

Innovative Activity and Access to Finance of SMEs: Views and Agenda

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Abstract

A rapidly growing body of research applies survey methods to examine the ability of SMEs to obtain external financing. These studies focus on firm-specific characteristics and demonstrate the impact of such ability on their own growth and overall economic growth, among other outcomes. However, the use of external financing is of crucial importance, especially whether SMEs can adopt innovation when they succeed in getting a loan. This paper reviews this literature that is not as extensive as the one focusing on typical investments with two purposes. First, we summarize recent work, providing a guide to its methodologies, datasets, and findings. Second, we consider applications of the literature in innovation, including insights for policymakers that seek to assess the potential economic effects of investments in innovation.

Keywords

Information Asymmetry, Small Business Lending, Credit Rationing, Innovation, Survey Data

1. Introduction

Investment in innovation is increasingly considered an essential source for sustaining economic growth and welfare (e.g., Tsai & Wang, 2004; Acemoglu et al., 2006; Mancusi & Vezzulli, 2010 etc.). For this reason, the inclusion of innovation plays a prominent role not only in the investment policy agendas of all firms but also across all industrialized countries. However, the adoption of innovation is not an easy task for all firms across the globe. A special case is that of SMEs who struggle to espouse innovative performance relative to their larger counterparts

to adopt, develop and grow via innovative activities. Such an issue is of significant importance as SMEs are rightfully considered the backbone of most economies since they contribute disproportionately to economic prosperity (e.g., [Audretsch, 2012](#); [Nightingale & Coad, 2014](#)). Indeed, according to World Bank, SMEs count for 90% of global firms and 50% of employment worldwide, making their impact on national economies crucial.

The relevant literature on innovation inclusion ([Mohnen et al., 2008](#); [Mancusi & Vezzulli, 2010](#); [Santos & Cincera, 2022](#)) associates this barrier with the possible limited access of SMEs to external finance. Unavoidably, innovative firms and especially innovative SMEs due to a lack of alternatives, rely heavily on bank credit once their internal funds are exhausted ([Canepa & Stoneman, 2003](#); [Freel, 2007](#); [Paunov, 2012](#)). It is beyond than clear that the decision to adopt innovation is a typical form of investment and hence actively related to firm's financial condition (e.g., [Segarra-Blasco et al., 2018](#); [Adegboye & Iweriebor, 2018](#); [Chundakkadan & Sasidharan, 2020](#) etc.). In this respect, the deviation from the paradigm of perfect capital markets becomes apparent as internal and external finance is not viewed as perfect substitutes.

This issue becomes even more relevant for SMEs as, due to their size, they usually suffer from informational opacity and lack of substantial collateral and thus may be more exposed to credit rationing problems (e.g., [Stiglitz & Weiss, 1981](#); [Jaffee & Stiglitz, 1990](#); [Audretsch & Elston 2002](#); [Berger & Udell, 2006](#); [Guiso & Minetti, 2010](#); [Öztürk & Mrkaic 2014](#); [Liberti & Petersen, 2018](#) etc.). In this context, a growing relevant literature has argued that innovative investment might be even more sensitive to financial conditions relative to other types of investment. Indeed, the effect of credit constraints is amplified by the fact that typical innovation projects are even riskier than ordinary investments due to their ambiguous sustainability, intangible nature and their questionable final outcome (e.g., [Mulkey et al., 2001](#); [Hall, 2002](#); [Hall & Lerner, 2010](#); [Mancusi & Vezzulli, 2010](#); [Brancati, 2015](#); [Chundakkadan & Sasidharan, 2020](#) etc.).

However, the importance of innovation inclusion in businesses' policy agenda is undoubtful, as firms can create new value in their markets and increase further their profits and growth. Moreover, innovation is a necessary tool to overcome changes that happen abruptly in their environment (e.g., COVID crisis, and energy crisis). Indeed, evidence shows that innovation adoption can provide an acceleration mechanism of businesses and economies' growth ([Tsai & Wang, 2004](#); [Potters et al., 2008](#); [Khan et al., 2017](#)). Hence, policymakers should work towards this direction, that is, to uncover particularly for SMEs ways to ease their ability to access finance.

This paper contributes to the existing literature in a number of ways. First, according to our knowledge, there are not enough recorded papers that provide an analytical review of the topic. Second, we attempt to create a road map that will bring together the different approaches to the relationship between innovation and access to finance in the empirical literature, focusing on bank finance.

Finally, we explain the theoretical background on banks and firms' difficulties in receiving/procuring funds and investing in innovation projects.

The paper is organized as follows. Section 2 presents a theoretical analysis of the problems pertaining to the relationship between access to finance and innovation between borrowers and lenders as well as within the firm. Measures and actions that can be taken to smoothen these problems are also included. In Section 2.1, we introduce the basic framework of our categorization and how we conducted our research. In Sections 2.2-2.4, we classify the existing literature into categories based on the dependent variables that the models used. We further break down the innovation dependent variable models into more subcategories due to the vast amount of literature and the difference in results relative to the measures used. Finally, in Section 2.5, we refer to the results of our review, the gaps of the current literature, and possible ways to counter them in future research. We conclude with policy measures that can be taken to narrow the gap between financing and innovation. For the convenience of the reader, authors offer tables providing a list of the most indicative papers throughout the manuscript.

2. Credit Restrictions and Innovation: Background

Schumpeter (1934) was the first to mention the importance of external financing and financing sources for innovation. However, innovative firms and innovation as a process is filled with uncertainty (Freel, 2007; Hall & Lerner, 2010; Blanchard et al., 2013) and low probability of success (Carpenter & Petersen, 2002), creating many obstacles that need to be addressed before successfully applying for a loan. One of those vital issues is asymmetric information (Canepa & Stoneman, 2003; Carpenter & Petersen, 2002; Brancati, 2015; Santos & Cincera, 2022). Indeed, when it comes to innovation, bank executives, cannot easily distinguish between good and bad new product opportunities, their usefulness in terms of productivity and efficiency and the relative costs pertaining to those activities (Hall & Lerner, 2010; Khan et al., 2017). On the other hand, firms may not be willing to disclose finer details of their projects for fear of mimicking (Hall & Lerner, 2010; Paunov, 2012; Mina et al., 2013) from their competitors, which in turn exacerbates the problem of asymmetric information.

Moreover, banks usually deal with moral hazard problems as, due to their limited knowledge regarding innovative projects, there is an incentive for firms to withhold critical information deliberately (Mina et al., 2013; Mushtaq et al., 2022). Banks, for example, cannot evaluate if some costs are exacerbated or needed for the innovation's overall creation and if the demand for a new product presented by a firm is realistic and trustworthy. R & D expenditures are also inherently difficult to be measured and monitored. Such a situation prevents banks from easily approving such loan applications due to the increased likelihood of applicants not meeting their obligations.

However, trust and lack of knowledge are not the only issues banks must face

when evaluating an innovative project. Uncertainty of output is unique to innovative projects (Paunov, 2012). Albeit there is a plan for how a particular product or process will be made, there is no guarantee that it will succeed. Thus, *ceteris paribus*, the earlier the stage in the innovation process the firm is asking for a loan, the more uncertain it is to produce an outcome (Hall & Lerner, 2010; Segarra-Blasco et al., 2018). For example, if a petition for a loan is conducted during the R & D stage of an innovation process, with no actual output yet, then there is high uncertainty and risk. On the contrary, if a patent for a product is already in place, then the effect of such uncertainty can be diminished (Mina et al., 2013).

Except for uncertainty, innovation projects have another unique characteristic that serves as a hampering factor in getting a loan. Innovation and R & D expenditures are procedures that generate knowledge within the firm. This knowledge is later incorporated into creating a new product or process. However, knowledge as an asset is intangible and thus cannot be collateralized (Hall, 2002; Brancati, 2015; Santos & Cincera, 2022). As a result, banks show a strong preference towards investments in tangible assets since, in the case of a loan default, they can balance out their losses, which is not the case when investing in innovation.

Due to the observations above, banks are either unwilling to provide loans to innovative firms or loan them with a higher interest rate to counter the risk of projects failing midway. This problem can be avoided if the firm can find alternative sources of funding which are not undervalued by the market. Thus, internal funds or a riskless debt involve no undervaluation and therefore will be preferred to equity or typical credit lines. Indeed, firms try to invest in innovative activities with internal funds rather than external (Hall & Lerner, 2010), a case especially typical for micro firms (Moritz et al., 2016; Masiak et al., 2017), following the pecking order hypothesis¹ (Myers, 1984). In this context, retained earnings are the best source of financing since it does not require any collateral, interest rate or minimizing other costs in order to be used. Equity on the other hand does not require collateral, thus making it a more viable option than bank loans; however not that applicable for the case of SMEs. In this line, recent literature (e.g., Mina et al., 2013; Hall, 2014, Lee et al., 2015 etc.) has pinpointed the dependence of innovative small firms on internal funds relative to the more costly access to external finance despite their recorded need for finance.

However, problems associated with financing innovation arise not only in the context of bank-firm relationships but also within the firms internally. For firms, undertaking innovative projects is not an easy task as the necessary R & D costs are higher than those of a regular investment and due to their intangible nature, they are even considered as sunk costs (Freel, 2007; Segarra-Blasco et al., 2018). In addition, R & D has high adjustment costs (Brown et al., 2012). In particular, more than 50% of R & D costs derive from salaries of researchers and engineers

¹Capital structure will be driven by firms' wishing to fund their investment plans initially by using own (internal) resources. External funds (borrowing or issuing shares) are not sought, until own resources are exhausted.

(Hall & Lerner, 2010). Considering that firms can't lay off personnel easily or even replace them due to the massive loss of knowledge that would entail, they are forced to preserve a rather fixed level of expenditures per annum regardless of the credit conditions in the economy (Brown et al., 2012) or even the status of the project. This typically amplifies the level of uncertainty in the market forcing firms to cover R & D expenditures with the permanent level of internal funds (Mancusi & Vezzulli, 2010).

Within the general context of asymmetric information, the typical problem of principal-agent in firms is present due to different priorities and interests when one entity takes actions on behalf of the other entity. However, in the specific framework of adopting innovation the agency problem may take a somehow peculiar form relative to the usual approach in corporate management. The manager's intention, subject to her risk averse behaviour, is to invest in safer projects (Johnson & Medcof, 2007; Hall & Lerner, 2010), since her main goal is to hold her position in the firm while avoiding unnecessary risks that may lead either to her dismissal or even to the firm's default. On the other hand, shareholders are willing to take risks in part of their investment agenda in order to obtain higher returns on their investments leading to a clear conflict of interests (Hall & Lerner, 2010; Santos & Cincera, 2022). In this case, the shareholders (or owner) should encourage the agent to align her interests with theirs, either through performance bonuses or a renewed contract (Hall & Lerner, 2010).

As a consequence of the above analysis, related policy discussions have strongly moved on the ways to tackle the problem of informational asymmetries and as a consequence to enhance the innovation investment within firms. One possible solution then to this problem is patents. Patents are seen in the literature as an intermediate stage of output (Francis et al., 2012), a prime result of the accumulation of inputs of firms. Patents can reveal innovation information to lenders (Francis et al., 2012; Hall, 2014) that may not be achieved otherwise and are especially important for SMEs that lack abundance of information. Hall (2014) stated that firms often patent their innovation outputs even when there isn't risk of mimicking from their competitors for the purpose of signalling quality to their lenders. In some cases, patents can also be used as collateral to a loan, as they may hold salvage value. Chava et al. (2012) found that firms with significant patent activity and higher quality patents can achieve less expensive loans than their peers.

We have seen so far that firms' access to credit financing is highly impeded by asymmetric information. Banks face significant problems of adverse selection and moral hazard when they lend to firms. We now focus on whether close relationship lending has facilitated innovative firms' credit financing. Relationship lending, as a definition, includes all information that a bank stores over time for a firm due to creation of close ties (Ongena & Smith, 2001). It is evident that close relations with bank officials are crucial in successfully raising funds for firms having innovative activity (Berger & Udell, 2002; Brancati, 2015). Trust

between a lender and a borrower is a crucial factor in breaching the gap of information of an innovative project, especially for informationally opaque SMEs. Small firms obtain relatively more value than large firms from the accumulation of soft information, due to a lack of hard data. The effect of soft information on innovative projects depends on the form of innovation that firms conduct, with product and process innovation being more heavily affected than softer forms of innovation like new organizational structures or new marketing methods (Branca-ti, 2015). Moreover, banks with high hierarchy and delocalized firms that don't have a bank in their province seem to negatively affect the importance of soft information in bank decision making (Alessandrini et al., 2010).

Finally, grants and government subsidies positively impact external access to finance (Howell, 2015) and promote innovation (Chundakkadan & Sasidharan, 2020). For example, if the government grants a firm, it signals to banks and other financial institutions that it has been graded positively by a non-firm official, which strengthens the statement of its viability (Hall et al., 2016). This additional form of financing also lowers the possibility and the amount of a nonperforming loan for the bank, as it shares the risk with the government.

2.1. Classifying the Empirical Literature

In the scope of the Stiglitz and Weiss model, the existing literature has documented the use of *a priori* criteria to classify firms in terms of the likelihood of being financially constrained or not. In particular, size and age are significant factors regarding the variations in the investment opportunity set (Fazzari et al., 1988) which is highly correlated to proxies capturing informational opacity (e.g., Oliner & Rudebusch, 1992; Carpenter & Rondi, 2000; Audretsch & Elston, 2002; Freel et al., 2012; Xiang et al., 2015; Ferrando et al., 2017; Rostamkalaei et al., 2020; Kallandranis, 2020 etc.).

Indeed, the mainstream of the credit rationing literature supports the hypothesis that smaller firms tend to be disadvantaged relative to the larger ones, in terms of access to capital (e.g., Carpenter & Rondi, 2000; Audretsch & Elston, 2002; Drakos & Kallandranis, 2005; Garcia-Teruel & Martinez-Solano, 2007; Psillaki & Daskalakis, 2009; Hashi & Toci, 2010; Drakos & Giannakopoulos, 2011; Farinha & Félix, 2015; Kallandranis et al., 2023 etc.). Thus, SMEs are more likely to have less access to external finance and to be more constrained in their operations, which is intensified when firms adopt innovation. Indeed, large firms can capitalize on their innovation and create their product or service in high quantities versus the low capacity of smaller firms. This also helps large firms spread their products' fixed costs more efficiently and make their innovation investment a more appealing offer to banks, contrary to SMEs.

However, the literature has conflicting results regarding the role of size on innovation activities (Khosravi et al., 2019). Even though previous research has shown that large and small firms conduct different forms of innovation (Salavou & Avlonitis, 2008), there is also evidence that points to size having a positive ef-

fect on innovation since they are resourceful (Mol & Birkinshaw, 2009). Moreover, the opposite results have also been spotted (Vaccaro et al., 2012), possibly because small firms adapt more easily to their environment than larger firms (van de Vrande et al., 2009).

In addition, firm age is expected to be related to the degree of informational asymmetries as its long past record would indicate quality and therefore reduce asymmetric information. The effect of age has been investigated in several empirical studies (e.g., Oliner & Rudebusch, 1992; Schaller, 1993; Beck et al., 2006; Serrasqueiro & Nunes 2011; Xiang et al., 2015; Anastasiou et al., 2022; Kallandranis et al., 2023 etc.), the majority of those reporting that older firms report less financing obstacles, while the younger ones face higher premiums or even their loan application is declined (e.g., Serrasqueiro & Nunes, 2011; Xiang et al., 2015; Bongini et al., 2021 etc.).

As for its effects on innovation, the results are again conflicting. Though there are studies that hint at the age not having a significant effect on innovation (Laforet, 2013; Öztürk & Ozen, 2021), other studies have found either adverse effects (Huergo & Jaumandreu, 2004; Rosenbusch et al., 2011) or positive ones (Winters & Stam, 2007). This controversy arises from particular characteristics of older and younger firms. Larger firms have more experience, knowledge and established relationships that help in promoting innovation while also being bureaucratic by nature (Bierly III & Daly, 2007) and less willing to adapt (Öztürk & Ozen, 2021), which serve as hampering factors. Young firms, on the other hand, are more flexible and willing to produce innovations but may still be immature and might lack the necessary knowledge (Sørensen & Stuart, 2000; Bierly III & Daly, 2007).

So far, we have highlighted that even though there is a voluminous number of studies with quite diverse features, they produce a set of predictions that seem to be robust across alternative setups within the context of innovation (e.g., Savignac, 2008; Mancusi & Vezzulli, 2010; Francis et al., 2012; Lee et al., 2015; Khan et al., 2017; Chundakkadan & Sasidharan, 2020; Santos & Cincera, 2022): 1) under asymmetric information and not fully collateralized loans, external funds are more expensive than internal funds, and 2) this cost differential varies inversely with borrower's net worth and especially traits. The empirical literature can be classified into three main categories depending on the focus of the relationship of innovation and financial constraints as well as access to bank finance. In particular, we focus on 1) a set of variables measuring credit rationing and how innovation affects it (Francis et al., 2012; Mina et al., 2013; Mushtaq et al., 2022), 2) measurements of innovation activity relative to finance related variables (Adegboye & Iweriebor, 2018; Fombang & Adjasi, 2018; Chundakkadan & Sasidharan, 2020) and 3) models of simultaneous calculation of finance and innovation variables to counter endogeneity issues (Savignac, 2008; Blanchard et al., 2013; Brancati, 2015; Santos & Cincera, 2022). The most prominent studies across the three categories are presented in **Tables 1-5**, giving the reader a comprehensive classification.

Table 1. Finance variable models.

Authors	Title	Country(ies)	Years	Data Sources	Sample	Dependent Variables	Independent Variables	Econometric model
Freel (2007)	Are Small Innovators Credit Rationed?	Scotland, Northumberland, County Durham, Tyne and Wear, Teeside and Cumbria	1998-2001	Survey of Enterprise in Northern Britain	256 Firms	Loan Application Success	R & D Expenditure, Innovation Output	Tobit
Francis et al. (2012)	Do Banks Value Innovation? Evidence from US firms	United States of America	1987-2004	NBER, PATSTAT of EPO, DealScan	933 Firms	Loan Spread	R & D Productivity, Patents	OLS, Probit
Mina et al. (2013)	The demand and supply of external finance for innovative firms	United States of America, United Kingdom	2004-2005	Joined Survey of University of Cambridge and MIT	3669 Firms	Petition to Obtain External Finance, Application Success	R & D Intensity, Innovation Output, Patents	Bivariate Probit with Selection
Lee et al. (2015)	Access to finance for innovative SMEs since the financial crisis	United Kingdom	2007-2008 2010-2012	UK Small Business Survey	10,708 Firms	Access to Finance, Difficulty of Access	Innovation output	Probit with Heckman Selection Effects
Mushtaq et al. (2022)	ICT adoption, innovation, and SME's access to finance	Global	2006-2020	World Bank Enterprise Survey	38,588 Firms	Access to Finance	Innovation index, Innovation output	OLS, 2SLS, Probit

Table 2. Stage and obstacles of innovation models.

Authors	Title	Country(ies)	Years	Data Sources	Sample	Dependent Variable	Independent variable	Econometric model
Canepa & Stoneman (2003)	Financial Constraints On Innovation: A European Cross Country Study	15 European Countries	1994-1996	Community Innovation Survey 2	Not Mentioned	Stage of Innovation	Obstacles to Innovation	Logit
Galia & Legros (2004)	Complementaries between obstacles to innovation: Evidence from France	France	1994-1996	Community Innovation Survey 2	1772 Firms	Obstacles to Innovation	Internal R & D, External R & D	Multivariate Probit
Mohnen et al. (2008)	Financial constraints and other obstacles: are they a threat to innovation activity?	Netherlands	2000-2002	Community Innovation Survey 3.5	3456 Firms	Stage of Innovation	Obstacles to Innovation	Probit with Sample Selection

Continued

Paunov (2012)	The global crisis and firms' investments in innovation	Latin America	2008-2009	Survey Under OECD Development Centre	1223 Firms	Innovation Stop	Access to External Finance	Probit
Segarra-Blasco et al. (2018)	Financial constraints and the failure of innovation projects	Spain	2004-2010	PITEC	4882 Firms	Abandon Innovation Project	Financial Barriers R & D Intensity	Recursive Bivariate Probit

Table 3. R & D models.

Authors	Title	Country(ies)	Years	Data Sources	Sample	Dependent Variable	Independent variable	Econometric model
Hall (2014)	Patents as quality signals? The implications for financing constraints on R & D	Belgium	2000-2009	Flemish R & D Survey, OECD/EPO database, Bureau van Dijk BEL-FIRST database	4390 Firms	R & D Intensity	Patent Applications	Tobit
Adegboye & Iweriebor (2018)	Does Access to Finance Enhance SME Innovation and Productivity in Nigeria? Evidence from the World Bank Enterprise Survey	Nigeria	Not mentioned	World Bank Enterprise Survey	2127 Firms	Conduct of R & D	Internal finance, External finance, Access to bank finance, Financial constraints	Logit
Ferrando & Lekpek (2018)	Access to finance and innovative activity of EU firms: A cluster analysis	Europe	2015	Survey of European Investment Bank	9067 Firms	Conduct of R & D, R & D Intensity	Clusters of Financing Sources	Logit
Chundakkadan & Sasidharan (2020)	Financial constraints, government support, and firm innovation: empirical evidence from developing countries	Global	2006-2017	World Bank Enterprise & Innovation Surveys	71,450 Firms	Conduct of R & D	Difficulty of access in external capital	Instrumental Variable Probit

Table 4. Innovation output models.

Authors	Title	Country(ies)	Years	Data Sources	Sample	Dependent Variable	Main independent variable	Econometric model
Clausen (2008)	Search Pathways to Innovation	Norway	2002-2004	Community Innovation Survey 4	4655 Firms	Innovation outputs	Lack of internal funds, Lack of external funds	Logit
Ayyagari et al. (2011)	Firm Innovation in Emerging Markets: The Role of Finance, Governance, and Competition	Global	2002-2004	World Bank Enterprise Survey	19,000 Firms	Innovation index	Use of External finance in investments	Ordered Logit
D'este et al. (2012)	What hampers innovation? Revealed barriers versus deterring barriers	United Kingdom	2002-2004	Community Innovation Survey 4	28,000 Firms	Barriers of Innovation	Innovation index	Multivariate Probit
Lööf & Nabavi (2016)	Innovation and credit constraints: evidence from Swedish exporting firms	Sweden	1997-2007	Statistics Sweden, PATSTAT	8300 Firms	Product Innovation, Patent Applications	Cash Flow	Negative Binomial Regression
Adegboye & Iweriebor (2018)	Does Access to Finance Enhance SME Innovation and Productivity in Nigeria? Evidence from the World Bank Enterprise Survey	Nigeria	Not mentioned	World Bank Enterprise Survey	2127 Firms	Innovation outputs	Internal finance, External finance, Access to bank finance, Financial constraints	Logit
Ferrando & Lekpek (2018)	Access to finance and innovative activity of EU firms: A cluster analysis	Europe	2015	Survey of European Investment Bank	9067 Firms	Product Innovation	Clusters of Financing Sources	Logit
Fombang & Adjasi (2018)	Access to Finance and Firm Innovation	Africa	2007-2014	World Bank Enterprise Survey	5304 Firms	Innovation index (aggregate)	Results of Applying for Finance	2SLS

Regarding the adopted methodology, a number of steps were taken in order to sort out the appropriate literature. First, we set out the basic criteria for our search, which is related with how access to finance affects all forms of innovation activities of a firm, focusing on SMEs and bank financing. Second, we chose the ResearchGate and Google Scholar engines to find relative papers along with

Table 5. Simultaneous calculation models.

Authors	Title	Country(ies)	Years	Data Sources	Sample (main)	Dependent Variables	Independent variables	Econometric model
Savignac (2008)	Impact of financial constraints on innovation: what can be learned from a direct measure?	France	1997-1999	FIT Survey	5500 Firms	Propensity to Innovate Level of Financing Constraints	Level of Financing Constraints	Recursive Bivariate Probit
Mancusi & Vezzulli (2010)	R & D, Innovation and Liquidity Constraints	Italy	2001-2003	Capitalia Survey	29,991 Firms	Conduct R & D Desired Additional Financing	Desired Additional Financing	IV Tobit, Recursive Bivariate Probit
Blanchard et al. (2013)	Where there is a will, there is a way? Assessing the impact of obstacles to innovation	France	2002-2004	Community Innovation Survey 4	19,214 Firms	Innovation output Financial Obstacles	R & D Intensity, Financial obstacles	Trivariate probit
Segarra-Blasco et al. (2018)	Financial constraints and the failure of innovation projects	Spain	2004-2010	PI TEC	4882 Firms	Abandon an Innovation Project Perceived Financial Constraints	Financial Barriers, R & D Intensity	Recursive Bivariate Probit
Brancati (2015)	Innovation financing and the role of relationship lending for SMEs	Italy	2008-2009 2011	MET database	13,550 Firms	Innovation output Financial Constraints on Investments	Conduct R & D	Recursive Bivariate Probit
Khan et al. (2017)	Innovation and Access to Finance: International Evidence from Developing Markets	Global (21 countries)	2010-2016	World Bank Enterprise Survey	26,700 Firms	Innovation output index Product Novelty Access to Finance	Access to Finance	Logit, Probit, Bivariate Ordered Probit
Santos & Cincera (2022)	Determinants of Financing Constraints	Europe	2014-2018	Survey of Access to Finance	27,546 Firms	Innovation output Access to Finance	Innovation output	Recursive Bivariate Probit

academic publishing companies specializing in related scientific fields. Our search was conducted in English and all the papers used in our review were published within the last 20 years (2002-2022). The keywords we used for our research were: “innovation and financial constraints”, “innovation and credit ra-

tioning” and “innovation and access to finance”. We also run the same keywords followed by “in SMEs” and “banks”, to monitor better relevant studies. Third, we started the basic screening procedure, by reading abstracts of relevant papers and reading in detail those that were close to the topic we were researching. After assessing the complete relevance of these papers, their quality in terms of results and the journals under which they were published, we ended up with the studies presented in Sections 2.2-2.4. In the fourth and final step, we classified those papers into 5 separate categories, based on the dependent variable of their econometric models. We included only the variables that were relevant with our study and excluded other independent and dependent variables for reader’s convenience, as they are not within the concept of our review.

One common factor across categories that should be mentioned is the employment of survey data for innovation and finance variables along with databases related to firm specific characteristics, like patent databases or balance sheet data. We also need to note that when research is not focused on a specific region or a small number of countries researchers mostly choose the World Bank Enterprise Survey for their analysis (Ayyagari et al., 2011; Khan et al., 2017; Chundakkadan & Sasidharan, 2020; Mushtaq et al., 2022), due to its worldwide data, a plethora of questions across different fields and its open accessibility. However, for individual countries or small cluster of countries analysis, there is a lot of diversity in data sources. Finally, EPO’s Worldwide Patent Statistical Database (PATSTAT) has been used extensively when researchers incorporate patent measurements in their models (Francis et al., 2012; Hall, 2014; Löf & Nabavi, 2016) and the Community Innovation Survey (CIS) for models on stages of innovation (Canepa & Stoneman, 2003; Galia & Legros, 2004; Mohnen et al., 2008).

The selected studies cover a time span of at least 20 years and include a wide variety of countries and samples (with the majority ranging in sample above 1000 firms), while the years researched range from 1987-2020, covering 33 years in total. Following this setup allows us to examine whether the correlation of finance and innovation variables follows a common trend across different nations and continents and under distinct economic cycles. The dependent variables used are an overwhelming majority of binary variables, thus, must be modeled by a Probit or Logit model providing evidence on the marginal effects of an independent variable on the dependent one. In some cases, the Ordinary Least Squares estimator is used, when the dependent variable is not binary. In order to test for endogeneity among financing and innovative variables, bivariate probit models are usually employed. As for countering potential endogeneity issues, the use of instruments and two-stage models become essential in the literature.

2.2. Financial Dependent Variable Models

Continuing with the main analysis, **Table 1** shows some representative research

of empirical models that use financial measurements as dependent variable. This category of papers investigates how banks comprehend different innovation measurements like R & D, innovation outputs and innovation indexes and if they are related with their decision to undertake a loan offer. Within the literature, there is a variety of measures of finance. Here, we refer to three main approaches: 1) Loan application success, 2) Reported access to finance and 3) Loan spreads.

The loan application success method (Freel, 2007; Mina et al., 2013) tests whether a firm actually gets the demanded loan provision with the desired loan terms like spreads and partial or total amount of money. In particular, it is examined whether firms with an innovative characteristic have a lower or higher likelihood of loan application success relative to non-innovative firms. Freel (2007) concludes that R & D expenditures and novel products have a negative impact on loan application success. Similarly, Mina et al. (2013) found that R & D intensity exerts a negative effect on the probability that firms obtain finance, a result that gradually disappears when more innovation factors are included. They report that separate forms of R & D measurements and innovation outputs can yield varying results on loan application success. Softer forms of innovation seem to be perceived negatively by banks, as well as earlier stages of innovation measurements like if the firm conducts R & D or not, even though the effects of its intensity are vague. On the other hand, core innovation outputs seem to positively affect loan application success.

The second way of measurement relates to perceived access to finance. Contrary to loan application success, where a certain benchmark is set in the form of successfully acquiring a loan or not, perceived access to finance is a more general measurement. It can also include problems that are non-loan related, like issues with line of credit and bank accounts, and even firms that were discouraged from applying for a loan in fear of possible rejection. In this measurement method, we observe contradicting results as Lee et al. (2015) mentioned that innovative firms are more likely to be turned down for finance, while Mushtaq et al. (2022) reported a positive correlation between innovation outputs and their innovation index with access to finance. A such contradiction of results may arise due to the different time frames of the samples, as Lee's et al. (2015) research was launched during the period of the economic crisis, while the dataset of Mushtaq et al. (2022) facilitates both an increased number of countries and a prolonged time frame.

The third measurement method involves loan spreads. Relative to the other two categories, loan spread is the only measurement that is non-binary. Through this method, it is tested whether firms with an innovative characteristic face higher or lower loan spreads compared to non-innovative firms. Francis et al. (2012) found that R & D productivity and patents seem to help firms alleviate loan spreads. Specifically, patents are more important for SMEs than large firms, as they can signal the quality of their innovation to banks in otherwise impossi-

ble ways, contrary to large firms that can counter such problems with extensive audits and the use of collateral.

All in all, we deduce that credit rationing and access to finance is harder for firms bearing innovative characteristics that are premature, like the conduct of R & D and R & D expenditures as well as soft innovations whose results in profitability are vague and intangible. On the other hand, banks possibly presume core innovations positively, though when the economic cycle is not favourable, evidence shows the opposite.

2.3. Innovation-Dependent Variable Models

The second category of empirical models explores the impact of access to finance and financial obstacles on different innovation metrics. Compared to the other two categories, this is the one that most researchers have been attracted to; hence for reader's convenience we present the quite rich output into three subcategories: 1) stage and obstacles of innovation models, 2) R & D models and 3) innovation output models.

Table 2 summarizes the most influential studies of this first subcategory. It was initiated due to one of the most famous surveys regarding innovation, as stated earlier, the Community Innovation Survey (CIS) conducted by the EU. Through this survey, researchers can distinguish among different stages where firms face problems with innovation and which obstacles they encounter. Specifically, in its earlier rounds (CIS 2), the survey distinguished 3 stages: postponed, uninitiated, and abandoned. In later surveys (CIS 3.5), prematurely stopped projects were also incorporated. Obstacles to innovation include innovation costs, lack of financing, lack of skilled personnel, lack of information on markets and technologies, lack of demand, regulatory issues, and organization rigidity. Researchers have exploited these two measures to test how obstacles to innovation (and, in our case, how obstacles to finance) affect a firm differently depending on the innovation stage (Canepa & Stoneman, 2003; Mohnen et al., 2008). Other researchers chose to investigate how firms that perform R & D perceive those obstacles relative to those that do not (Galia & Legros, 2004), while part of this literature focuses on characteristics of firms that decided to stop an innovation project (Paunov, 2012; Segarra-Blasco et al., 2018).

In terms of findings, financial obstacles were found to be more crucial on uninitiated, stopped and postponed innovation projects but not for a project to be abandoned (Canepa & Stoneman, 2003; Mohnen et al., 2008), suggesting that firms will not give up an innovation idea mainly for financial reasons. Furthermore, firms engaging in internal R & D and those that postponed their innovation projects are more prone to perceive financial costs of innovation as an important impediment (Galia & Legros, 2004). This result hints towards the importance of revealed innovation barriers which can only be perceived after the firm's engagement in innovation activity due to the increase in awareness of the hampering factors involving innovation (D'este et al., 2012). Finally, regarding

abandoned projects, firms seem to quit them during the concept stage and not after its initiation (Segarra-Blasco et al., 2018), probably due to high sunk cost and investment commitment, while firms that have access to public financing are less likely to abandon a project (Paunov, 2012).

The second subcategory consists of R & D models (see Table 3). Generally, innovation as a process is measured by 3 main ways. First, R & D is one of those measurements and it is a sign of innovation input for a firm with uncertain output, since just the conduct of R & D does not equate to a result. In order to create an innovation output, R & D costs are often required, thus making it a good proxy in innovation models as a representative measurement of a firm in its early stages of innovation. It is mostly researched under 4 forms: 1) Conduct of R & D (whether a firm carries out R & D activities), 2) R & D Expenditures, 3) R & D Intensity (mainly by using R & D expenditures relative to some other balance sheet measurement, like assets, turnover or sales) and 4) R & D productivity (measured as R & D expenditure relative to patents or as the number of employees on R & D relative to patents). R & D productivity, however is used by researchers mostly as an explanatory variable for models, rather than as a dependent one and it is not a very common measurement. As an innovation variable, patents are considered an intermediate innovation output, between R & D and innovation output, which helps alleviate information asymmetries for SMEs, as stated earlier. However, the fact that only 4% of SMEs apply for a patent (Hall et al., 2013) makes it a problematic source of measurement, resulting to researchers using alternative metrics of R & D instead.

In this literature, the conduct of R & D and R & D expenditures measurements have been found to positively affect the difficulty of access to finance and financial constraints (Adegboye & Iweriebor, 2018; Chundakkadan & Sasidharan, 2020). Moreover, innovative activities increase with a firm's diversification of financial instruments (Ferrando & Lekpek, 2018). Firms that use several financing instruments are more likely to invest in R & D and software activities and invest more in the R & D to turnover ratio. Generally, R & D models are the most straightforward in terms of results. The use of R & D, without an innovation output, increases the riskiness of financing firms from the side of banks, exacerbating their financial problems and constraints. However, there are ways to alleviate this problem like using multiple sources of financing, as well as patents, especially for smaller firms, that signal quality and help in increasing R & D intensity (Hall, 2014).

The third and final subcategory, consists of innovation output models (see Table 4). Innovation outputs are the end results of the innovation process and are associated with the least faced risk from banks, as there is a small amount of information asymmetry among them and the firms. Arguably, it is the most commonly used measure of innovation, as contrary to previous subcategories, it can yield a variety of results at times since an external financing entity can interpret a firm that produces innovation outputs both positively and negatively

depending on the form of output (Mina et al., 2013; Adegboye & Iweriebor, 2018). When researchers refer to innovation output models, they mostly include new products, processes and technology incorporated into the firm recently (Löf & Nabavi, 2016; Ferrando & Lekpek, 2018; Chundakkadan & Sasidharan, 2020). Most survey questions set a limit of either one year or three years to consider a product or process new. Aside from this classification, the more meticulous analysis includes product and process newness relative to the firm or the market (Khan et al., 2017), measuring if the innovation is internal, national or global, and if it was completely new or an upgraded version of a previous product or process of the firm. In some cases, softer forms of innovations like organizational innovations and marketing innovations are included, as well as ICT (Information and Communication Technology) measurements (Clausen, 2008; Adegboye & Iweriebor, 2018; Fombang & Adjasi, 2018).

Occasionally, innovation output measurements are also conducted in the form of indexes (Ayyagari et al., 2011; D'este et al., 2012; Fombang & Adjasi, 2018) to measure how intensive a firm is in its innovation outputs. These indexes are similar in nature to the baseline measurement, but in the form of sums, meaning that if a firm made both a product and a process innovation, then its index score is higher than a firm that created only a new product. Just like in the measurements above, these indexes can be spotted in the literature under two categories: i) those that account for only core innovations (product, process, technology) and ii) those that incorporate softer forms of innovation as well.

As for research approaches, we observe researchers either testing how access to finance and financial constraints affect innovation outputs (Ayyagari et al., 2011; Löf & Nabavi, 2016; Fombang & Adjasi, 2018) or how firms, based on their output intensity, report potential financial obstacles they face (D'este et al., 2012; Santos & Cincera, 2022). The first branch of this literature reported that external finance is crucial in introducing all forms of innovation outputs, especially for new and upgraded product innovations relative to other core innovations (Ayyagari et al., 2011). The effect of external finance, especially in the form of overdrafts, overwhelmingly drives innovation across all countries (Fombang & Adjasi, 2018), while cash flow has been reported as important for innovation outputs only for high-technology exporters (Löf & Nabavi, 2016). On the other hand, regarding reported financial problems relative to innovation intensity, it is found that the most intense innovators report the highest financial barriers to innovation together with non-innovators (D'este et al., 2012).

All in all, innovation dependent variable models, as observed, can be examined in many forms. All forms of innovation correlate positively with easier access to finance and less financial constraints, as expected. However, the effect that different innovation formats have on access to finance depends on the measure employed and the innovation stage. Hence, in order for a researcher to perform a complete analysis she/he should explore all the above variables. In particular, the part of this literature that gathers the most interest is innovation

output measurements and how banks' financing decisions are affected after observing different innovation outputs from firms. Thus, researchers might want to elaborate more on this subcategory of innovation measurements relative to others. From the following tables, it can be observed that the majority of recent papers use innovation output variables for their models.

In these two categories, we analysed the existing literature regarding the bidirectional relationship between finance and innovation. This relationship also holds importance for policymaking, since knowledge of how innovation responds to economic environment changes helps identify potential future policies that will promote financial development and economic prosperity. Financial assistance may reduce the high costs of innovation and the accompanied risk that leads to suboptimal investment levels (Arrow, 1972), especially for SMEs that face higher risk and worse funding requirements.

2.4. Simultaneous Calculation Models

Table 5 depicts models of simultaneous calculation of finance and innovation variables. The difference, when compared to the previous categories, is that researchers create explanatory models for both finance and innovation. Doing such, they succeed to address the endogeneity issues in this relationship, which derives possibly from two sources: 1) the fact that innovative firms are more conscious about potential financial problems relative to non-innovative ones and 2) the more innovative projects a firm undertakes, the easier it is to face financial constraints, as more cash is committed. To test for endogeneity in such bivariate probit models, one of the two variables must be assumed to have zero explanatory power over the other on its model. Some researchers choose financial variables to have zero explanatory power over their innovation variable (Brancati, 2015; Santos & Cincera, 2022) while others exactly the opposite (Savignac, 2008; Mancusi & Vezzulli, 2010; Khan et al., 2017). There are also cases where both variables are used as explanatory variables on two models, however, one of the two dependent variables is loosely related to innovation or finance. For instance, Segarra-Blasco et al. (2018) used "abandon an innovation project" as a loosely related variable to innovation.

Nevertheless, in most studies, the covariates of the errors are found to be different from zero, thus pointing to endogeneity issues within the models and, in general, among innovation and finance variables. The most effective countermeasure was introduced recently by excluding from the sample the non-innovators that didn't have financial constraints, meaning firms that did not want to engage in innovation (e.g., Savignac, 2008; Brancati, 2015; Khan et al. 2017, etc.). On the other hand, Mancusi & Vezzulli (2010) preferred to use an IV Tobit model and fitted values of R & D spending to counter the endogeneity issues of their model.

The results of this set of studies are in line with those mentioned in the categories above, as the relationship between financial constraints and innovation,

after controlling for endogeneity, is found to be negative (Savnac, 2008; Blanchard et al., 2013; Santos & Cincera, 2022) and is more evident in product innovations than process upgrades (Brancati, 2015) as well as in less novel products than more novel ones (Khan et al., 2017). However, we decided to create a separate category for these papers since Savnac (2008) solved a prevalent problem within the literature. Up to that point in time, researchers had found a positive correlation between financial constraints and innovation, a counterintuitive result, as typically financially constrained firms have less leeway to begin innovative activities. This problem was often apparent in Community Innovation Survey (CIS), that was used extensively to measure this relationship between 2000 and 2010. It seems that the empirical literature has appreciated Savnac's (2008) approach since then as it provides the most robust results in a well-defined sample.

This strand of papers also has important implications for policymaking. The classification of firms that Savnac (2008) first implemented helps identify more precise targets for innovation policy. Specifically, firms that seek to innovate, relative to those that do not have an incentive to innovate should be targeted differently for innovation policies. Regarding the first group, governments should focus on uplifting potential obstacles that hamper innovation efforts, while in the second group, governments should find incentives that encourage firms to seek innovation (Blanchard et al., 2013).

3. Conclusion

Having established the significant role of SMEs, there are concerns across the globe and not only within industrialized countries that access to finance is an increasingly significant barrier to business growth and survivability (Malhotra, 2007; Dinh et al., 2012). This is even more evident if it prevents innovative firms from accessing the finance they need to offer new innovative products and processes to market and enhance economic growth across countries. This paper has used a large scale of papers covering the empirical literature in this specific context for the first time, offering a road map for empirical researchers in their future research. We effectively tried to provide a systematic review of the major methodologies used so far in the relevant literature along with the most commonly used variables for both innovation and access to finance.

We reported that information asymmetries (Canepa & Stoneman, 2003; Brancati, 2015; Santos & Cincera, 2022) of innovation projects between lenders (banks) and borrowers (firms), lack of knowledge of the sector's characteristics from banks (Hall & Lerner, 2010; Khan et al., 2017) and the intangible nature and uncertainty of innovation as a form of investment (Hall, 2002; Paunov, 2012) lead to a negative relation of financing from banks to firm's innovation projects. In turn, firms suffer from higher interest rates and lower money supply. Taking also into consideration internal firm problems relative to launching a new innovative project like sunk costs, high adjustment costs and incentive

problems among shareholders and upper management (Freel, 2007; Hall & Lerner, 2010; Segarra-Blasco et al., 2018; Santos & Cincera, 2022), contributes to exacerbating firm's unwillingness to fund such projects. These issues can be partially omitted via close ties with bank officials, patents as a signal of quality to banks and other forms of financing like grants, that boost firm's trustworthy profile against banks (Berger & Udell, 2002; Francis et al., 2012; Hall, 2014; Chundakkadan & Sasidharan, 2020).

We further break down the literature into the following categories regarding the followed methodology in the empirical studies: models based in their core on access to finance variables, innovation variables, as well as simultaneous calculation models of both variables. Furthermore, since innovation literature has been researched under different measurements, we break down the innovation literature in stage and obstacles of innovation models, R & D models and innovation output models. In general, we find that easier access to finance has a positive effect on innovation (Ayyagari et al., 2011; Ferrando & Lekpek, 2018; Fombang & Adjasi, 2018), while innovation has a negative effect on access to finance in its premature forms and softer forms of innovation outputs (Freel, 2007; Mina et al., 2013). Moreover, innovation projects seem to be more phased by financial issues when uninitiated, stopped or postponed (Canepa & Stoneman, 2003; Mohnen et al., 2008).

Albeit there are a vast number of papers regarding innovation and financial access, the existing literature comes with its limitations and omissions. First, the measurements of innovation intensity are in the form of either indexes or R & D expenditures relative to a balance sheet measurement like total assets or total sales. It would be probably more beneficial to test how innovation intensive a firm is under the scope of its innovations' contributions to its total sales, as using indexes in the form of sums focuses more on quantity instead of importance of innovation. Second, it would be beneficial to see research that focuses more on the bank's perception of financing innovation projects, by using bank surveys, covering the possible supply side effect. Finally, the metrics chosen by researchers are sometimes restricted to questions that mainstream surveys of international organizations employ and not under their own methodical theoretical framework based on previous research. This restricts their liberty and contributes to research done under similar themes. It would be more preferable if researchers conducted their own targeted surveys for their sample of interest in order to make them more effective and avoid respondents that do not add that much in the process.

Regarding policymaking, the results of our research have crucial implications. We analyzed the reasons why difficulty in access to finance for innovative firms is a major hampering factor for economic growth. In the past, governments globally have tried to limit the obstacles of financing innovation by varying policies like tax subsidies on R & D, intellectual property systems, grants, and research funding for scientific and technical personnel. Even though these policies are in

the right direction, the problem of suboptimal investment in innovation is not only centred around financial problems (Canepa & Stoneman, 2003; Galia & Legros, 2004). A policy mix is required to include solutions corresponding to the varieties of innovation obstacles, like lack of skilled personnel and training programs as well as legislative issues. Respective to bank issues, measures like partial credit guarantee schemes when funding SMEs should be implemented to promote their funding relative to established firms. However, financial policies should not stop easing access to bank financing only. As Ferrando & Lekpek (2018) mentioned, a firm's diversification of financial instruments is crucial to successfully conducting innovation processes. This is especially the case for SMEs, who face higher financial constraints and are the driving force of innovation, especially during economic downturns. Thus, on the financial front, policymakers should focus on measures that ease access to different external finance sources for firms, especially SMEs.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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