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Innovation and the Financial Performance of Firms during the Great Recession and Recovery Period

Inovação e Desempenho Financeiro das Empresas durante a Grande Recessão e o Período de Recuperação

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ABSTRACT
This study analyzes the relationship between innovation and financial constraints. To this end, a database extracted from the Community Innovation Survey (CIS) and the System of Business Accounts (SCIE) was used. The sample consisted of 24,679 active companies operating in Portugal in the manufacturing and service industry between 2008 and 2016. A Recursive Bivariate Probit Model (RPBM) was used for making estimates. When analyzing the relationship between innovation and financial constraints, the results reveal a negative relationship between the two, confirming that firms that are financially constrained are more limited in their investments in R&D, and innovation is less accessible to them. The severity of the effects of financial constraints is heterogeneous across economic activities, strongly affecting innovative industries, while service industries appear to be the least affected. It was also observed that larger companies are better able to innovate. There was a positive relationship between *innovation* and the variables *sales* and *exports*, indicating that innovation will positively affect the financial results of companies.
Keywords: Innovation; R&D investment; financial constraints; Portugal.

JEL Classification: O30; D92; G32; L00; L20

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1. Introduction[1]

Innovation is a key element for long-term economic growth. At the micro level, innovation is also extremely important, leading to the competitive differentiation of firms from their competitors, with good production and financial performances of the firms.

The innovation process is expensive, time-consuming and the end results are uncertain. Firms need funds to develop these projects, which they may not have and, therefore, they must seek funds in the financial market. Because the outcomes of R&D investments are uncertain, financial institutions prefer to invest in more traditional, non-innovative projects (Mazzucato, 2013). When this happens, firms are often left without financing or being partially financed, leading to financial constraints on the firms.

Innovative projects are associated with a higher risk, which can cause a higher loss for the financier in the event of default. One of the reasons for this is that most of the R&D investment is directed towards the creation of intangible assets. These firms therefore have fewer physical assets, most of them instead having intangible assets that are harder to use as collateral, which leads to greater uncertainty on the part of investors and financiers in embracing innovative projects (Hall and Lerner, 2010).

The main objective of this study will be to analyze the relationship between innovation and financing, controlling for other fundamental characteristics of the company such as the financial results of its economic activity, size, or age, analyzing for this purpose a sample of 24,679 active Portuguese companies in the period between 2008 and 2016. This study highlights the period of deep Portuguese economic recession and recovery period. In fact, the issue gained greater relevance after the outbreak of the 2008 financial crisis, when enterprises saw their external financing costs increase due to the uncertainty in the markets and the greater information asymmetries found in small companies compared to those in larger ones (Guellec and Wunsch-Vincent, 2009).

2. Literature Review

2.1. Market failures and sources of financing

There are several formal and informal channels for financing the innovative projects of firms. The formal financing can be of two types, either through sources external to the firm, such as bank loans and other forms of debt, or through internal financing, using funds held by the company itself. Informal channels can be defined as funding sources that escape the structures mentioned, such as friends and family. One advantage of these channels over formal ones is the absence of bureaucracy. It should be noted that external financing is not always private, and the creation of subsidies for firms that want to innovate is the States' response to market failures. State intervention helps overcome the fact that R&D investments and innovation activities are particularly prone to financial constraints.

[1] A previous version of this work was presented by Nelson Gomes, as a Master's Thesis, with the title "Inovação e o seu impacto nas finanças das empresas", under the supervision of Prof. Carlos Carreira, at the University of Coimbra, Faculty of Economics.

There may be several reasons why credit to finance innovation projects is rationed or not granted, due to the existence of market failures. Modigliani and Miller (1958) state that in perfect capital markets, investment decisions would not depend on the financial structure of the firms or their financial policy, so there would be no financial constraints for firms. However, the existing conditions prevent this from happening. One of these is the existence of information asymmetries, that is, at the time of any transaction, one of the agents has more or better information than the other party. This creates an imbalance in the market, giving rise to situations of moral hazard and adverse selection as explained by Akerlof (1970) in his famous study on the lemon market, and by works of Stiglitz and Weiss (1981) and Myers and Majluf (1984). Moral hazard occurs when an economic agent changes its behavior after granting credit, in accordance with the different contexts that present themselves, and fails to comply with what was previously agreed (Jensen and Meckling, 1976). Adverse selection leads to firms with good projects not being financed or not being fully financed, or, on the other hand, high risk projects are financed, resulting in an inefficient allocation of credit (Leland and Pyle, 1977).

2.2. R&D investment, innovation and financial constraints

Most studies show that financial constraints in developed countries have a negative effect in R&D investment (Savignac, 2008; Aghion et al., 2012; Carreira and Silva, 2010; Lööf and Nabavi, 2016; García-Quevedo et al., 2018; Santos and Cincera, 2020). However, this conclusion has not been confirmed for some developing countries, such as Vietnam, a socialist market economy (Archer et al., 2020), India (Sasidharan et al., 2015), and even for some developed economies, such as Ireland (Hewitt-Dundas, 2006).

García-Quevedo et al. (2018) provided evidence that financial constraints increase the probability of bankruptcy for Spanish firms with innovative projects. Silva and Carreira (2012) found a negative relationship between credit constraints and innovation in Portuguese firms and state that support allocated to innovative projects does not mitigate financial constraints despite promoting innovation. In Sweden, firms with credit constraints are less likely to invest in patents (Lööf and Nabavi, 2016). Aghion et al. (2012) show that, due to sensitivity to long-term exogenous shocks, firms operating in France with financial constraints are less likely to invest in innovative projects. Again, in regard to the reality of French firms, Savignac (2008) states that, in the period between 1997 and 1999, the existence of constraints decreased the likelihood of innovation. In a study conducted with companies from various European countries, being an innovative company is known to increase the probability of financial constraints from 21% to 32% (Santos and Cincera, 2020).

Of the companies that invest more in R&D, those that invest in the development of physical assets are less likely to suffer restrictions compared to those that seek to develop intangible assets. This is due to the difficulty in quantifying intangible assets and their being accepted as collateral for external financing (Hall and Lerner, 2010) and because of the associated uncertainty and risk (Mazzucato, 2013). In contrast, a recent study by Montresor and Vezzani (2022) shows that there is no difference between credit constraints on intangible innovative firms and those on non-innovative firms.

It is important to note that the degree of financial constraint is not homogeneous across firms. Lee et al. (2015) conducted a study on SME access to credit following the financial crisis and show that when SMEs present projects for new products, they have an even greater difficulty in obtaining financing. Efthyvoulou and Vahter (2016) found that the impacts of financial constraints vary according to the sector of activity, their negative effect being greater in the goods production sector than in the services sector, and the constraints are greater if the company is a non-exporter. Financial constraints are also more pronounced in smaller and younger firms (Czarnitzki, 2006; Oliveira and Fortunato, 2006). Companies with limited access to finance are less likely to survive (Lahr and Mina, 2021), which is also the case when relations are unstable (Farinha, 2005).

3. **Data and Methodology**

The database used in this study is extracted from the System of Business Accounts (SCIE), and the Community Innovation Survey (CIS), which is the responsibility of the National Statistics Institute (INE) (Table A.1 in Online Appendix describes the industries analyzed). It covers four periods (surveys): the 1st period from 2008 to 2010; the 2nd period from 2010 to 2012; the 3rd period from 2012 to 2014; and finally, the 4th period of the years 2014 to 2016.

When the relationship between financial constraints and innovation is analyzed, endogeneity is an issue that we must keep in mind, due to the existence of unobserved factors that affect both variables. The factors presented in the literature include the uncertainty associated with the results and the time required to develop the innovation; the confidentiality of the project for strategic reasons can create or aggravate financial constraints; and in regard to the decision to move forward or not with the innovative project, the decision to engage is usually made at the time the funding is obtained (Savignac, 2008).

Simultaneous equation models are the most commonly used to study this topic (Savignac, 2008; Silva and Carreira, 2012; Santos and Cincera, 2020; Lahr and Mina, 2021), thus making it possible to deal with the problem of endogeneity. For that reason, in our estimates we used a Recursive Bivariate Probit Model (RPBM) with random effects, choosing to estimate the models based on the full sample regardless of a firm's attitude towards innovation, whether it is a potential innovator or not. This allowed us to avoid spurious relationships between innovation and financial constraints (Savignac, 2008). The RPBM assumes that the dependent variable in the second equation is explanatory in the first equation and the error terms are assumed to be correlated across equations:

$$\begin{cases} IN_{i,t}^{A} = FC2y_{i,t}^{A} + Z_{i,t}^{A}\beta^{A} + c_i^{A} + \varepsilon_{i,t}^{A} \\ FC2y_{i,t}^{B} = Z_{i,t}^{B}\beta^{B} + c_i^{B} + \varepsilon_{i,t}^{B} \end{cases} \tag{1}$$

with, $\begin{pmatrix} \varepsilon_{i,t}^{A} \\ \varepsilon_{i,t}^{B} \end{pmatrix} \sim N\begin{bmatrix} 0 \\ 0 \end{bmatrix}\begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix}$

The model assumes that the error terms are independent and identically distributed following a bivariate normal distribution, c_i^A and c_i^B are the time invariant error terms, $\varepsilon_{i,t}^A$ and $\varepsilon_{i,t}^B$ is a time shock-specific idiosyncratic term. The correlation coefficient ρ (rho) between the error terms explains the possible existence of omitted or unobservable factors that simultaneously affect the decision to innovate and the probability of facing financing constraints. If $\rho = 0$, FC2y is not correlated with the error term $\varepsilon_{i,t}^A$, and will be taken as an exogenous variable. In this case, the two equations could be estimated separately, through a univariate probit model. Whereas, if $\rho \neq 0$, a joint estimation is necessary to obtain consistent estimates.

The dependent variables IN and FC2y are binary, that is, whether firm *i* innovated (IN = 1), or not (IN = 0) and whether firm *i* is financially constrained (FC2y = 1) or not (FC2y = 0). We believe that innovation, in addition to financial constraints, is also influenced by the sales and the average percentage of sales in international markets, these variables being expressed by their average value over the last 3 years, AvSAL and AvEXP, respectively. Finally, we also consider the size of the company, translated through the number of employees (L) and the age of the company (AGE), which will be the age assumed when answering the first questionnaire.

The innovation variable comprises the development of new products and processes. It should be noted that product and process innovation does not only include conducting in-house R&D activities, but also the external acquisition of machinery, equipment, software and buildings, as well as the acquisition of existing knowledge from other companies or institutions, training, marketing, and design.

The sample has 24,679 companies, totaling 3,701,850 observations during the four periods mentioned. As can be seen in Table 1, 51.55% of the companies innovated and 42.72% of the companies had investments in R&D. Of the same universe, 43.08% of the enterprises presented process innovation and 36.08% presented product innovation. Of the total number of companies, 11,957 (48.45%) did not innovate; 3,621 (14.67%) companies innovated only in process; 2,090 (8.47%) innovated only in product; and 7,011 (28.41%) presented at least one innovation in process and product during the period described (Tables A.2 and A.3 in Online Appendix).

Table 1: Innovation activity and R&D investment

Has the company innovated?	Number	Percent
No	11,957	48.45
Yes	12,722	51.55
Total	24,679	100.00
Has the company invested in R&D?	Number	Percent
No	14,137	57.28
Yes	10,542	42.72
Total	24,679	100.00

One of the main questions on this topic is the definition and measurement of financial constraints. It should be noted that this issue depends on the company's own assessment

and is not directly observable (Carreira and Silva, 2010). Two of the most widely used definitions are that a company suffers from financial constraint if there is a cost between obtaining external or internal financing, and its inability to obtain the optimal level of financing for its projects. To identify the financial constraints of firms, the ASCL index was used (Mulier et al., 2016). The index ranking is based on company size, age, cash flow and leverage, identifying for each variable whether a company is scoring below (0) or above (1) the industry median in each year, at the end summing all the scores by company and year. The ASCL index is compressed between 0 (unconstrained) and 4 (constrained). Finally, companies with a score of 3 or higher on the ASCL index in at least two of the last three years are financially constrained.

Of the total of 24,679 companies, and according to the index we constructed, 2,615 (10.59%) suffered from financial constraints, 1,203 (0.48%) of which managed to present innovation, and 980 invested in R&D (0.39%). There were 22,064 (89.40%) companies that did not suffer from financial constraints (Tables 2 and A.4 in Online Appendix).

Table 2: Innovation/R&D investment and financial constrains

Has the company innovated?	Has the company found itself financially constrained?		
	No	Yes	Total
No	10,545	1,412	11,957
Yes	11,519	1,203	12,722
Total	22,064	2,615	24,679
Has the company invested in R&D?	Has the company found itself financially constrained?		
	No	Yes	Total
No	12,502	1,635	14,137
Yes	9,562	980	10,632
Total	22,064	2,615	24,679

To understand the impact of financial constraints, the following explanatory variables were used: the average of the last 3 years of the company's results before depreciation; financing expenses and taxes, considering the total assets of the company, respectively cash flow (AvCF) and average leverage ratio (AvLEV, i.e., short- and long-run borrowings over total assets).

The same models are estimated replacing the dependent variable of innovation with investment in R&D (RD), product innovation (INPROD) and process innovation (INPROC), all of them dummies. The same models are estimated with the explanatory variables lagged using a simple probit model. All variables are logarithmic, except the dummies. The descriptive statistics can be seen in Table A.5 in Online Appendix.

4. Results

4.1. Univariate random-effects probit regressions

The first step was to estimate the univariate probit models – in this case we are considering the financial constraint variable as being exogenous. The results obtained in the probit models are as expected and corroborate the findings in the literature, all variables being significant at the 1% level. The results are presented in Table 3.

In all the estimated models 1 to 4 of Table 3, there is an inverse relationship between the dependent variables and financial constraints; a positive relationship between innovation and average sales, exports and firm size; and a negative relationship with firm age. In regard to financial constraints (model 5), the probability of being financially constrained decreases with company size, good results and company age; the probability of being restricted increases with the level of debt. The restrictions seem to be greater in process innovation than in product innovation. The results are consistent with the literature and there are no significant differences between models.

Table 3: Results of Random-effects probit regression

Variable	IN	INPROD	INPROC	R&D	FC2y
	(1)	(2)	(3)	(4)	(5)
FC2y	-0.165*** (0.044)	-0.160*** (0.048)	-0.164*** (0.042)	-0.158*** (0.046)	
AvSAL	0.123*** (0.016)	0.103*** (0.017)	0.094*** (0.015)	0.134*** (0.016)	
AvEXP	0.037*** (0.004)	0.045*** (0.004)	0.030*** (0.003)	0.043*** (0.004)	
AvCF					-0.220*** (0.0117)
AvLEV					0.143*** (0.013)
L	0.183*** (0.023)	0.198*** (0.025)	0.194*** (0.014)	0.202*** (0.023)	-0.301*** (0.042)
AGE	-0.108*** (0.015)	-0.088*** (0.016)	-0.118*** (0.014)	-0.120*** (0.015)	-1.690*** (0.065)
Constant	-2.457*** (0.210)	-3.044*** (0.245)	-2.236*** (0.197)	-2.993*** (0.223)	2.580*** (0.297)
Industry dummies	YES	YES	YES	YES	YES
Log-likelihood	-15,439.10	-14,257.04	-15,555.45	-14,966.46	-4,793.20
Num. of obs. Wald chi2 Prob>chi2	24,645 1,272.96 0.000	24,645 1,278.25 0.000	24,645 1,100.77 0.000	24,645 1,418.11 0.000	24,672 717.24 0.000

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$ indicate the statistical significance levels. Standard erros are given in parentheses.

The marginal effects of the probit models were computed and show that firms with financial constraints have between -3.90% and -4.80% probability of innovating, which are respectively the marginal effects of financial constraint in firms with product and process innovation (Table 4).

The same models were estimated, but with the explanatory variables lagged. This approach seems to make more economic sense, since the innovation process is time-consuming and influenced by the firm's results observed in previous periods, however it is not possible to do so in the RPBM since the second equation dependent variable must be used in the first equation as an explanatory element. This approach also helps to see if there are significant differences using lagged variables.

Comparing these results with the results of the same models and marginal effects with lagged explanatory variables (Tables A.6 and A.7 in Online Appendix), we observe that the signs and magnitude of the coefficients are similar, which leads us to believe that there are no significant differences that alter the meaning or conclusions of our work, and the marginal effects are also similar, with no major differences. Note that the estimates of probit models without lag have 24,645 (models 1, 2, 3 and 4) and 24,672 (model 5) observations, and in the lagged models' observations decrease to 10,386 (models A1 and A2), 10,394 (models A3 and A4) and 10,401 (models A5).

Table 4: Marginal effects on probability to innovate, R&D invest and financially constrained

Variable	IN	INPROD	INPROC	RD	FC2y
	(1)	(2)	(3)	(4)	(5)
FC2y	-0.046*** (0.012)	-0.039*** (0.012)	-0.048*** (0.012)	-0.042*** (0.012)	
AvSAL	0.034*** (0.004)	0.025*** (0.004)	0.027*** (0.004)	0.036*** (0.004)	
AvEXP	0.010*** (0.001)	0.011*** (0.001)	0.009*** (0.001)	0.011*** (0.001)	
AvCF					-0.013*** (0.001)
AvLEV					0.008*** (0.001)
L	0.051*** (0.006)	0.048*** (0.006)	0.056*** (0.006)	0.054*** (0.006)	-0.018*** (0.002)
AGE	-0.030*** (0.004)	-0.021*** (0.004)	-0.034*** (0.004)	-0.032*** (0.004)	-0.099*** (0.002)

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$ indicate the statistical significance levels. Standard erros are given in parentheses.

4.2. Recursive bivariate probit

The results of the RPBM estimations (models 6 to 9 in Table 5) are similar to those in the probit models and have the same signs of the coefficients. This shows the robustness of our models. All variables have statistical significance at 1% level.

The rho is positive and significant at 10% at least in all models. This means that the equations should be calculated together considering the endogeneity of the financial constraint variable. If we do not do this, the coefficients of the FC2y variables will be overestimated; for example, the coefficient is larger in model 1 (= -0.165), than in model 6 (= -0.323). The same happens in all comparable models. The other coefficients of the remaining variables do not undergo important changes.

Comparing the results of the second equation (RPBM) with the probit model 5, there are differences in coefficient magnitude, mainly in the coefficient of the AGE variable.

Table 5: Recursive bivariate probit

Variable	IN	INPROD	INPROC	R&D
	(6)	(7)	(8)	(9)
FC2y	-0.323*** (0.081)	-0.274*** (0.083)	-0.384*** (0.081)	-0.362*** (0.084)
AvSAL	0.087*** (0.011)	0.067*** (0.011)	0.069*** (0.010)	0.093*** (0.011)
AvEXP	0.032*** (0.003)	0.037*** (0.003)	0.027*** (0.003)	0.037*** (0.003)
L	0.137*** (0.015)	0.146*** (0.015)	0.154*** (0.015)	0.153*** (0.015)
AGE	-0.109*** (0.015)	-0.084*** (0.015)	-0.129*** (0.015)	-0.123*** (0.016)
Constant	-1.639*** (0.150)	-1.989*** (0.158)	-1.534*** (0.150)	-1.977*** (0.155)
Endogenous variable	FC2y	FC2y	FC2y	FC2y
AvCF	-0.137*** (0.005)	-0.136*** (0.005)	-0.138*** (0.005)	-0.138*** (0.005)
AvLEV	0.078*** (0.006)	0.079*** (0.006)	0.078*** (0.006)	0.077*** (0.006)
L	-0.139*** (0.017)	-0.140*** (0.017)	-0.138*** (0.017)	-0.138*** (0.017)
AGE	-0.874*** (0.016)	-0.874*** (0.016)	-0.874*** (0.016)	-0.874*** (0.016)
Constant	1.187*** (0.127)	1.189*** (0.127)	1.183*** (0.126)	1.171*** (0.128)
rho	0.114** (0.047)	0.092* (0.049)	0.154*** (0.048)	0.140*** (0.050)

Variable	IN	INPROD	INPROC	R&D
	(6)	(7)	(8)	(9)
Log-likelihood	-21,131.40	-20,106.90	-21,117.70	-20,663.51
Wald chi2	6,529.82	7,127.84	6,022.80	7,062.57
Prob > chi2	0.000	0.000	0.000	0.000
Wald test of rho	5.846	3.623	10.2343	8.046
Prob > chi2	0.016	0.057	0.001	0.005
Num. of obs.	24,645	24,645	24,645	24,645

Note: *** *p<0.01*, ** *p<0.05*, * *p<0.1* indicate the statistical significance levels. Standard erros are given in parentheses.

Again, the effect of restrictions in product innovation is less severe than in process innovation, and firms with credit restrictions are less likely to invest in R&D than in innovation activities. Industry dummies can be interpreted as the differences in probability of innovating or the risk that exists across the different sectors of Portuguese industry (Tables A.8 to A.11 in Online Appendix).

The results of the marginal effects are given in Table 6. Due to homogeneity, and once controlled for, the effect of the variable FC2y is now more intense. The marginal effects of the remaining variables remain almost the same. The marginal effects of financial constraints range from -9.4% to -14.2%, and firms with process innovation are once again more constrained in obtaining credit, which affects the probability of firms innovating more.

Table 6: Marginal effects on probability to innovate and to invest in R&D

Variable	IN	INPROD	INPROC	RD
	(6)	(7)	(8)	(9)
FC2y	-0.120*** (0.030)	-0.094*** (0.029)	-0.142*** (0.029)	-0.129*** (0.030)
AvSAL	0.032*** (0.004)	0.0230*** (0.004)	0.025*** (0.004)	0.033*** (0.004)
AvEXP	0.012*** (0.001)	0.013*** (0.001)	0.010*** (0.001)	0.013*** (0.001)
L	0.050*** (0.006)	0.050*** (0.005)	0.057*** (0.005)	0.055*** (0.005)
AGE	-0.040*** (0.005)	-0.029*** (0.005)	-0.048*** (0.005)	-0.044*** (0.005)
Marginal effects on probability for being financially constrained (models 6 through 9)				
AvCF	-0.016*** (0.001)			
AvLEV	0.009*** (0.001)			
L	-0.016*** (0.002)			
AGE	-0.100*** (0.001)			

Note: *** *p<0.01*, ** *p<0.05*, * *p<0.1* indicate the statistical significance levels. Standard erros are given in parentheses.

These results are significantly lower than ones found by Savignac (2008) and García-Quevedo et al. (2018), in regard to French and Spanish firms respectively, which point to approximately -21% of the likelihood to take part in innovation activities, in both cases. Also, the marginal effects of financial constraints are lower than in the European case (Efthyvoulou and Vahter, 2016), results that were not expected at all. The magnitude of financial restrictions is influenced by the indicator we choose. Since our financial constraints variable is based on the characteristics of credit-constrained firms identified in the literature, rather than on whether *de facto* firms are financially restricted or not, we suspect the results are underestimated. In a situation of severe financial crisis and economic downturn, there is no reason why the constraints should be so low, even considering the economic recovery.

Finally, the probabilities of firms innovating were calculated using the mean values of each non-binary variable (see mean values in Table A.5). The probability of innovating decreases from 37.28% to 25.87% when the firm is in financial constraint. The likelihood of process innovation is lower compared with product innovation, 29.37% and 30.77% respectively, and the likelihood in each case drops to 20.71% and 18.77% in a situation of financial restriction. The probability differences between process and product innovation are not distinct; when firms are not financially constrained, they are more likely to innovate with a new product, which demonstrates the preference of financial intermediaries and companies to finance new products rather than a new process.

When firms are financially constrained, they are more likely to introduce process innovation, this type of innovation possibly having lower costs than those for introducing a new product.

The probability of engaging in investment in R&D is the lowest, registering 28.11% when not financially restricted and decreasing to 17.32% when financially restricted. In some sense, this is logical. In the previous examples, the firm can copy or buy a product or process; in this example, the firms choose to engage in a costly development process without the guarantee of a positive output. The higher risk is reflected in a lower probability.

5. Discussion

The results of the RPBM model estimations show there is an inverse relationship between innovation and financial constraints; a positive impact on the probability of innovating due to sales volume, degree of export orientation, and firm size; and, finally, a negative effect due to firm age. R&D investment is more constrained than innovation, but not more than process innovation. All these results corroborate the literature on the subject. The results of the various estimated models are similar, the difference to point out being that the impact of financial constraints on the probability of innovating is lower for product innovation than for process innovation.

Companies with good financial performance will find it easier to obtain external financing. Sales growth is usually seen as a good indicator of investment opportunities, and good investment opportunities attract more funding. Firms with a large sales volume might reserve some cash to self-finance their R&D projects. Also, less-constrained firms are also the ones who are more export oriented, evidence found previously in Portuguese reality

(Silva and Carreira, 2011). On the other hand, innovation is also fundamental to having a good market performance and financial performance, however this link is not always linear. In fact, Gök and Peker (2017), found a negative relationship or an inexistent link between innovation and financial performance when considering market performance. Older firms are less likely to present innovation, thus, the propensity to introduce innovations declines with a firm's increasing age. Larger firms are also more prone to innovate and make R&D investment, since they can more easily obtain funds to innovate and are more resistant and have the resilience to absorb the expenditures of an innovation or R&D project failure.

With respect to financial constraints, better results before depreciation and taxes, size and age decrease the probability of the company being in a financially constrained situation. Bigger firms are less likely to be constrained, and accordingly, smaller firms are more likely to be financially constrained. Oliveira and Fortunato (2006) had already found a positive relationship between external financing and firm size prior to the financial crisis, and the same relationship seems to hold.

Financially constrained Portuguese SMEs demonstrated a poorer financial performance than firms that are not constrained, and they have the highest odds of failure in the market. Access to credit sometimes is essential to firm survival, especially in tough crisis periods. In Portuguese cases during the great recession, the credit constraints reduced the efficiency in resource reallocation and productivity, an unfavorable economic cycle being one of the main factors of the increased exit of firms and a lower employment creation (Carreira and Teixeira, 2016).

Having close relations with banks combats information asymmetries and alleviates financial constraints (Farinha, 2005), something that is gained over time and as the firm grows in size. Due to the lack of information about younger and smaller firms, or because they still lack visibility or position in the markets, financial intermediaries can be expected to be more reluctant to grant them credit.

As expected, higher indebtedness increases the probability of financial constraint, and if the firm borrows more money, it runs the risk of being overburdened with future liabilities and being unable to pay them back. This is consistent with what we see through the results variable of firms, so having better financial results decreases the probability of financial constraint. Good firm performance is a positive indicator of the reliability of the firm's financing, while financial debt is a weakness indicator (Savignac, 2008), as it is to be expected that the most profitable industries are those with the least constraints.

Industry dummies show strong disparities in the likelihood of undertaking innovative projects across industries. So, as expected, the severity of financial constraints, as well as their effect on innovation performance, may vary across firms operating in different sectors, which contributes to a better understanding of sectoral risk heterogeneities.

Financial restrictions have a greater effect on product innovation industries than on service innovation. Some of the most restricted sectors were also the most innovative ones, showing some inefficiencies in credit channels, especially in regard to *manufacture of chemicals and chemical products, except pharmaceutical products* which appears as the leading process and product innovator, and R&D investor. The least restricted activity, by far, was *accommodation, restaurants and similar*, economic activities that are closely linked to tourism, reflecting the support that the recovery of the Portuguese economy had in tourism. The *building* sector,

one of the least restricted in credit, is shown to be an industry that is not innovative. The *information and communication activities* industry present product innovations and is one of the least restricted.

6. Conclusion

This study presents an analysis of the influence of the financial results of 24,645 Portuguese companies on the impact of financial constraints on innovation carried out. The temporal arc of the study extends from 2008 to 2016, in a period encompassing the Great Recession and the recovery period.

As expected, when a firm has a good sales volume and/or the more it is export-oriented, it more easily obtains financing from banks, and its probability of innovating increases. In line with what the literature has shown, size and age positively affect innovation and negatively affect the possibility of being credit constrained. Indebtedness increases the likelihood of being credit constrained, while having good cash flow results decreases the likelihood of being financially constrained.

Our results show that the effects of financial constraints decrease the likelihood of innovating by between 9% and 14%, and depending on whether one is likely to invest in R&D, or on the type of innovation one engages in, the probability of innovating can drop from 37.28% to 25.87%.

It is important to state that companies that innovate present better financial performance after innovating, given the positive relationship with the variables sales and exports, and companies that innovate present a higher probability of boosting financial performance, when compared with companies that do not innovate.

Observing the results, it can be seen that a large proportion of Portuguese companies have not invested in R&D or innovated. The reasons may be many, from the high bureaucracy of applying for financial support to reasons related to those who promote innovation, namely the very nature of Portuguese small and medium-sized companies, family businesses and the fact that a large part of their managers have low qualifications. The Great Recession period was a severe recession of counterproductive destruction, accompanied by the application of austerity policies, which contracted aggregate demand, consequently reducing the demand perspectives for the future and resulting in a lack of incentives and/or difficulties in obtaining external private financing to invest due to the unpredictable outcome of projects and market instability.

References

Aghion, P.; Askenazy, P.; Eymard, L.; Cette, G. (2012) Credit constraints and the cyclicality of R&D investment: evidence from France. *Journal of the European Economic Association*, 10(5), 1001-1024.

Akerlof, G.A. (1970) The market for "lemons": Quality uncertainty and the market mechanism. *Quarterly Journal of Economic*, 84(3), 488-500.

Archer, L.T.; Sharma, P.; Su, J. J. (2020) Do credit constraints always impede innovation? Empirical evidence from Vietnamese SMEs. *Applied Economics*, 52(44), 4864-4880.

Carreira, C.; Silva, F. (2010) No Deep Pockets: Some stylized results on firms' financial constraints. *Journal of Economic Surveys*, 24(4), 731-753.

Carreira, C.; Teixeira, P. (2016) Entry and exit in severe recessions: Lessons from the 2008-2013 Portuguese economic crisis. *Small Business Economics*, 46(4), 591-617.

Czarnitzki, D. (2006) Research and development in small and medium-sized enterprises: The role of financial constraints and public funding. *Scottish Journal of Political Economy*, 53(3), 335-357.

Efthyvoulou, G.; Vahter, P. (2016) Financial Constraints, Innovation Performance and Sectoral Disaggregation. *Manchester School*, 84(2), 125-158.

Farinha, L. (2005) The survival of new firms: Impact of idiosyncratic and environmental factors. *Financial Stability Report*, 101-113.

García-Quevedo, J.; Segarra-Blasco, A.; Teruel, M. (2018) Financial constraints and the failure of innovation projects. *Technological Forecasting and Social Change*, 127, 127-140.

Gök, O.; Peker, S. (2017) Understanding the links among innovation performance, market performance and financial performance. *Review of Managerial Science*, 11(3), 605-631.

Guellec, D.; Wunsch-Vincent, S. (2009) Policy Responses to the economic Crisis: Investing in innovation for long term economic growth. *I-WAYS, Digest of Electronic Commerce Policy and Regulation*, 32(4), 216-218.

Hall, B.H.; Lerner, J. (2010) The Financing of R&D and Innovation. *Handbook of the Economics of Innovation*, Vol. 1. Amsterdam, North-Holland, 609-639.

Hewitt-Dundas, N. (2006) Resource and capability constraints to innovation in small and large plants. *Small Business Economics*, 26(3), 257-277.

Jensen, M. C.; Meckling, W.H. (1976) Theory of the firm: Managerial behaviour, agency costs and ownership structure. *Journal of Financial Economics*, 3, 305-360.

Lahr, H.; Mina, A. (2021) Endogenous financial constraints and innovation. *Industrial and Corporate Change*, 30(3), 587-621.

Lee, N.; Sameen, H.; Cowling, M. (2015) Access to finance for innovative SMEs since the financial crisis. *Crisis. Research Policy*, 2, 370-380.

Leland, H. E.; Pyle, D. H. (1977) Informational Asymmetries, Financial Structure, and Financial Intermediation. *Journal of Finance*, 32(2), 371-387.

Lööf, H.; Nabavi, P. (2016) Innovation and credit constraints: Evidence from Swedish exporting firms. *Economics of Innovation and New Technology*, 25(3), 269-282.

Mazzucato, M. (2013) Financing innovation: Creative destruction vs. destructive creation. *Industrial and Corporate Change*, 22(4), 851-867.

Modigliani, F.; Miller, M. H. (1958) The cost of capital, corporation finance and the theory of investment. *American Economic Review*, 48(3), 261-297.

Montresor, S.; Vezzani, A. (2022) Financial constraints to investing in intangibles: Do innovative and non-innovative firms differ? *Journal of Technology Transfer*, 47(1), 1-32.

Mulier, K.; Schoors, K.; Merlevede, B. (2016) Investment-cash flow sensitivity and financial constraints: Evidence from unquoted European SMEs. *Journal of Banking and Finance*, 73, 182-197.

Myers, S. C.; Majluf, N. S. (1984) Corporate financing and investment decisions when firms have information that investors do not have. *Journal of Financial Economics*, 13(2), 187-221.

Oliveira, B.; Fortunato, A. (2006) Firm growth and liquidity constraints: A dynamic analysis. *Small Business Economics*, 27(2–3), 139-156.

Santos, A.; Cincera, M. (2020) Determinants of financing constraints: Evidence from European SMEs.

Sasidharan, S.; Jijo Lukose, P. J.; Komera, S. (2015) Financing constraints and investments in R&D: Evidence from Indian manufacturing firms. *Quarterly Review of Economics and Finance*, 55(December 2010), 28-39.

Savignac, F. (2008) Impact of financial constraints on innovation: What can be learned from a direct measure? *Economics of Innovation and New Technology*, 17(6), 553-569.

Silva, F.; Carreira, C. (2011) Financial constraints and exports: An analysis of Portuguese firms during the European monetary integration. *Notas Económicas*, 34, 35-56.

Silva, F.; Carreira, C. (2012) Do financial constraints threat the innovation process? Evidence from Portuguese firms. *Economics of Innovation and New Technology*, 21(8), 701-736.

Stiglitz, J. E.; Weiss, A. (1981) Credit rationing in markets with imperfect information. *American Economic Review*, 71(3), 393-410.

Appendix

(Appendix Tables A.1 through A.10 are available upon request)