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CREDIT CONSTRAINTS AND OPEN INNOVATION STRATEGIES

Pierluigi Murro
Valentina Peruzzi

Working Paper No. 1
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Credit constraints and open innovation strategies

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July 2022

Abstract

We investigate whether credit constraints affect firms' reliance on open innovation strategies. Using data on 7,000 Italian small and medium-sized enterprises, we find that credit restricted firms are 26% more likely to collaborate for innovation than firms not suffering from credit constraints. This result is confirmed both for product and process innovators. However, when accounting for the intensity of the product innovation, we find a negative impact of credit rationing on open innovation for firms introducing completely new products in the market. This confirms the relevance of opportunity costs in the choice between internal and open innovation in presence of credit restrictions. We also look at the role played by innovation partners. In particular, we show that the existence of credit constraints positively affects the probability of firms innovating with their suppliers. Finally, we provide evidence that the impact of credit frictions on innovation collaborations varies with the innovation environment and with the socio-economic conditions of the province where firms are located.

Keywords: credit constraints; open innovation; product innovation; process innovation.

JEL codes: O36; G32; D22.

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1 Introduction

It has been widely recognized by economic research and policy practice that innovation represents a relevant driving force of firm-level productivity, competitiveness and sustainable economic growth (Cassiman and Veugelers, 2006). For this reason, it is a concern for both policy makers and practitioners that financing constraints due to imperfections in capital markets may reduce investments in innovation below desired levels (Himmelberg and Petersen, 1994; Hottenrott and Peters, 2012).

During the last decades, the innovation paradigm has profoundly changed. The conventional view of having core R&D activities exclusively in-house has become less critical, and more recent models of innovation have suggested that firms should open up their innovation borders to tap into external sources of knowledge (Chesbrough, 2003, Berchicci, 2013). Open innovation strategies can certainly alleviate some of the challenges firms face when innovating. First, they represent a way to access the technological and human resources owned by partnering organizations and to pool the monetary risks associated with innovation activities in uncertain technological environments (Von Hippel, 1994; Belderbos et al., 2004; Wassmer and Dussauge, 2012; Kobarg et al., 2019). Second, open innovation strategies, when implemented with suppliers and customers, improve the management of supply chains and ensure a better innovation performance (Liker et al., 1996; Tether, 2002; Obradovic et al., 2021). Expanding firms' access to external knowledge, however, is not without costs. External collaborations are often subject to high opportunism and knowledge spillovers risks. Moreover, searching for and coordinating an increasing number of new collaborators are activities that require greater investments in time and money (Cassiman and Veugelers, 2002; 2006; Berchicci, 2013).

Despite the considerable attention paid to cooperative innovation in the last years, there is still no evidence on the impact of credit constraints on open innovation strategies. The aim of this paper is to fill this gap in the literature by investigating whether the existence of credit constraints affects firms' reliance on open innovation. From a theoretical point of view, financial constraints may have either positive or negative effects on the probability of firms to collaborate for innovative activities with external partners. On the one hand, firms suffering from credit constraints may collaborate for innovation in order to share the costs and risks associated with innovative activities and to overcome the lack of internal technological and human resources. On the other hand, in line with the transaction costs theory, firms being credit restricted may not engage in open innovative activities because of the transaction and opportunity costs associated with innovation collaborations.

In order to perform our empirical investigation, we draw information from the VIII UniCredit Survey on small and medium-sized enterprises (SMEs), carried out by the Italian banking group UniCredit on over 7,000 Italian firms.[1] The survey data we use are an ideal testing ground for our purposes. In fact, the survey produces detailed information about firms' credit constraints, as measured by a precise indicator of bank credit rationing. Moreover, the data also provide rich information on firms' innovation decisions, distinguishing investments in product and process innovation, and whether they have been carried out in-house or through open innovation systems. Finally, the survey contains rich details on a broad range of firm characteristics that are traditionally viewed as determinants of credit constraints and open

[1] The same survey has also been used for other objectives, such as exploring the impact of lending relationships on global value chain participation (Minetti et al., 2019) and investigating the effect of bank support on firms' export (Bartoli et al., 2014).

innovation initiatives.

Endogeneity issues plug any analysis of the linkages between credit constraints and firms' decision to innovate, both internally and through cooperation agreements. First, credit constraints could affect investments in innovation and, at the same time, investments in innovation could influence banks' credit allocation (reverse causality). Second, unobservable firm characteristics can jointly determine credit provision and firms' propensity to cooperate for innovation. Building on an established body of studies on the drivers of credit constraints (Shaffer, 1993; Peek and Rosengren, 1998; Berger et al., 1999; Sapienza, 2002; Minetti et al., 2019), we address these endogeneity issues by exploiting the merger between two major Italian banking groups occurred in 2007. In particular, we use a measure of the relative presence of the merged banks in the local (provincial) credit markets as a proxy for the intensity of the merger shock on firms' access to bank credit. On the positive side, a bank merger can increase banks' efficiency in loan origination and management because of information sharing, and economies of scale and scope. On the negative side, a merger can increase market power and partially dilute existing credit relationships, thus producing some loss of soft information on firms. For the validity of our instrument, we have strong reasons to believe that at the time of the merger, the relative branch presence of the two banking groups in the provinces was not correlated with the economic features of the province. As discussed by Minetti et al. (2019), this presence was the result of the historical evolution of the Italian banking sector in the decades during which the 1936 banking regulation was in place, as well as the historical presence of the banks in the provinces, due to ties to the local communities and the strong geographical roots of the banks. Thus, we expect the instrument to be not correlated with economic conditions relevant for firms' decision to invest in open innovation.

Our results reveal a positive and statistically significant effect of credit constraints on firms' adoption of open innovation strategies. This finding is robust to alternative definitions of credit constraints and to different estimation techniques aimed at accounting for endogeneity issues. The economic magnitude of the effect is sizable. In fact, a firm that is credit restricted is 26.4 percentage points more likely to collaborate for innovation than a firm not suffering from credit constraints. This result is particularly intense for small and medium-sized firms, whereas it is not confirmed for a subsample of micro-enterprises.

To dissect the scenarios in which the above effect is more pronounced, we then slice our data based on a variety of characteristics of the innovation being introduced. Estimation results confirm the positive impact of credit constraints on open innovation strategies both for product and process innovators. In both cases, firms being subject to credit rationing are more likely to collaborate with external partners, in comparison to non-rationed firms. However, when accounting for the intensity of the product innovation, we find a positive relationship between credit constraints and open innovation for firms improving existing products, and a negative relationship for firms introducing completely new products in the market. These findings confirm the relevance of opportunity costs in the choice between internal and open innovation in presence of credit constraints. These costs are binding for the introduction of new products, because of the appropriability of the innovation's returns and the potential disclosure of relevant information, whereas they are not perceived as a critical issue in the context of product improvements. We also look at the role played by the type of innovation collaborator. In this respect, we find that the existence of credit constraints positively affects the probability of firms innovating with their suppliers. This result is in line with several studies on the integration of suppliers in product development, which show that early and

extensive supplier involvement leads to superior innovation performance (Laursen and Salter, 2006). Moreover, collaborating with them allows firms to reduce the search and coordination costs usually associated with open innovative activities.

Finally, we investigate whether the impact of credit constraints on open innovation varies with the characteristics of the innovation environment where the firm operates, and with the socio-economic conditions of the province where the firm is located. Results reveal that the existence of credit constraints is negatively associated with the adoption of open innovation strategies when external partners are hard to find, the market is highly concentrated, and the level of trust and judicial efficiency in the province are particularly low. On the contrary, a positive relationship between credit rationing and open innovation is found in those provinces where material infrastructures are strong.

By providing this evidence, the paper contributes to two main strands of the current literature. First, we add to the literature on financial frictions and technological innovation. Whereas there is substantial evidence about the impact of financial constraints on firms' investments in closed innovation, to the best of our knowledge, we are the first investigating the effect of credit constraints on firms' decision to rely on open innovation strategies. Second, we relate to the literature on the determinants of open innovation. Existing studies have almost completely neglected the role played by financial factors. Moreover, most analyses have focused on large firms operating in high-technology sectors. The uniqueness of our data allows us to investigate the phenomenon of open innovation in the context of small and medium-sized enterprises in the manufacturing and services industries. Furthermore, we exploit the detailed information provided about open innovation activities to distinguish product and process innovators, as well as the type of innovation collaborator involved in the open innovation strategy.

The remainder of the paper is organized as follows. Section 2 presents the institutional background. Section 3 reviews the current literature on open innovation strategies and lays out the hypotheses to be tested. Section 4 describes the dataset and the empirical strategy. Sections 5 and 6 discuss the empirical results. Section 7 concludes.

2 Institutional background

Small and medium-sized enterprises represent a large share of economic activity in industrialized countries and are particularly relevant in the Italian context. In 2012, firms with less than 10 employees accounted for 87% of the total number of Italian businesses, and slightly less than 40% of the total value added and total employment. In the following year, 2013, enterprises with less than 50 employees represented more than 50% of the total value added and total employment (ISTAT, 2013).

In terms of innovation, Italy exhibits a relatively low R&D intensity. Business formal R&D spending relative to the GDP was 1.2% in 2010, compared to 2.3% in the OECD countries and 1.9% in the European Union (World Bank, 2010). Data from the EU Community Innovation Survey (CIS) indicate that, in 2010-2012, 51.9% of Italian enterprises with at least ten employees undertook innovation activities, with 35.5% of all enterprises focusing on product and process innovations (ISTAT, 2014). Large enterprises were the most active (69.2%), well ahead medium and small businesses (respectively, 54.8% and 32.7%). Unfortunately, few innovators chose to cooperate with other enterprises or institutions (12.5% of all the prod-

uct and process innovators). Suppliers were the main cooperation partners (6.8%), while the scientific community was less frequently involved.

Turning to the characteristics of the Italian financial system, this can be described as a bank-based system (Minetti et al., 2019). According to the World Bank data, in 2010, the stock market capitalization, as percentage of the gross domestic product was 15.4% in Italy, compared to 117.5% in the United States (World Bank, 2010). Specialized financial intermediaries, such as private equity and credit funds, have a limited presence in the country, so that for small and medium-sized enterprises the main source of external finance are bank loans. For this reason, in the empirical analysis, our core measure of financial constraints consist of bank credit constraints. A relevant feature of the Italian banking system is its delimitation within provinces (Sapienza 2002; Guiso et al., 2004), local entities defined by the Italian law that are similar in size to US counties. Tight regulatory restrictions on lending and branching were in place in Italian provinces until the 1990s, so that firms' access to bank credit is still heterogeneous across provinces. In particular, as distance matters in the provision of loans (Guiso et al., 2004), it is particularly difficult for firms, especially small and medium-sized enterprises, to borrow in a market other than the local (provincial) one. Indeed, distant lenders face pronounced informational disadvantages that can lead to a higher loan default rate for banks entering a new provincial market without having a branch in the province (see, e.g., Alessandrini et al., 2009).

The relevance of small and medium-sized businesses and the central role of banks in the Italian financial system, provide the ideal environment to study the impact of financial (bank credit) constraints on open innovation strategies of small and medium-sized enterprises.

3 Related literature and hypotheses framing

This paper contributes to two main strands of the current literature. First, it adds to the research on the impact of financial constraints on technological innovation. Second, it contributes to the growing studies on open innovation strategies. In the following subsections, we revise these literatures (3.1 and 3.2) and develop the hypotheses to be tested empirically (3.3).

3.1 Financial constraints and technological innovation

A big concern among academics and policy makers is that financial constraints due to capital markets imperfections may reduce investments in innovation below the desired levels (Hottenrott and Peters, 2012). Investments in innovation may be particularly affected by financial constraints. Starting from Arrow (1962), several papers have tried to elaborate the reasons why financial constraints significantly matter for investments in innovation (Stiglitz and Weiss, 1981; Anton and Yao, 2002). First, information asymmetries arising due to the specific characteristics of innovation cause lenders to demand a premium on their required rate of return. Innovative projects are not well understood by outside observers, since previous experience or observed past realizations can offer little guidance in assessing the prospects of completely new projects. On the contrary, it is likely that the entrepreneur undertaking the innovative project has, if not more knowledge, at least a better perception of its likelihood of success (Guiso, 1998; Murro, 2013). Strategic considerations may also induce innovative firms to maintain information asymmetries, so as to avoid the leaking of information to rivals, which

should reduce the prospective value of innovation (Mancusi and Vezzulli, 2014). Besides information asymmetries, another relevant factor making investments in innovation more costly than other types of projects is their intangible nature. Banks prefer to use physical and redeployable assets to secure loans, since these can be easily liquidated in case of project failure or bankruptcy. Finally, serving debt requires a stable cash flow, which makes the external financing of innovation projects more difficult, since most of them do not immediately lead to returns (Hottenrott and Peters, 2012). The empirical evidence has supported the thesis that firms first rely on internal funds to finance innovation projects (Himmelberg and Petersen, 1994). However, internal capital is naturally limited, and raising new equity may be costly and often unwanted. As a consequence, the extent to which firms can invest in technological innovation depends on their ability to access the credit market.

Empirical studies on financial constraints and investments in innovation have initially been based on the analysis of the sensitivity of R&D expenditures to the firm's cashflow, coherently with the research on investments and financial constraints and the seminal work of Fazzari et al. (1988). Hall (1992), using a large panel of US manufacturing firms, finds a strong effect of cash flow on R&D investments and suggests that innovation projects are significantly limited by the existence of credit constraints. Himmelberg and Petersen (1994) concentrate their analysis on a short panel of US small firms in high-tech industries and find that R&D expenditure is positively and significantly related to the firm's cash flow. Hao and Jaffe (1993) obtain a similar result using a relatively small panel of US firms but with a long time series dimension.

One problem with these studies is that the effect of firms' internal capital on R&D expenditure may reflect pessimistic expectations on future profits rather than current liquidity constraints. Hence, more recent papers have started to employ different measures of financial constraints, but with similar results. Savignac (2008) examines the impact of financial constraints on innovation for established firms in France and finds that financial constraints significantly reduce the likelihood that firms promote innovative activities. Silva and Carreira (2012) analyze the extent to which financial constraints hinder firms' investment in R&D and innovation and investigate the role of public financial support in alleviating such constraints. Their findings suggest that, while financial constraints have a perverse effect upon R&D investment and innovation, there is no evidence that subsidies mitigate such constraints. Mancusi and Vezzulli (2014) study the effects of credit rationing on R&D investment using survey data on a large representative sample of manufacturing SMEs and find that credit restrictions have a significantly negative effect on both the probability to set up innovation activities and on the level of R&D spending.

The aim of this paper is to contribute to this strand of literature by investigating whether the existence of financial constraints, measured by the probability of firms being credit rationed by banks, affects firms' decision to invest in open innovation. Below, we discuss the main theories and empirical evidence on open innovation strategies.

3.2 Open innovation strategies

Since Chesbrough's (2003) seminal work, open innovation has been identified as a collaborative approach to innovation whereby firms integrate external knowledge and expertise into their innovative processes (Chesbrough, 2006; Brockman et al., 2018). Over the last years, given the relevance of this topic and its managerial implications, scholarly awareness of open innovation

has substantially improved (Obradovic et al., 2021). In particular, various theories of firm behavior have been used to explain the shift from closed to open innovation models and to justify the increasing reliance on external innovative activities by manufacturing and services firms.

The most traditional theory on open innovation developed by the academic research is the resource-based view. This theory views open innovation as a way to access the resources owned by partnering organizations and to pool the monetary risks associated with innovation activities in uncertain technological environments (Wernerfelt, 1984; Wassmer and Dussauge, 2012). In this regard, innovation cooperation allows to maximize firm value through the combination of partners' resources and the exploitation of complementarities (Kogut, 1988; Belderbos et al., 2004). An extension of this theory is represented by the knowledge-based view, the most frequently employed theory to explain open innovation within the manufacturing industry (Kobarg et al., 2019). According to this theory, firms' main motivation to collaborate with external associates is to allow them to profit from new technologies that are not present within the firm (Grant, 1996; Von Hippel, 1994). In this sense, open innovation extends the knowledge base available for knowledge recombination, which is a central driver of innovation. Closely related to the resource-based and the knowledge-based views is the organizational learning perspective. In addition to physical resources and technological knowledge, innovation collaboration allows firms to acquire skills and competences associated with the innovation process and organization (Argote and Miron-Spektor, 2011).

Another explanation for the increasing reliance on open innovation strategies is related to the management of supply chains. Innovation collaborations with suppliers and customers are found to be crucial for business success (Obradovic et al., 2021). Since the 1970s, it has been recognized the relevance of customers in helping to define innovations and, therefore, to reduce the risk associated with their market introduction. Working closely with customers can come up with interesting benefits, which have been highlighted by the current literature (Tether, 2002). First, in line with the knowledge-based view, it can provide complementary knowledge, including customers' know-how. Second, it can help to find the right balance between performance and price, thus improving the marketing activity. Third, it can offer an understanding of customers' behavior, which can be relevant for marginal refinements to the innovation. Finally, it amplifies the chances that the innovation will be accepted and adopted by other firms within the same customer community. The interest for innovation collaborations with suppliers has started a decade later, during the 1980s, when the success of Japanese automobile and electronic firms was attributed to their close relationships with suppliers and their involvement in the innovation process (Liker et al., 1996). Innovation agreements with suppliers share many of the benefits described above, as customers and suppliers are positioned in the same vertical relationship. However, open innovative activities with suppliers may have additional strategic implications in terms of "make or buy" decisions. In this sense, firms may decide to downsize by focusing on some core competencies, and collaborate with suppliers on others, in order to improve their efficiency and competitive position.

Firms can rely on open innovative activities, but this process is not without costs. Potential detrimental aspects of innovation collaborations have been identified by the transaction cost economics perspective (Cassiman and Veugelers, 2006; Berchicci, 2013; Obradovic et all., 2021). This theory suggests that the integration of external knowledge and expertise into innovative processes is associated with substantial transaction costs (Kobarg et al., 2019). First

of all, in order to internalize external sources of knowledge, companies need to invest time and money in searching and selecting suitable innovation partners. Then, once selected, firms must sustain additional costs for the coordination, management and control of the innovative activities of their associates. Finally, as companies move from internal to open innovation models, internal structures require a fundamental transformation, which implies considerable reorganization costs (Chesbrough, 2006). In addition to transaction costs, innovation collaboration is subject to sizeable opportunity costs (Berchicci, 2013). In particular, in choosing between internal and open innovations, firms need to consider the risks from openness to external partners such as the reduced appropriability of the innovation's returns and the potential disclosure of relevant information about the innovation project. Sometimes, firms fear the leakage of critical knowledge about the firm's innovation efforts to its competitors (Cassiman and Veugelers, 2002). For example, knowing where a firm is focusing its innovative efforts could provide important information to skilled rivals about how to shape their own search efforts and target the same markets.

The theories explaining firms' reliance on open innovation have been complemented by the empirical literature that has analyzed the determinants of innovation cooperation activities. Cassiman and Veugelers (2002), for a sample of Belgian manufacturing firms, find that there is a significant relationship between external information flows and the decision to cooperate for innovation: firms that value more the availability of incoming spillovers for their innovation process are more likely to be actively engaged in open innovation strategies. Fritsch and Lukas (2001), by analyzing the propensity to maintain different forms of innovation cooperation for a sample of German manufacturing firms, uncover a positive relationship between firm size and the reliance on open innovation. This result is consistent with Negassi (2004) showing that R&D cooperation increases with firm size and R&D intensity. Bayona et al. (2001) and Miotti and Sachwald (2003), for Spanish and French firms, respectively, provide evidence that companies operating in more technology intensive sectors have a greater propensity to establish cooperative arrangements for innovations. De Faria et al. (2010) by using the Portuguese Community Innovation Survey, indicate that employees' education level and appropriability have a significant impact on the probability of cooperation. Brockman et al. (2018), for a large sample of firms across 21 countries, find a strong evidence that greater societal trust is associated with higher levels of subsequent open innovation, as captured by the number of co-owned patents.

This paper aims to contribute to this growing strand of literature by examining whether firms' decision to invest in open innovation strategies is affected, among other factors, by the existence of credit constraints.

3.3 Anecdotal evidence and testable hypotheses

Based on the theories about the adoption of open innovation strategies discussed in the previous section, we conjecture that financial constraints may have either positive or negative effects on the probability of firms to collaborate for innovative activities with external partners. On the one hand, we expect firms suffering from credit constraints to be more likely to invest in open innovation when they lack the resources (technological knowledge, skills, and organizational structures) that are necessary to carry out innovation projects. The same relationship, i.e., a positive link between financial constraints and open innovation strategies, may also characterize businesses aiming at sharing the costs and risks usually associated

with innovative activities. In both cases, experiencing credit restrictions may lead firms to cooperate for innovation with external parters, rather than focusing on closed innovation models. On the other hand, in line with the transaction costs theory, we expect to find a negative effect of credit constraints on firms' adoption of open innovation strategies when collaborations for innovation imply high transaction and opportunity costs. In this case, the existence of credit constraints may make firms less likely to engage in open innovation and more likely to keep investing in closed innovative activities.

Anecdotal evidence demonstrates that financial constraints can successfully shape open innovation strategies. For example, in 2005, the NASA human research and development program experienced a 45% reduction on its budget. While this resulted in the loss of some core capabilities, including personnel, contracts and grants, the Human Health and Performance Directorate (HH&P) leadership reacted by formulating a new strategy based on collaborations to advance its mission and improve organizational performance and efficiency. Key strategies included establishing strategic relationships to leverage the resources of others, and developing an integrated risk management approach to guide the prioritization and management of human health and performance activities. Similarly, in the 1990s, despite the declining resources from within the FIAT Group, Centro Ricerche FIAT (CRF) exploited some external opportunities to maintain the vitality of its R&D activities. In particular, it selected what knowledge to keep private and what to expose, and then shared non-core technologies with external partners to generate additional income. CRF also established long-term strategic partnerships with customers and new partners to diversify the exploitation of their complementary assets. Such open approaches helped FIAT to avoid substantial reduction of R&D and innovation capability that would have impacted negatively the firm in the long term. In spite of this "positive" evidence of open innovation adoption in bad times, cooperation for innovation can be extremely costly for firms that are small in size. In fact, a survey on small Italian firms confirms that the most binding factor for exploiting the opportunities related to open innovation practices is the search and coordination costs associated with them (UniCredit, 2010).

Hence, in line with the theories described above, we develop two opposite hypotheses to be tested empirically:

Hypothesis 1: Credit constraints are positively associated with the adoption of open innovation strategies. Firms suffering from bank credit constraints are more likely to cooperate for innovation in order to share the costs and risks associated with innovative activities and to overcome the lack of internal technological and human resources.

Hypothesis 2: Credit constraints are negatively associated with the adoption of open innovation strategies. Firms suffering from bank credit constraints are less likely to engage in open innovative activities because of the transaction and opportunity costs related to innovation collaborations.

4 Data and method

4.1 Data sources

To perform our empirical investigation, we draw information from the VIII UniCredit Survey on small and medium-sized enterprises (SMEs), carried out by the Italian banking group UniCredit in 2011.[2] The survey gathers data on a sample of Italian firms that are UniCredit's customers and provides information for the year 2010. The 2011 wave targeted 7,433 small and medium-sized enterprises, that were selected with a stratified sampling method in order to ensure the representativeness of the sample at the industry and province level.

The main strength of the survey is the detailed information provided about (a) firms' financial structure and relationships with the banking system; (b) investments in product and process innovation; (c) extent of internationalization and export; (d) organizational structure and number of employees.[3]

Table 1 reports a detailed description of all the variables employed in the empirical analysis. Table 2 provides summary statistics (for all firms, by open innovation strategies and credit rationing status). At the average, the surveyed firms have been in business for 18 years and have slightly more than 15 employees; beyond 50% of businesses have fewer than 10 employees, and below 5% of them have more than 70 workers; 32.9% of firms are corporations and 80.7% are family owned. The majority of firms are located in the North of Italy (57.6%), while 18.6% of companies operate in the Center and 23.7% in the South of the country. The sector composition is affected by the nature of the sample. In fact, small firms, compared to larger ones, usually dominate sectors such as trade (28.3% of the firms in the sample) and services (30.1%). Manufacturing firms account for 26.2% of the total, whereas construction, tourism and agriculture businesses represent, respectively, 9.9%, 2.6% and 1.8% of the surveyed firms.

4.2 Measurement

4.2.1 Open innovation

Open innovation involves a collaborative approach to innovation whereby firms integrate external knowledge and expertise into their innovative processes (Chesbrough, 2006; Brockman et al., 2018). Our measure of open innovation is strictly related to this definition and is based on firms' answers to the following question of the UniCredit survey: "*Who is the main partner with whom the firm has cooperation agreements on technological innovation activities? (i) research centers/universities; (ii) customers or clients; (iii) suppliers; (iv) firms belonging to the same business group; (v) competitors; (vi) trade associations; (vii) the firm has no cooperation agreements on technological innovation activities.*" Following Tether (2002), we define firms adopting open innovation strategies those ones that answered (i)-(vi). As the

[2]The survey was conducted by highly qualified personnel of a major Italian institute of statistics (Doxa, the Italian branch of the Gallup International association) on behalf of UniCredit and firms' answers were carefully checked. Exhaustive instructions to respondents about the interpretation of the questionnaire were also provided, and particular attention was devoted to make the questions intelligible and to minimize measurement errors.

[3]The Italian law (675/1996) on the treatment of personal data forbids using them for objectives other than that mentioned in the survey. The interviewers made clear that firms' responses would have been used only to compile statistical tables and to understand businesses' point of view. Hence, we do not expect firms to misreport information with the objective of building better reputation in the credit market.

question on cooperation agreements was only asked to the firms that recognized themselves as innovating, i.e. firms that introduced either a product or a process innovation in the previous three years, our analysis is restricted to those firms that engaged in innovation activities rather than embracing all of the surveyed firms.

As reported in Table 1, of the 5225 firms identified as innovative businesses, 67% claimed to adopt an open innovation strategy by collaborating on technological innovation activities with external partners. Suppliers and customers are the most widely engaged cooperation partners (respectively, 28.56% and 18.58% of innovating firms), but significant proportions of companies also engage firms belonging to the same business group (7.33%) and trade associations (6.05%).[4] Figure 1(a) draws the distribution of firms involved in innovation agreements across Italian provinces. The figure indicates that firms relying on open innovation strategies are not clustered in few provinces, but are almost homogeneously distributed in the Italian territory.

4.2.2 Bank credit rationing

Our main measure of credit rationing is based on firms' responses to the following question of the UniCredit survey: "*In 2010, would the firm have liked to obtain more credit at the prevailing market interest rate? (i) yes; (ii) no.*". Following Angelini and Generale (2008), Minetti and Zhu (2011) and Minetti et al. (2019), we define credit rationed firms those ones that gave a positive response to this question. As shown in Table 1, 37.7% of the surveyed firms experienced credit restrictions. This figure is slightly higher than the ones reported in some previous studies. Minetti and Zhu (2011), for the year 2000, find a share of credit rationed firms of approximately 20%; Murro and Peruzzi (2019), for the period 1995-2006, report a percentage of credit rationed businesses of 13%. A plausible explanation for our higher figure is that our sample firms are smaller than the ones considered in other studies, as the average firm size reported in the cited papers is around 80 employees. In fact, Albareto and Finaldi Russo (2012) estimate that the percentage of credit rationed firms in Italy is significantly higher for businesses with fewer than 50 employees.

Figure 1(b) draws the distribution of credit rationed firms across Italian provinces. The figure indicates that rationed firms are not clustered in few provinces. Although companies in Southern and Central Italy are more likely to be rationed overall, we still find that some Northern provinces have a relatively high share of rationed firms.

As alternative proxy for the existence of financial constraints, we also use the length of the relationship with the firm's main bank. The literature suggests that longer credit relationships ease information acquisition and monitoring by financial intermediaries, thus increasing firms' access to bank credit (Petersen and Rajan, 1994; Berger and Udell, 1995). In our sample, the average length of the firm's main lending relationship is 13.5 years, and it is in line with previous studies on Italian SMEs (Herrera and Minetti, 2007). It is worth noting that, while our measure of credit rationing is binary and cannot provide information on the intensity of rationing, the length of the firm's main credit relationship is roughly continuous and can help capture the intensity of financial constraints (Minetti et al., 2019). Moreover, consistently with our expectations and the banking literature, credit rationing exhibits a slightly negative correlation with the length of the firm's main lending relationship (see the correlation matrix in Table 3).

[4] See Table A1.

4.2.3 Control variables

To correctly estimate the impact of financial constraints on open innovation strategies and mitigate the omitted variables concern associated with the cross-sectional structure of our dataset, we control for a large set of possible confounding effects.

First, in line with the current literature on open innovation (Tether, 2002), we control for firm age (*Age*, expressed in logarithm) and size, measured by the number of employees (*Size*, expressed in logarithm). On the one hand, prior research has indicated that younger and smaller firms may have greater resource constraints and hence higher demand for open innovation and faster adjustment speed in decision making (Chesbrough, 2010; Brockman et al., 2018). On the other hand, there is evidence suggesting that large firms may be more likely to collaborate as they have greater absorptive capacity, which allows them to better identify, absorb and utilize external knowledge in an open innovation regime (Dahlander and Gann, 2010). Second, we control for the firm's internal knowledge by including the share of graduate employees (*Graduates*). Firms with few graduates may lack the human resources required to perform closed innovation activities, and may be more likely to collaborate with innovative partners (Maietta, 2015). Third, following Brockman et al. (2018), we control for a firm's ownership structure by including two dummy variables: *Corporation*, that is equal to one if the firm is a public limited company, and zero otherwise; *Family firm*, that is equal to one if the firm is family owned, and zero otherwise. Publicly held firms may be incentivized to form strategic alliances and profit from collaborations (Arora et al., 2016; Brockman et al., 2018), whereas family owned businesses may be reluctant to disclose information with other parties and cooperate (Murro and Peruzzi, 2019). For a subsample of firms we have additional firm-specific information drawn from balance sheets and income statements. Hence, as a robustness check, we include proxies for firm profitability (*ROI*), growth opportunities (*Sales growth*), and intangible assets (*Intangibles*).

To capture regional factors that may affect firms' adoption of open innovation strategies, we then include three province-specific controls. First, we include the level of local banking development (*Local banking development*), measured by the number of bank branches in the province (per 100,000 inhabitants). Second, we control for the level of judicial inefficiency (*Judicial inefficiency*), measured by the number of civil suits pending (Jappelli et al., 2005). Third, following Brockman et al. (2018), we include a proxy for the level of provincial trust (*Trust*), measured with voter turnout using data for the European elections of 1979, 1984, 1989, 1994 and 1999, and six referenda (Guiso et al., 2004).

Finally, we saturate the empirical model with a comprehensive array of fixed effects: geographical dummies (at the NUTS-1 level), based on the area where the firm is located, and sector dummies according to the one-digit NACE classification.[5]

[5]The survey asks each firm to indicate its activity sector based on the following categorization: Agriculture, Manufacturing, Services, Trade, Tourism, and Construction. The reader could wonder whether this classification is sufficiently fine to capture technological factors that influence the adoption of open innovation strategies. In this regard, it is worth noting that our sample covers small and medium-sized firms operating in industries (such as services and trade) characterized by a low degree of product differentiation, and hence, technological differences across subsections are probably small. This is confirmed by the fact that a finer classification is not available for the majority of sample firms, especially those ones operating in non-manufacturing sectors. In spite of that, as a robustness check, we reestimate our regressions using the two-digit NACE classification.

4.3 Empirical model

The aim of this paper is to study whether firms' access to credit may influence the adoption of open innovation strategies, instead of closed innovation models. The probability that firm i cooperates with external partners on technological innovation can be written as:

$$P(Open\ innovation_i = 1) = \Phi(\alpha_1 + CR_i\beta_1 + Z_i\gamma_1) \tag{1}$$

where Φ is the standard normal cdf; CR_i denotes our measure of firm i's access to bank credit, i.e., Credit rationing, as described in section 4.2.2; Z_i is a vector of exogenous covariates, as discussed in section 4.2.3, as well as controls for differences across geographical areas and industries. As our dependent variable is a dummy variable taking values zero and one, we estimate Equation (1) by maximum likelihood probit regressions.[6]

One might be concerned that a firm's access to credit may be endogenous. First, some omitted variables could be correlated with a firm's credit availability and also affect its adoption of open innovation strategies. Our empirical specification controls for a large set of factors that may affect the firm's decision to cooperate on technological innovation, including firm-specific characteristics, industry and region fixed-effects. This should reduce the risk of omitting factors correlated with both credit availability and open innovation. Second, there is a possibility of reverse causality. To mitigate endogeneity concerns, we complement probit estimates with an instrumental variable approach. Since both open innovation and credit rationing are binary variables, we estimate a bivariate probit model that comprises Equation (1) and the following probit equation for firms' access to credit:

$$P(CR_i = 1) = \Phi(IV_i\delta_1 + Z_i\lambda_1) \tag{2}$$

where IV_i represents our instrument, and Z_i is the vector of exogenous covariates and controls for differences across regions and industries included in Equation (1).[7]

In building our instrument, we aim at capturing exogenous shocks to the structure of the Italian provincial credit markets that could have affected firms' credit availability. The banking literature has widely documented that bank mergers can have a significant impact on firms' exposure to credit rationing and firms' relationships with banks at the local level. On the one hand, bank mergers can increase banks' efficiency in loan origination and management because of economies of scale and scope or technological and managerial improvements (Shaffer, 1993; Peek and Rosengren, 1998). Mergers can also produce informational gains, due to the adoption of advanced technologies for loan screening and monitoring, and the possibility to share information on loan applicants among local bank branches. Given the relevance of informational frictions in the credit market, these gains can significantly improve firms' access to bank credit. But bank mergers can also have negative effects. In particular, they may increase market power and dilute existing credit relationships, by producing some loss of soft information on firms (Sapienza, 2002).

Based on this literature, and following Minetti et al. (2019), we construct our instrument by exploiting the merger occurred in 2007 between two major Italian banking groups,

[6] In all the regressions, standard errors are heteroskedasticity robust, clustered at the firm level.

[7] Equations (1) and (2) constitute a recursive bivariate probit model. The effect of firms' access to credit on the adoption of open innovation strategies can be identified under the assumption that the instrument IV_i is excluded from Equation (1). Although CR_i enters Equation (1) as an endogenous variable, Equations (1) and (2) can be estimated using a standard bivariate probit software (Greene, 2002).

UniCredit and Capitalia, which in turn comprised Banca di Roma, Banco di Sicilia, and Bipop-Carire. Although these banks operated in the whole country, their branch presence differed quite significantly across provinces at the time of the merger. Hence, we expect a different impact of the merger on firms' access to credit depending on the importance of the merged banks, relative to other banks, in the local credit market at the time of the merger. To measure the intensity of the merger shock in the provincial credit market, we use the provincial share of branches of the banking groups involved in the 2007 merger over the total number of branches in the province (*Share UniCredit group*).

In order to be valid, the instrument must be correlated with our measures of credit rationing and relationship length, whereas it must not be correlated with unobservable variables that could also correlate with firms' adoption of open innovation strategies. Regarding the first point, it is worth noting that Italian small and medium-sized enterprises strongly rely on bank financing and their relevant credit market is the provincial one. Moreover, the small size of our sample firms, and the associated informational opaqueness, imply that if the bank merger resulted in informational gains for the banks, this could have profoundly affected their credit availability (Minetti et al., 2019). With respect to the second issue, that is the non-correlation between our instrument and firms' adoption of open innovation strategies, we have strong reasons to believe that at the time of the merger, the relative branch presence of the two banking groups in the provinces was not correlated with the economic features of the province. As discussed by Minetti et al. (2019), this presence was the result of the historical evolution of the Italian banking sector in the decades during which the 1936 banking regulation was in place, as well as the historical presence of the banks in the provinces, due to ties to the local communities and the strong geographical roots of the banks.

A scatter plot of the share of credit rationed firms in the provinces against the provincial share of branches of the merged banks indicates a negative relationship between the two variables (Figure A1). As we will see, consistent with this descriptive evidence, in the first stage regressions we obtain that the larger the share of branches of the merged banks in the province, the smaller the probability of credit rationing.

5 Main results

This section presents the baseline findings (5.1) and discusses some preliminary insights into the underlying mechanisms (5.2).

5.1 Credit constraints and open innovation

Table 4 presents the estimation results for the impact of credit constraints on firms' adoption of open innovation strategies. Panel A reports the baseline estimates obtained by using our main measure of financial constraints and the set of control variables described in section 4.2.3. Panel B shows the results for a set of robustness checks.

Panel A column (1) reports the marginal effects from the probit model in Equation (1). After controlling for various firm characteristics, industry and area fixed effects, we find that credit rationing is significantly and positively associated with firms' adoption of open innovation strategies, instead of closed innovation models. The marginal effect of credit rationing is estimated to be 0.071 (statistically significant at 99%), suggesting that a credit rationed firm is 7.1 percentage points more likely to rely on open innovative activities than

a non-rationed business. In column (2), we treat credit rationing as endogenous and use as instrument the provincial share of branches of the banking groups involved in the bank merger. As noted, since both open innovation and credit rationing are binary variables, we estimate a bivariate probit as specified in Equations (1) and (2). We detect an even larger effect of credit rationing on firms' probability to rely on open innovation strategies. As shown in column (2), the marginal effect for the variable *Credit rationing* is 0.264 (statistically significant at 99%), implying that a firm that is credit restricted is 26.4 percentage points more likely to collaborate for innovation than a firm not suffering from credit constraints.[8] The positive impact of credit restrictions on firms' reliance on open innovation strategies is consistent with Hypothesis 1. As discussed in section 3 when framing our hypotheses, we interpret this finding as suggesting that financially constrained firms cooperate for innovation in order to share the costs and risks associated with innovative activities and to overcome the lack of internal technological and human resources.

The bottom of column (2) reports the estimated coefficient of the instrument from the probit equation of credit rationing (to save space, the coefficients on firm controls, area and industry dummies are not reported). We find that the higher the share of branches of the merged banking groups in the province, the smaller the probability of firms being credit restricted. This result indicates that the merger favored borrowers when the involved banks accounted for a larger portion of the local credit market. This finding is in line with the idea that mergers allow banks to better exploit economies of scale and to share information previously segmented across banks.

The estimated coefficients for the control variables are consistent with the evidence provided by previous studies. First, we find that the probability of open innovation adoption decreases with firm age (Tether, 2002). Second, in line with the knowledge-based view, we detect that firms' internal knowledge, as proxied by the presence of graduated workers, is negatively associated with innovation collaborations (Maietta, 2015). Finally, we confirm a positive association between the local level of trust and the reliance on open innovation strategies (Brockman et al., 2018).

Panel B reports the estimations of a set of robustness checks. In columns (3)-(4), we employ an alternative measure for the existence of credit constraints, that is the length of the firm's main credit relationship. Estimation results for the probit and IV probit models highlight a negative and statistically significant association between the length of the firm's main lending relationship and the reliance on open innovation strategies. When endogeneity is accounted for, as shown in column (4), the marginal effect for the variable *Relationship length* is -0.061 (statistically significant at 99%). As the banking literature suggests that longer lending relationships ease information acquisition and improve credit availability (Berger and Udell, 1995), this result corroborates our previous finding and further supports Hypothesis 1: firms with shorter credit relationships, that means higher financial constraints, are more likely to cooperate with external partners on innovation projects. In columns (5)-(6), we reestimate our baseline regressions by including three other firm-level variables, i.e., the return

[8] One interpretation for the larger marginal effect obtained with the bivariate probit estimation is related to the reverse causality mechanism. More specifically, we expect reverse causality to imply a negative relationship between credit constraints and the adoption of open innovation strategies: innovation collaborations may represent a good signal for banks and may attenuate the probability of firms to experience credit restrictions. In this case, using an instrumental variable approach should correct this mechanism by generating a larger effect of credit rationing on open innovation.

on investments (*ROI*), the growth rate of sales (*Sales growth*), and the amount of intangible assets (*Intangibles*), which are available only for a subsample of firms.[9] As shown at the bottom of Table 4, the inclusion of these controls leads to a substantial loss of observations. In spite of that, the positive impact of credit rationing on open innovation is confirmed. The marginal effects for the probit and bivariate probit models are both positive and statistically significant. In columns (7)-(8), we rerun the baseline estimates by adding the two-digit industry dummies for manufacturing firms, while retaining the broader industry dummies for non-manufacturing businesses (as noted, also in these regressions we experience a loss of observations due to missing data). The results remain virtually unchanged and further support the idea that the existence of credit constraints fosters firms' adoption of open innovation strategies.

As last robustness check, in column (9), we further account for omitted variables concerns by following a propensity score matching (PSM) approach. In order to follow this estimation technique, we first split the sample of innovative firms into credit rationed and non-credit rationed businesses, on the basis of the dummy variable Credit rationing. Then, we match the firms of the two groups so that the two subsamples are similar as possible in terms of the variables that might be correlated with the adoption of open innovation strategies. More specifically, we estimate a probit model where the dependent variable is Credit rationing. This probit regression includes all the firm-specific controls used in our baseline estimations[10] and requires a tolerance level for the maximum propensity score distance (caliper) between the treatment and the control group equal to 0.0001 (Murro and Peruzzi, 2019).[11] Once obtained the treatment and control groups, we end the procedure by rerunning our baseline regression as in Equation (1). Estimation results are reported in column (9) and are fully consistent with the baseline regressions discussed above.

5.2 Non-linear effects

The impact of credit constraints on firms' reliance on open innovation strategies may vary depending on some characteristics of the firm. In this section, we aim at gaining further insights about the relationship between credit rationing and innovation collaborations by investigating for which firms our findings are stronger. In particular, we proceed by distinguishing businesses on the basis of their size and age. Estimation results are reported in Table 5.

Panel A re-estimates the baseline regression of Table 4 for the subsamples of micro, small, and medium-sized businesses. Following the definition adopted by the European Commission, we partition firms using the threshold of 10 employees for micro enterprises, and 50 employees for small businesses. The marginal effects of the bivariate probit regressions in columns (1)-(3)

[9] These data are drawn from the Centrale dei Bilanci database, which collects yearly data on the balance sheets, income statements and other indicators of about 35,000 Italian firms. The information is assembled and standardized by a consortium of banks from sources such as the Italian Chambers of Commerce. The database is representative of the Italian business sector and has a very comprehensive coverage of small and medium-sized firms (Minetti et al., 2019).

[10] The control variables included in the estimation are: Age, Size, Graduates, Corporation; Family firm, Local banking development, Judicial efficiency, Trust.

[11] Figure A2 reports the kernel density of the estimated propensity score for the treated and control groups before and after the matching. The graphs indicate that matching strongly improves the degree of similarity between the two subsamples in terms of the covariates we use for the matching strategy. This confirms that the PSM procedure reduces the likelihood that omitted differences, rather than credit rationing, drive our results.

suggest that credit constraints are positively and significantly related with firms' probability of cooperating for innovation only for the subsamples of small and medium-sized enterprises. Among small and medium firms, those suffering from credit constraints are, respectively, 30.4 and 14.2 percentage points more likely to rely on open innovation strategies than non-rationed businesses. Conversely, micro enterprises are not characterized by a significant effect of credit constraints on innovation collaborations. This finding is consistent with prior literature on firm size and open innovation strategies. Micro-enterprises have less ability to access external resources and fewer technological and human assets that they can exchange than larger firms (Tether, 2002; Lee et al., 2010). Conversely, businesses of a larger size, albeit less flexible, tend to have stronger resources to develop inventions into products and processes, and these resources act as complementary assets in attracting partners to collaborate with (Lee et al., 2010). From our perspective, this result is also in line with the transaction costs theory: very small businesses suffering from credit restrictions cannot sustain the monetary costs related to innovation collaborations.[12]

Panel B splits our sample based on firm age. In particular, we distinguish firms with less than 7 years (the 25th percentile of the distribution), 7-15 years (the median value of our sample), 15-26 years (the 75th percentile of the distribution), and more than 26 years. The regressions in columns (4)-(7) indicate that our baseline findings, i.e., a positive impact of credit constraints on firms' adoption of open innovation, are driven by relatively young firms. Among businesses with less than 7 years, credit rationed ones are 33.9 percentage points more likely to engage in innovation agreements than non-rationed firms. Similarly, among firms operating for 7-15 years, the ones experiencing credit restrictions are 19.5 percentage points more likely to rely on open innovation than non-restricted businesses.

6 Mechanisms

The impact of credit constraints on firms' adoption of open innovation strategies may be explained by the theories discussed in section 3. On the one hand, firms suffering from credit rationing are expected to collaborate for innovation in order to share the costs and risks associated with innovative activities and to overcome the lack of internal technological and human resources. On the other hand, in line with the transaction costs theory, credit restricted businesses are expected not to engage in open innovative activities because of the transaction and opportunity costs associated with innovation collaborations. In this section, we investigate the relevance of these mechanisms in our context by analyzing whether the impact of credit constraints on firms' adoption of open innovation strategies varies with the type of innovation being introduced (Table 6), with the partner to collaborate with for the innovation (Table 7), with the characteristics of the innovation environment where the firm operates (Table 8), and with the socio-economic conditions of the province where the firm is located (Table 9).

6.1 Product and process innovation

The literature has stressed the importance of distinguishing between product and process innovation, as they are usually associated with different objectives: process innovation reduces

[12] Firm size also proxies for market power, which is likely to influence the pattern of innovation agreements, especially within the supply chain.

production costs, while product innovation increases the price that buyers are willing to pay (Herrera and Minetti, 2007). In addition, product and process innovation are characterized by different incentives and secrecy needs (Cohen and Klepper, 1996). In this section, we aim to gather additional insights about the relationship between credit constraints and firms' reliance on open innovation strategies by focusing on the subsets of product and process innovators. In particular, we expect to find a different impact of financial constraints on firms' adoption of open innovative activities, depending on the type of innovation being developed.

Based on the information provided by the UniCredit survey, in Table 6, we classify the surveyed firms as being product or process innovators.[13] Panel A reports the results for the impact of credit constraints on the adoption of open innovation strategies for the subsample of firms introducing product innovation. In Panel B, we present the same estimates for the subsample of firms introducing process innovation. Starting with the full subsamples of product and process innovators, the results reported in columns (1) and (4) indicate that both types of innovators are more likely to rely on open innovation strategies when suffering from bank credit restrictions. The marginal effect in column (1) is 0.269 (statistically significant at 99%), which implies that firms introducing product innovations being subject to credit rationing are 26.9 percentage points more likely to collaborate with external partners on these innovations, in comparison to non-rationed product innovators. Similarly, the marginal effect in column (4), equal to 0.230 (statistically significant at 99%), suggests that process innovators suffering from financial constraints are 23 percentage points more likely to adopt open innovation strategies, than process innovators that are not credit restricted.

We then specifically focus on the type of product and process innovations introduced by the surveyed firms. Regarding product innovations, the UniCredit survey allows us to distinguish between firms introducing completely new products and businesses focusing their innovation activity on some improvements of existing products. For the subsample of firms introducing new products, we detect a negative impact of credit constraints on the adoption of open innovation strategies. The marginal effect reported in column (2) indicates that firms introducing new products suffering from credit restrictions are 8.6 percentage points less likely to rely on innovation collaborations, in comparison to non-rationed businesses investing in the same type of innovation. The opposite relationship is found with respect to the introduction of product improvements. Firms improving existing products and suffering from credit constraints are 26.1 percentage points more likely to collaborate for innovations with external partners than non-rationed companies focusing on the same level of product innovation (column 3). These findings confirm the relevance of opportunity costs in the choice between internal and open innovation in presence of credit constraints. These costs are binding for the introduction of new products, because of the appropriability of the innovation's returns and the potential disclosure of relevant information. In this case, despite the existence of financial constraints, firms result to be less likely to engage in open innovation strategies. Conversely, opportunity costs are not perceived as a critical issue in the context of product improvements. The reduced secrecy needs and economic returns associated with this level of product innovation make firms suffering from credit constraints more likely to rely on open innovative activities, rather than focusing on internal innovation.

Concerning process innovators, our data allow us to distinguish among different areas for

[13] The UniCredit survey specifically asks: "*In the last three years, did the firm introduce product innovations? (i) yes; (ii) no.*"; "*In the last three years, did the firm introduce process innovations? (i) yes; (ii) no.*".

process innovations: production, logistics, purchasing, maintenance, and IT. For the subsamples of firms introducing process innovations related to production, purchasing, and maintenance systems, we find a positive, albeit non-statistically significant, relationship between firms' credit constraints and their reliance to open innovation strategies. Conversely, with respect to process innovators focusing on logistics and IT systems, we detect a positive and statistically significant impact of financial constraints on innovation collaborations. Process innovators focusing on logistics systems suffering from credit constraints are 21.9 percentage points more likely to rely on open innovations, in comparison to non-rationed businesses investing in the same type of process innovation (column 6). Similarly, firms innovating their IT systems are 30.6 percentage points more likely to adopt open innovation strategies in presence of bank credit restrictions (column 9). These results are consistent with some of the theories on open innovation adoption discussed previously in the paper. First, it is plausible that, in presence of firms' credit restrictions, innovations related to the logistics systems are coordinated with the firms' suppliers. This not only reduces the monetary costs associated with the process innovation, but also enhances the management of the supply chain and the linkages between the firms and their suppliers. Second, in line with the knowledge-based view, it is common to observe that firms suffering from credit constraints are more likely to delegate the innovation of IT processes to specialized businesses, instead of investing their (limited) money in developing such systems. Third, as for the results on product innovations, it seems that for those types of process innovations characterized by a higher level of novelty, such as innovations on production systems, opportunity costs play a role. In this case, credit rationed firms are not significantly different from non-rationed ones in terms of adoption of open innovation strategies.

6.2 Open innovation partners

Firms can engage in cooperative arrangements for innovation with several types of partner. In our sample, as displayed in Table A1, suppliers and customers are the most widely engaged cooperation partners, but significant proportions of companies also engage firms belonging to the same business group, trade associations, and research centers and universities. Without doubt, cooperation with competitors raises the greatest suspicions, and indeed only a few firms in our sample declare to collaborate for innovation with firms operating in the same business sector. For the purposes of this paper, we argue that the existence of financial constraints may affect firms' motivations to collaborate with different partners. Hence, in this section, we investigate whether the impact of credit restrictions on open innovation adoption differs depending on the type of innovation collaborator. Based on the information provided by the UniCredit survey, in Table 7, we refine our dependent variable by focusing on the innovation partner engaged by the sample firms (research centers/universities; customers and clients; suppliers; firms of the same business group; competitors; trade associations). Estimation results indicate that the existence of credit constraints positively affects firms' reliance on open innovation with suppliers. Firms suffering from credit rationing are 11.2 percentage points more likely to collaborate for innovation with suppliers than firms not subject to financial constraints (column 3). On the contrary, credit restrictions do not display any significant effect on firms' innovation agreements with other partners. Albeit positive, the marginal effects for open innovation strategies with customers (column 2) and firms of the same business group (column 4) are not statistically significant.

This result highlights the relevance of suppliers as open innovation partners, especially for firms suffering from credit constraints. This is in line with several studies on the integration of suppliers in product development, which show that early and extensive supplier involvement leads to superior innovation performance (Laursen and Salter, 2006). Indeed, in the innovation process of firms, suppliers increasingly play a role as external sources of ideas. First, suppliers possess complementary knowledge compared with the focal firm in terms of having a specialized set of skills. Moreover, when collaborating with them, firms can reduce the search and coordination costs usually associated with open innovative activities. Hence, our result is consistent with both the knowledge-based view and the transaction cost economics perspective: when suffering from credit restrictions, firms are more likely to collaborate for innovation with partners with greater knowledge and already related with the firms' business.

6.3 The innovation environment

External factors may be as relevant as internal firm characteristics in shaping the relationship between the existence of credit constraints and the firm's reliance on open innovation strategies (Pellegrino and Savona, 2017). Hence, in Table 8, we investigate the role played by the firm's innovation environment in determining the impact of credit restrictions on innovation collaborations. In Panel A, sample firms are classified on the basis of the obstacles to innovation activity they perceive as being more binding.[14] The marginal effects reported in columns (1) and (5) indicate that the existence of credit constraints is negatively associated with the adoption of open innovation strategies when external partners are not easy to find and the market is highly concentrated. In these cases, rationed firms are 13.4 and 11.1 percentage points less likely to engage in open innovation activities, in comparison to firms not suffering from credit constraints. Opposite results are found when considering other obstacles to innovation. In fact, the experience of credit restrictions is positively associated with the probability of firms relying on innovation collaborations when market demand is low (column 4), and the firm lacks technological knowledge and qualified personnel (columns 2-3). In all three cases, financial constraints increase the probability of firms adopting open innovation by almost 30 percentage points. Overall, these findings are consistent with our predictions. On the one hand, when innovation partners are not available in the market and searching costs are high, credit constraints are negatively associated with the adoption of open innovation strategies. On the other hand, when firms lack the technological knowledge and the human resources needed to carry out innovation projects, credit restrictions are positively associated with the probability of firms relying on open innovative activities.

In Panel B, we distinguish firms on the basis of the factors they perceive as relevant in the decision to collaborate with external partners not for innovation purposes.[15] The marginal effect reported in column (3) indicates that the existence of financial constraints reduces the probability of firms' adopting open innovation strategies by 8.1 percentage points when potential partners are inconveniently located. This result, is once again consistent with the transaction costs economics perspective: firms suffering from credit restrictions are less likely to engage in innovation agreements because of the high searching and coordination costs associated with them. Finally, in Panel C, firms are classified on the basis of the

[14] The UniCredit survey specifically asks: "*Which are the main obstacles to the innovation activity?*".

[15] The UniCredit survey asks: "*Which are the main obstacles to collaborations with external partners (not for innovation purposes)?*"

information sources they employ in the innovation process.[16] The marginal effects reported in columns (2)-(5) highlight a positive relationship between the existence of credit constraints and open innovation strategies for firms employing information coming from enterprises of the same business group, competitors, customers and suppliers. Conversely, for firms acquiring information on innovation from internal sources, the probability of relying on innovation collaborations is not significantly affected by the existence of credit restrictions. The marginal effect shown in column (1), albeit positive, is not statistically significant at conventional levels.

6.4 The socio-economic environment

To exploit the benefits of innovation agreements and sustain long-term relationships, partners engaging in open innovation may rely on socio-economic informal and structural mechanisms that facilitate the adaptation process, reduce coordination frictions, and enhance the collaborative efficiency (Brockman et al., 2018). The relevance of these mechanisms intensifies when firms suffer from credit constraints. In this case, information uncertainty and appropriability risks, which may be mitigated by socio-economic factors, become more binding for firms' decisions to cooperate for innovation activities. Hence, in this section, we investigate the relevance of the socio-economic context where the firm operates on the relationship between the existence of financial constraints and the firm's reliance on open innovation strategies. More specifically, we focus on the role played by societal trust, judicial efficiency, social capital, and material infrastructures.

Estimation results are reported in Table 9. In Panel A, firms are classified on the basis of the level of provincial trust, measured as voter turnout using data for the European elections of 1979, 1984, 1989, 1994 and 1999, and six referenda (Guiso et al., 2004). In Panel B, we distinguish surveyed firms based on the local judicial efficiency, measured by the number of days provincial courts take to complete a first-degree trial (Guiso et al., 2004). In Panel C, sample firms are classified on the basis of the provincial level of social capital, measured by blood donation (Guiso et al., 2004). Finally, in Panel D, firms are distinguished based on the local level of material infrastructures, measured by a provincial synthetic index that considers road network, railways, ports, airports, environmental energy networks, broadband services, and business structures.[17] The marginal effects displayed in Panel A column (1) and Panel B column (3) indicate that credit constraints reduce the probability of firms engaging in open innovation strategies when the level of trust and judicial efficiency are particularly low (i.e. under the median provincial value). In these cases, appropriability risks and opportunism heighten the transaction and opportunity costs of innovation collaborations, so that firms suffering from credit constraints cannot afford this kind of investment. The baseline result, i.e. a positive association between credit rationing and open innovation strategies, is instead confirmed when firms operate in provinces with high levels of trust (Panel A, column 2), judicial efficiency (Panel B, column 4). The marginal effect reported in Panel D column (4) also points out the relevance of local infrastructures in shaping the link between financial constraints and open innovation activities. The existence of credit constraints increases the probability of firms' relying on open innovation by 27.3 percentage points when the firm is located in a province with high levels of material infrastructures. This result substantially

[16] The UniCredit survey asks: "*Which are the information sources used for the innovation activity?*"

[17] This indicator is provided by Geoweb Starter, a database containing local, provincial and regional statistical information for the Italian territory, produced by the Istituto Guglielmo Tagliacarne.

confirms the transaction cost economics perspective. In fact, when searching and coordination costs are reduced by the presence of material infrastructures, which improve the communication and coordination among businesses, firms suffering from financial constraints are more likely to cooperate for innovation activities.

7 Conclusions

This paper has examined the impact of credit constraints on firms' adoption of open innovation strategies for a sample of Italian small and medium-sized enterprises. The results reveal that firms facing bank credit restrictions are 26.4 percentage points more likely to rely on innovation cooperation than firms not suffering from credit constraints. This finding is robust to alternative definitions of credit constraints and to different estimation techniques aimed at accounting for endogeneity issues.

To dissect the scenarios in which the above effect is more pronounced, we have then sliced our data based on a variety of characteristics of the innovation being introduced. Estimation results confirm the positive impact of credit constraints on open innovation strategies both for product and process innovators. In both cases, firms being subject to credit rationing are more likely to collaborate with external partners, in comparison to non-rationed firms. However, when accounting for the intensity of the product innovation, we find a positive relationship between credit constraints and open innovation for firms improving existing products, and a negative relationship between credit rationing and open innovation for firms introducing completely new products in the market. These findings confirm the relevance of opportunity costs in the choice between internal and open innovation in presence of credit constraints. These costs are binding for the introduction of new products, because of the appropriability of the innovation's returns and the potential disclosure of relevant information, whereas they are not perceived as a critical issue in the context of product improvements. We also look at the role played by the type of innovation collaborator. In this respect, we find that the existence of credit constraints positively affects firms' reliance on open innovation with suppliers.

Our results have important policy implications. Since innovation is one of the main drivers of economic growth, it is crucial to verify and quantity the extent to which investments in innovation are affected by financial constraints. In particular, if open innovation is a way to overcome financial barriers, as suggested by our results, then helping firms to cooperate for innovation with external agents by providing assistance in the searching and coordination stages must be a priority for policy makers. At the same time, financial support to remove bank credit constraints should be provided to those enterprises, like product innovators, whose characteristics and innovation nature prevent the reliance on open innovation initiatives. These considerations are relevant also from a managerial perspective. Managers should realize that opening up their innovation boundaries is an effective solution when credit constraints are narrow. This strategy should be followed also by small and medium-sized enterprises and even in presence of substantial searching and coordination costs. In this case, small firms' managers should exploit the relationships built along the supply chain with the most innovation-oriented customers and suppliers.

Despite the interesting results obtained, this study is not exempt from limitations. First, the cross-sectional structure of our dataset prevents us to consider the dynamic of innovation collaborations and credit rationing. In this sense, a longitudinal dataset could enable us to

obtain more in-depth understanding about the impact of credit constrains on firms' adoption of open innovation strategies. Second, despite the richness of our dataset, more detailed information on firms' networks would be useful to better explore the benefits and costs of innovation collaborations in presence of financial frictions. We leave these and other issues to future research.

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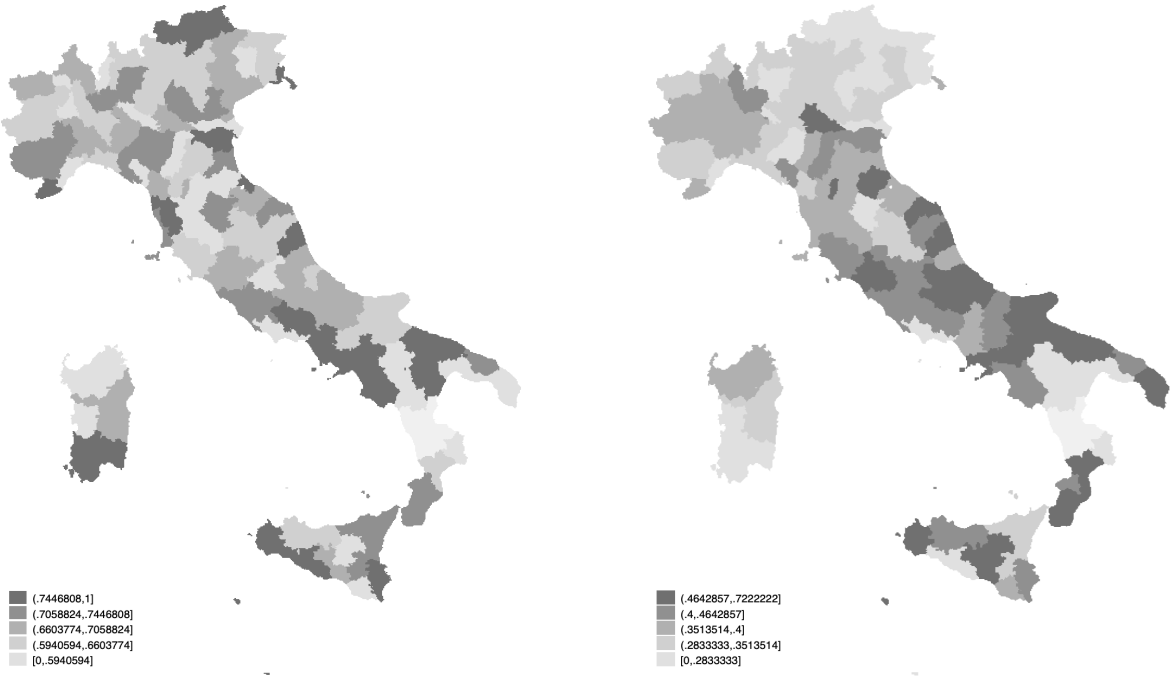
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Tables and Figures

Figure 1
Credit constraints and open innovation adoption across Italian provinces (NUTS-3)



(a) Open innovation (b) Credit rationing

Notes: The figures show the percentage of open innovation adoption and credit rationing for the firms in our sample.

Table 1
Variable definitions

Variable	Description
Dependent variables:	
Open innovation	Dummy variable equal to one if the firm cooperates with external partners on technological innovation, and zero otherwise.
Independent variables:	
Credit rationing	Dummy variable equal to one if the firm is credit rationed, and zero otherwise.
Relationship length	Length of the relationship with the main bank (in years).
Control variables:	
Age	Number of years since inception.
Size	Number of employees in the year of the survey.
Graduates	Number of graduate employees over the total number of employees.
Corporation	Dummy variable equal to one if the firm is a public limited company, and zero otherwise.
Family firm	Dummy variable equal to one if the firm is family owned, and zero otherwise.
Local banking development	Number of bank branches in the province in the year 2009, per 100,000 inhabitants.
Judicial inefficiency	Number of civil suits pending in the province, scaled by the population.
Trust	Voter turnout using data for the European elections of 1979, 1984, 1989, 1994 and 1999, and six referenda.
Instrumental variables:	
Share UniCredit group	Share of branches of the merged banking groups in the province.
Other variables:	
ROI	Return on investments.
Sales growth	Growth rate of sales.
Intangibles	Intangible assets.
Geographical areas:	
North	Dummy variable equal to one if the firm is located in the North of Italy, and zero otherwise.
Center	Dummy variable equal to one if the firm is located in the Center of Italy, and zero otherwise.
South	Dummy variable equal to one if the firm is located in the South of Italy, and zero otherwise.
Industry sectors:	
Agricolture	Dummy variable equal to one if the firm operates in the agriculture sector, and zero otherwise.
Construction	Dummy variable equal to one if the firm operates in the construction sector, and zero otherwise.
Trade	Dummy variable equal to one if the firm operates in the trade sector, and zero otherwise.
Tourism	Dummy variable equal to one if the firm operates in the tourism sector, and zero otherwise.
Services	Dummy variable equal to one if the firm operates in the services sector, and zero otherwise.
Manufacturing	Dummy variable equal to one if the firm operates in the manufacturing sector, and zero otherwise.

Table 2
Summary statistics and univariate tests

	All firms			Open innovation strategies					Credit rationing status				
	Mean	Std. Dev.	Obs.	Open innovation=1		Open innovation=0		t-test	Credit rationing=1		Credit rationing=0		t-test
				Mean	Obs.	Mean	Obs.		Mean	Obs.	Mean	Obs.	
Dependent variables:													
Open innovation	0.670	0.470	5225						0.719	2047	0.644	3050	-5.685
Independent variables:													
Credit rationing	0.377	0.485	7247	0.428	3434	0.346	1663	-5.692					
Relationship Length	13.529	11.202	7433	13.517	3502	14.748	1723	3.612	13.483	2731	13.740	4516	0.963
Control variables:													
Age	18.959	17.817	7121	19.054	3402	21.749	1627	4.684	17.492	2638	19.763	4340	5.413
Size	15.379	42.401	7153	18.133	3405	21.881	1641	2.541	12.374	2641	16.922	4373	4.651
Graduates	0.227	0.419	7279	0.236	3427	0.287	1672	3.809	0.182	2694	0.247	4415	6.612
Corporation	0.329	0.470	7433	0.379	3502	0.408	1723	1.959	0.283	2731	0.353	4516	6.294
Family firm	0.807	0.394	7412	0.788	3491	0.780	1717	-0.648	0.833	2719	0.794	4507	-4.245
Local banking development	0.627	0.198	7294	0.619	3430	0.627	1693	1.364	0.598	2689	0.644	4423	9.465
Judicial inefficiency	0.758	0.772	7275	0.780	3420	0.737	1690	-1.834	0.847	2679	0.708	4413	-7.213
Trust	0.813	0.080	6931	0.812	3281	0.813	1634	0.285	0.803	2555	0.820	4205	8.240
Instrumental variables:													
Share UniCredit group	0.148	0.079	7433	0.147	3502	0.148	1723	0.477	0.149	2731	0.148	4516	-0.361
Other variables:													
ROI	0.089	0.161	3314	0.084	1767	0.078	899	-0.941	0.087	1159	0.090	2062	0.462
Sales growth	-0.051	0.519	2920	-0.046	1560	-0.059	806	-0.564	-0.026	1017	-0.062	1820	-1.679
Intangibles	0.037	0.087	3302	0.038	1758	0.033	898	-1.689	0.040	1154	0.034	2055	-1.610
Geographical areas:													
North	0.576	0.494	7433	0.562	3502	0.583	1723	1.446	0.506	2731	0.618	4516	9.362
Center	0.186	0.389	7433	0.180	3502	0.186	1723	0.561	0.197	2731	0.178	4516	-2.070
South	0.237	0.425	7433	0.257	3502	0.229	1723	-2.188	0.295	2731	0.203	4516	-8.741
Industry sectors:													
Agricolture	0.018	0.135	7433	0.019	3502	0.017	1723	-0.430	0.020	2731	0.017	4516	-0.869
Construction	0.099	0.299	7433	0.095	3502	0.080	1723	-1.860	0.121	2731	0.086	4516	-4.711
Trade	0.283	0.450	7433	0.283	3502	0.242	1723	-3.190	0.310	2731	0.269	4516	-3.705
Tourism	0.026	0.161	7433	0.027	3502	0.024	1723	-0.656	0.030	2731	0.024	4516	-1.419
Services	0.301	0.458	7433	0.274	3502	0.277	1723	0.185	0.302	2731	0.303	4516	0.154
Manufacturing	0.262	0.439	7433	0.292	3502	0.351	1723	4.223	0.205	2731	0.291	4516	8.350

Notes: The table reports summary statistics and univariate tests for the main variables used in the regressions. All of the variables are defined in Table 1.

Table 3
Correlation matrix

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1)	Open innovation	1.000										
(2)	Credit rationing	0.083	1.000									
(3)	Relationship length	-0.057	-0.034	1.000								
(4)	Age	-0.063	-0.077	0.506	1.000							
(5)	Size	-0.045	-0.099	0.231	0.389	1.000						
(6)	Graduates	-0.051	-0.117	0.117	0.227	0.547	1.000					
(7)	Corporation	-0.028	-0.111	0.141	0.261	0.678	0.438	1.000				
(8)	Family firm	0.007	0.061	-0.014	-0.068	-0.296	-0.118	-0.342	1.000			
(9)	Local banking development	-0.020	-0.112	0.131	0.141	0.171	0.128	0.140	-0.080	1.000		
(10)	Judicial inefficiency	0.033	0.089	-0.107	-0.145	-0.161	-0.131	-0.091	0.071	-0.655	1.000	
(11)	Trust	-0.008	-0.098	0.126	0.141	0.174	0.132	0.118	-0.084	0.726	-0.675	1.000

Table 4
Financial constraints and open innovation

	Panel A: Baseline results		Panel B: Robustness checks						
			Alternative measure of financial constraints		Additional controls		2-digit NACE		Propensity score matching
	Probit	Bivariate probit	Probit	IV Probit	Probit	Bivariate probit	Probit	Bivariate probit	Probit
Dependent variable	Open innovation		Open innovation		Open innovation		Open innovation		Open innovation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Credit rationing	0.071***	0.264***			0.055**	0.251***	0.071***	0.252***	0.073***
	(0.008)	(0.031)			(0.027)	(0.017)	(0.010)	(0.031)	(0.012)
Relationship length			-0.001*	-0.061***					
			(0.001)	(0.018)					
Age (log)	-0.024***	-0.015***	-0.019**	0.279***	-0.028	-0.021**	-0.024***	-0.015***	-0.029***
	(0.006)	(0.004)	(0.009)	(0.104)	(0.018)	(0.010)	(0.008)	(0.004)	(0.010)
Size (log)	-0.000	0.007	0.001	0.029	-0.019	-0.009**	-0.004	0.003	0.004
	(0.009)	(0.005)	(0.009)	(0.026)	(0.012)	(0.004)	(0.007)	(0.004)	(0.012)
Graduates	-0.027	-0.033***	-0.029	-0.115**	-0.004	-0.008	-0.021	-0.032***	-0.022
	(0.019)	(0.008)	(0.020)	(0.047)	(0.022)	(0.007)	(0.018)	(0.008)	(0.025)
Corporation	0.017	-0.005	0.013	0.001	0.012	-0.023**	0.006	-0.010	0.041
	(0.022)	(0.010)	(0.022)	(0.076)	(0.036)	(0.011)	(0.032)	(0.011)	(0.032)
Family firm	-0.007	0.008	-0.008	0.036	0.008	0.004	-0.010	0.014	0.016
	(0.017)	(0.010)	(0.018)	(0.046)	(0.020)	(0.010)	(0.018)	(0.009)	(0.014)
Local banking development	0.111	0.018	0.120*	0.407**	0.176**	0.026	0.159**	0.034	0.118*
	(0.072)	(0.033)	(0.066)	(0.172)	(0.077)	(0.037)	(0.080)	(0.027)	(0.070)
Judicial inefficiency	0.038***	0.026***	0.039***	0.117***	0.057***	0.018**	0.046***	0.028***	0.040***
	(0.010)	(0.007)	(0.010)	(0.032)	(0.018)	(0.009)	(0.012)	(0.006)	(0.010)
Trust	0.306**	0.133**	0.289**	0.870***	0.132	-0.021	0.371***	0.138***	0.231*
	(0.120)	(0.056)	(0.115)	(0.290)	(0.310)	(0.106)	(0.092)	(0.046)	(0.126)
ROI					-0.009	-0.077*			
					(0.075)	(0.045)			
Sales growth					-0.022*	-0.001			
					(0.011)	(0.006)			
Intangibles					0.059	0.067			
					(0.099)	(0.057)			
Instrumental variables:									
Share UniCredit group		-0.139***		11.881***		-0.115		-0.129***	
		(0.047)		(1.776)		(0.081)		(0.039)	
Area dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,360	4,360	4,432	4,432	1,926	1,926	3,884	3,884	2,988

Notes: The table reports marginal effects for the probit and bivariate probit regressions. Three, two and one star (*) mean, respectively, a 99, 95 and 90 percent level of significance. Standard errors clustered at the province level are in parentheses. All of the variables are defined in Table 1.

Table 5
Non-linear effects

	Panel A: Firm size			Panel B: Firm age			
	Micro	Small	Medium	Age<7 years	Age 7-15 years	Age 15-26 years	Age >26 years
Dependent variable	Open innovation	Open innovation	Open innovation	Open innovation	Open innovation	Open innovation	Open innovation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Credit rationing	0.154	0.304***	0.142*	0.339***	0.195**	0.148	0.210
	(0.178)	(0.041)	(0.078)	(0.012)	(0.079)	(0.152)	(0.178)
Age (log)	-0.054***	-0.012	-0.010	0.021	0.141*	0.094	-0.030
	(0.018)	(0.008)	(0.012)	(0.021)	(0.076)	(0.097)	(0.053)
Size (log)	0.005	0.026**	-0.000	0.024*	0.002	0.001	0.010
	(0.009)	(0.010)	(0.005)	(0.012)	(0.010)	(0.016)	(0.015)
Graduates	-0.037	-0.019	0.015	-0.106***	-0.038	-0.030	-0.026
	(0.037)	(0.019)	(0.015)	(0.031)	(0.027)	(0.028)	(0.052)
Corporation	-0.044	-0.010	0.009	0.000	-0.023	0.007	-0.013
	(0.028)	(0.042)	(0.018)	(0.026)	(0.032)	(0.032)	(0.036)
Family firm	-0.003	0.022	0.023	-0.055**	-0.002	0.041*	0.017
	(0.017)	(0.021)	(0.028)	(0.022)	(0.032)	(0.023)	(0.050)
Local banking development	-0.229	0.022	0.100	0.033	0.168	0.051	-0.072
	(0.170)	(0.046)	(0.081)	(0.109)	(0.110)	(0.108)	(0.153)
Judicial inefficiency	-0.001	0.036***	0.026*	0.031	0.022	0.040**	0.022
	(0.021)	(0.013)	(0.015)	(0.026)	(0.021)	(0.018)	(0.025)
Trust	-0.055	0.291***	0.014	0.299	0.012	0.202	0.128
	(0.225)	(0.106)	(0.065)	(0.238)	(0.356)	(0.214)	(0.089)
Instrumental variables:							
Share UniCredit group	-0.177*	-0.140	-0.114	-0.079	-0.216**	-0.100	-0.148**
	(0.108)	(0.093)	(0.083)	(0.132)	-0.095	(0.208)	(0.065)
Area dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,234	2,145	981	1,059	995	1,055	1,251

Notes: The table reports marginal effects for the bivariate probit model. In Panel A, firms are classified on the basis of the number of employees: Micro enterprises are firms with less than 10 employees; Small enterprises are firms with more than 10 and less than 50 employees; Medium enterprises are firms with more than 50 employees. In Panel B, firms are classified on the basis of their age: 7, 15, and 26 years are, respectively, the 25th percentile, the median value, and the 75th percentile of the distribution. Three, two and one star (*) mean, respectively, a 99, 95 and 90 percent level of significance. Standard errors clustered at the province level are in parentheses. All of the variables are defined in Table 1.

Table 6
Product and process innovation

Dependent variable	Panel A: Product innovators			Panel B: Process innovators					
	Open innovation			Open innovation					
	All	New product	Improved product	All	Production	Logistics	Purchasing	Maintenance	IT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Credit rationing	0.269***	-0.086***	0.261***	0.230***	0.147	0.219***	0.049	0.025	0.306***
	(0.033)	(0.023)	(0.040)	(0.066)	(0.209)	(0.072)	(0.561)	(0.107)	(0.029)
Age (log)	-0.017***	-0.010	-0.016***	-0.012*	-0.020	-0.016	-0.006	0.006	-0.014
	(0.003)	(0.013)	(0.003)	(0.006)	(0.012)	(0.014)	(0.014)	(0.012)	(0.009)
Size (log)	0.002	0.011	0.004	0.009	0.007	0.019*	0.000	0.004	0.011
	(0.006)	(0.010)	(0.007)	(0.006)	(0.012)	(0.011)	(0.014)	(0.013)	(0.007)
Graduates	-0.033***	-0.033	-0.030***	-0.035***	-0.033	-0.057**	-0.030	-0.015	-0.027***
	(0.008)	(0.040)	(0.009)	(0.012)	(0.022)	(0.027)	(0.065)	(0.027)	(0.009)
Corporation	-0.018	-0.052***	-0.019	-0.008	-0.022	-0.031	-0.026	-0.057*	0.001
	(0.012)	(0.017)	(0.014)	(0.013)	(0.036)	(0.024)	(0.052)	(0.033)	(0.014)
Family firm	0.005	0.015	0.007	0.012	0.035	0.044***	0.044	0.051	-0.006
	(0.011)	(0.026)	(0.014)	(0.011)	(0.035)	(0.015)	(0.051)	(0.033)	(0.015)
Local banking development	0.018	0.012	0.002	0.046	0.029	0.036	0.046	0.064	-0.005
	(0.040)	(0.088)	(0.040)	(0.042)	(0.063)	(0.072)	(0.107)	(0.090)	(0.049)
Judicial inefficiency	0.028***	-0.004	0.031***	0.035***	0.044**	0.042***	0.013	0.027	0.034***
	(0.008)	(0.021)	(0.010)	(0.010)	(0.018)	(0.015)	(0.037)	(0.028)	(0.008)
Trust	0.101	-0.202	0.110	0.142**	0.184	0.327***	-0.138	-0.045	0.177***
	(0.067)	(0.181)	(0.097)	(0.068)	(0.227)	(0.113)	(0.430)	(0.128)	(0.050)
Instrumental variables:									
Share UniCredit group	-0.143**	0.199**	-0.142**	-0.113*	-0.046	-0.204*	-0.117	-0.064	-0.142**
	(0.062)	(0.092)	(0.065)	(0.062)	(0.167)	(0.112)	(0.247)	(0.156)	(0.066)
Area dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,226	2,198	2,922	3,660	1,678	1,631	1,860	1,605	2,257

Notes: The table reports marginal effects for the bivariate probit model. In Panel A, we consider the subsample of product innovators. In column (1) we consider all product innovators; in column (2) we consider firms introducing new products; in column (3) we consider firms improving existing products. In Panel B, we consider the subsample of process innovators. In column (4) we consider all process innovators; in column (5) we consider firms innovating production processes; in column (6) we consider firms innovating logistics processes; in column (7) we consider firms innovating purchasing processes; in column (8) we consider firms innovating maintenance processes; in column (9) we consider firms innovating IT processes. Three, two and one star (*) mean, respectively, a 99, 95 and 90 percent level of significance. Standard errors clustered at the province level are in parentheses. All of the variables are defined in Table 1.

Table 7
Open innovation partners

Dependent variable	Research centers/ Universities	Customers and clients	Suppliers	Firms of the same business group	Competitors	Trade associations
	Open innovation	Open innovation	Open innovation	Open innovation	Open innovation	Open innovation
	(1)	(2)	(3)	(4)	(5)	(6)
Credit rationing	-0.040	0.014	0.112***	0.014	-0.204	-0.140
	(0.051)	(0.047)	(0.005)	(0.023)	(0.969)	(0.145)
Age (log)	0.002	-0.009**	-0.003	-0.003	-0.010	0.012*
	(0.002)	(0.004)	(0.002)	(0.003)	(0.017)	(0.006)
Size (log)	0.008	0.002	-0.001	0.003	-0.001	0.004
	(0.005)	(0.003)	(0.001)	(0.003)	(0.010)	(0.006)
Graduates	0.017*	-0.025*	-0.007**	-0.005	-0.020	-0.030
	(0.009)	(0.013)	(0.003)	(0.004)	(0.084)	(0.020)
Corporation	0.009	-0.006	0.001	-0.005	-0.008	-0.023
	(0.008)	(0.006)	(0.004)	(0.005)	(0.012)	(0.020)
Family firm	0.001	0.002	0.006**	-0.001	0.020	0.001
	(0.006)	(0.006)	(0.003)	(0.004)	(0.064)	(0.010)
Local banking development	-0.007	0.014	-0.009	-0.005	0.023	0.024
	(0.015)	(0.028)	(0.009)	(0.007)	(0.060)	(0.037)
Judicial inefficiency	-0.003	0.014**	0.002	0.003	0.008	0.008
	(0.003)	(0.006)	(0.002)	(0.003)	(0.013)	(0.008)
Trust	0.020	0.061	0.009	-0.009	0.129**	0.011
	(0.041)	(0.086)	(0.020)	(0.019)	(0.053)	(0.082)
Instrumental variables:						
Share UniCredit group	-0.004	-0.023	-0.037**	-0.007	-0.000	-0.007
	(0.003)	(0.020)	(0.015)	(0.007)	(0.007)	(0.008)
Area dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,360	4,360	4,360	4,360	4,360	4,360

Notes: The table reports marginal effects for the bivariate probit model. Three, two and one star (*) mean, respectively, a 99, 95 and 90 percent level of significance. Standard errors clustered at the province level are in parentheses. All of the variables are defined in Table 1.

Table 8
The innovation environment

Panel A: Obstacles to innovation activity						
	No partners available	Low technological knowledge	No qualified personnel	Low market demand	Highly concentrated market	Very expensive innovation
Dependent variable	Open innovation	Open innovation	Open innovation	Open innovation	Open innovation	Open innovation
	(1)	(2)	(3)	(4)	(5)	(6)
Credit rationing	-0.134***	0.336**	0.293***	0.344***	-0.111***	0.066
	(0.007)	(0.166)	(0.101)	(0.030)	(0.009)	(0.128)
Instrumental variables:						
Share UniCredit group	0.339**	-0.055	-0.215	0.038	0.327***	-0.064
	(0.166)	(0.197)	(0.273)	(0.374)	(0.114)	(0.090)
+ Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Area dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	779	633	831	562	1,034	1,717

Panel B: Obstacles to collaborations (not for innovation purposes)			
	No autonomy limitations	No trust among firms	Potential partners far away
Dependent variable	Open innovation	Open innovation	Open innovation
	(1)	(2)	(3)
Credit rationing	-0.032	0.021	-0.081*
	(0.905)	(0.209)	(0.037)
Instrumental variables:			
Share UniCredit group	0.001	0.044	-0.865
	(0.744)	(0.283)	(0.621)
+ Control variables	Yes	Yes	Yes
Area dummies	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes
Observations	2,090	599	126

Panel C: Information sources for innovation activity						
	Internal sources	Firms of the same business group	Competitors	Suppliers	Customers and clients	Research centers/ Universities
Dependent variable	Open innovation	Open innovation	Open innovation	Open innovation	Open innovation	Open innovation
	(1)	(2)	(3)	(4)	(5)	(6)
Credit rationing	0.169	0.344***	0.277***	0.228**	0.284***	0.186
	(0.183)	(0.080)	(0.064)	(0.108)	(0.044)	(0.132)
Instrumental variables:						
Share UniCredit group	-0.245**	-0.295**	-0.350**	-0.167**	-0.228***	-0.139
	(0.107)	(0.131)	(0.139)	(0.083)	(0.083)	(0.180)
+ Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Area dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,020	1,605	1,546	2,892	2,616	908

Notes: The table reports marginal effects for the bivariate probit model. In Panel A, we consider the subsample of firms reporting a specific obstacle to innovation activity. In Panel B, we consider the subsample of firms reporting a specific obstacle to collaborations (not for innovation purposes). In Panel C, we consider the subsample of firms indicating a specific source of information for the innovation activity. Three, two and one star (*) mean, respectively, a 99, 95 and 90 percent level of significance. Standard errors clustered at the province level are in parentheses. All of the variables are defined in Table 1.

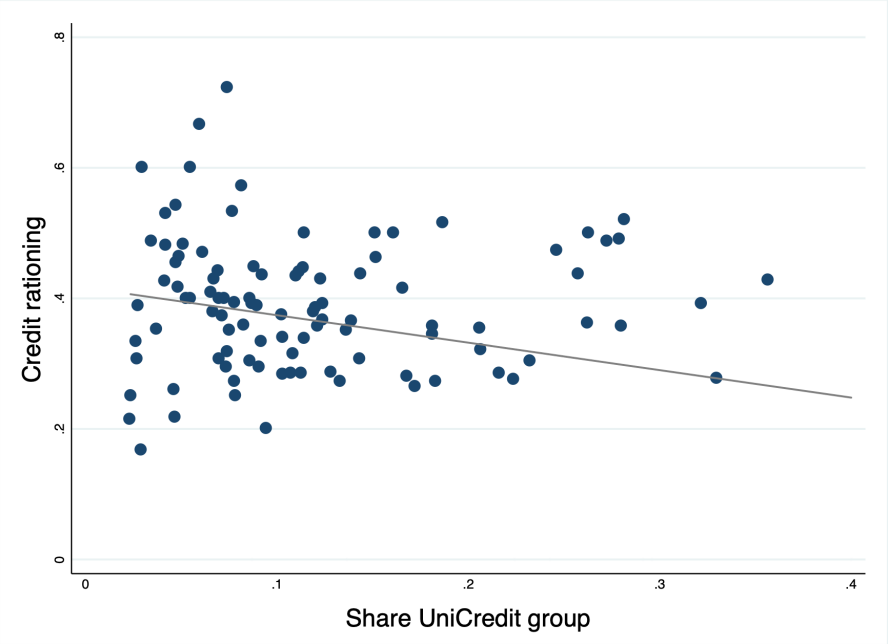
Table 9
The socio-economic environment

	Panel A: Trust		Panel B: Judicial efficiency	
	Low trust	High trust	Low judicial efficiency	High judicial efficiency
Dependent variable	Open innovation		Open innovation	
	(1)	(2)	(3)	(4)
Credit rationing	-0.113***	0.190***	-0.082**	0.280***
	(0.032)	(0.040)	(0.037)	(0.006)
Instrumental variables:				
Share UniCredit group	0.195	-0.221***	0.269**	-0.423***
	(0.130)	(0.071)	(0.122)	(0.122)
+ Control variables	Yes	Yes	Yes	Yes
Area dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Observations	2,103	2,257	2,359	2,001
	Panel C: Social capital		Panel D: Material infrastructure	
	Low social capital	High social capital	Low infrastructure	High infrastructure
Dependent variable	Open innovation		Open innovation	
	(1)	(2)	(3)	(4)
Credit rationing	0.303***	0.188***	0.200	0.273***
	(0.044)	(0.043)	(0.151)	(0.033)
Instrumental variables:				
Share UniCredit group	-0.205**	-0.124***	-0.125	-0.157***
	(0.091)	(0.996)	(0.149)	(0.040)
+ Control variables	Yes	Yes	Yes	Yes
Area dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Observations	2,212	2,148	1,693	2,667

Notes: The table reports marginal effects for the bivariate probit model. In Panel A, firms are classified as operating in provinces with low (high) trust, based on the median value of Italian provinces. In Panel B, firms are classified as operating in provinces with low (high) judicial efficiency based on the median value of Italian provinces. In Panel C, firms are classified as operating in provinces with low (high) social capital, measured by blood donations, based on the median value of Italian provinces. In Panel D, firms are classified as operating in provinces with low (high) material infrastructures, measured by a synthetic indicator provided by Geoweb starter, based on the median value of Italian provinces. Three, two and one star (*) mean, respectively, a 99, 95 and 90 percent level of significance. Standard errors clustered at the province level are in parentheses. All of the variables are defined in Table 1.

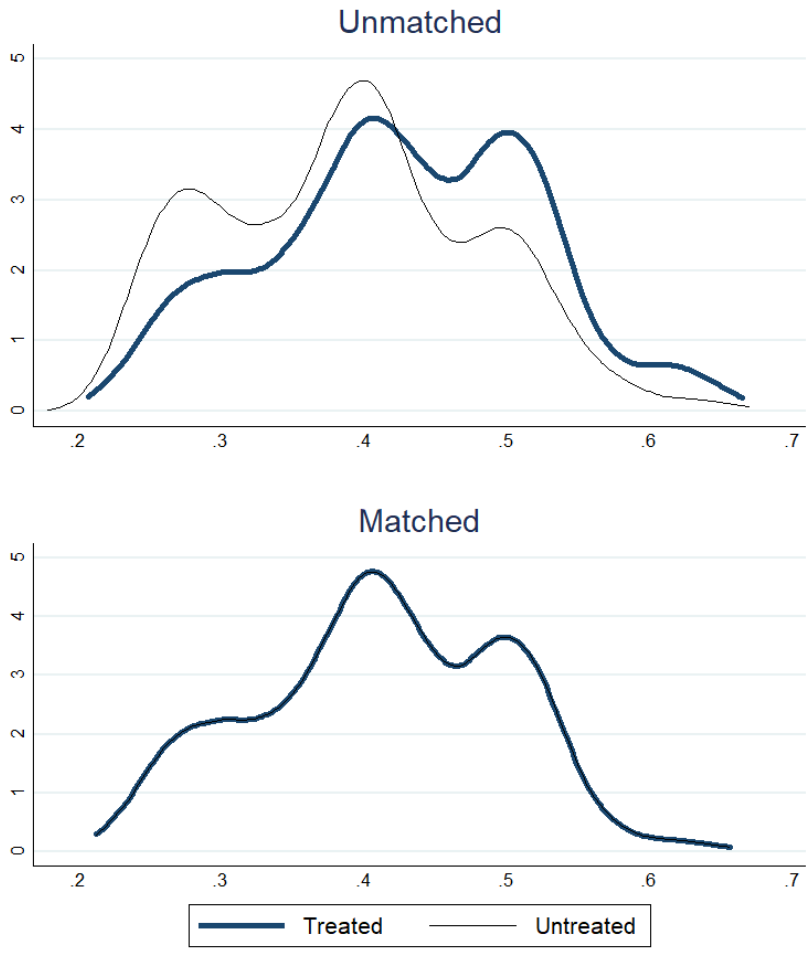
Appendix

Figure A1
Share of UniCredit group and credit rationing in Italian provinces



Notes: This figure plots the share of credit rationed firms in Italian provinces against the provincial share of brances of Unicredit group.

Figure A2
Balancing test for the propensity score matching (PSM)



Notes: This figure reports the performance of the balancing test between rationed (treated group) and non-rationed (control group) firms for the sample before and after matching.

Table A1
Partners of open innovation strategies

	Observations	%
Open innovation partners	3,502	67.02
Research centers/Universities	225	4.31
Customers or clients	971	18.58
Suppliers	1,492	28.56
Firms belonging to the same business group	383	7.33
Competitors	115	2.20
Trade associations	316	6.05
No innovation partners	1,723	32.98

Notes: The percentages reported in this table are computed with respect to the subsample of innovating firms.