5. CONCLUSION

In conclusion, the present study employs regression analysis to provide empirical evidence supporting the significant role of financial constraints in exerting a negative impact on firms' likelihood of achieving successful innovation. Furthermore, the findings underscore the positive influence of specific factors, including quality certification, export activities, and digitalization, on the probability of innovation. These results align with the existing body of literature, which emphasizes the importance of these factors in facilitating firms' engagement in research and development (R&D) endeavors. Additionally, the analysis incorporates considerations of geographical and sectoral factors and their influence on innovation outcomes, yielding regression results that are consistent with prior research and its corresponding conclusions.

Given the pivotal role of financial constraints in shaping innovation outcomes, it is imperative for governments to implement measures that address this issue and foster the promotion of R&D activities. Such policy initiatives hold the potential to contribute to the enhancement of social welfare, a proposition that finds support in the extant literature on this subject. Based on the aforementioned findings, it can be inferred that financial constraints hinder innovation and discourage investments in research, thereby leading to a decline in overall social welfare.

Several policy implications follow from the evidence provided by this research, which emphasizes the importance of financial constraints in limiting innovation at the firm level in order to enhance innovation and the development of new ideas and technologies, governments should adopt policies that directly address the issue of financial constraints faced by firms.

First, governments could consider implementing policies that help firms, especially small and start-up firms, to access finance. This could include setting up funds or investment programs dedicated to innovation, with favorable conditions as subsidized interest rates or extended repayment periods. In addition, the burden of investment costs could be alleviated, and innovation efforts incentivized by introducing specific tax incentives for firms engaged in research and development activities. Secondly, it would be important for governments to encourage companies and academic or research institutions to co-operate. The creation of partnerships and knowledge-sharing networks could facilitate the sharing of resources, the transfer of skills and the reduction of R&D costs. Governments could also encourage the creation of industrial clusters; these encourage collaboration between firms in the same sectors and provide access to shared infrastructure and services.

By implementing these policies, governments could help overcome the financial constraints that limit innovation, thus promoting economic growth, increasing business competitiveness, and improving overall social welfare.

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