



## Credit constraints and open innovation strategies <sup>★</sup>

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### ARTICLE INFO

#### JEL classification:

O36  
G32  
D22

#### Keywords:

Credit constraints  
Relationship lending  
Open innovation

### ABSTRACT

We examine how credit constraints influence firms' use of open innovation. Analyzing data from 7000 Italian small and medium-sized enterprises, we find that credit-rationed firms are 26% more likely to collaborate on innovation. This applies to both product and process innovators. However, credit rationing negatively impacts open innovation when introducing entirely new products, suggesting that opportunity costs become crucial in choosing between internal and open innovation under credit constraints. We investigate the role of innovation partners and discover that credit constraints increase the chances of innovation with suppliers. Moreover, we establish that credit's effect on innovation collaborations varies with the innovation environment and province socio-economic conditions.

### 1. Introduction

It has been widely recognized by economic research and policy practice that innovation represents a relevant driving force for firm-level productivity, competitiveness and sustainable economic growth (OECD, 2009; Cohen, 2010). 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; Amore et al., 2013).

Over 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 boundaries 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; Obradović 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 require greater investments in time and money (Cassiman and Veugelers, 2002, 2006; Berchicci, 2013).

Despite the considerable attention paid to cooperative innovation in recent years, there is still scant 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,

<sup>★</sup> We wish to thank Antonio Majocchi, Raoul Minetti, Tommaso Oliviero, Maria Savona, Giovanni Valentini, Alberto Zazzaro, and several seminar and conference participants for helpful comments and conversations. All remaining errors are ours. Declarations of interest: none.

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and under which conditions, the existence of credit constraints affects firms' reliance on open innovation. From a theoretical point of view, it is unclear whether firms with limited access to bank credit are more or less inclined to collaborate with external partners for innovative activities. Firms that are more exposed to credit rationing may have more incentives to rely on open innovation strategies in order to share the costs and risks associated with innovative activities, especially when they lack the necessary technological and human resources. However, they may find it more difficult to sustain the transaction and opportunity costs related to innovation collaborations. In this case, the existence of credit restrictions may reduce firms' involvement in open innovation activities. In order to perform our empirical investigation, we draw information from the VIII UniCredit Survey on small and medium-sized enterprises (SMEs), carried out in 2011 by the Italian banking group UniCredit on over 7000 Italian firms.<sup>1</sup> The survey data we use are an ideal testing ground for our purposes.<sup>2</sup> 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 innovation initiatives.

Endogeneity issues plague 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. To control for possible endogeneity of firms' exposure to credit rationing, we construct instruments capturing exogenous shocks to the structure of the Italian banking system. More specifically, we exploit the merger between two major Italian banking groups that occurred in 2007 and 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. A broad literature suggests that a bank merger can significantly affect the availability of credit to firms (Shaffer, 1993; Peek and Rosengren, 1998; Sapienza, 2002). In particular, the exploitation of economies of scale and scope in loan screening and monitoring, as well as the adoption of improved managerial and technological resources, can enhance banks' efficiency and the possibility to share information on loan applicants among local bank branches (Shaffer, 1993; Peek and Rosengren, 1998). Given the relevance of informational frictions in the credit market, these gains can significantly improve firms' access to bank credit. As we will see, the first-stage results will confirm this mechanism by highlighting a positive and significant effect of the bank merger on firms' credit availability. 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 not to be 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. Moreover, we show that this pattern is unlikely to be driven by a pure cost-shifting mechanism, where financially constrained firms transfer innovation costs onto partners by leveraging market power, but instead appears to reflect the quality and attractiveness of the focal firm's innovative projects.

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 the 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.

In additional tests, 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

<sup>1</sup> As a robustness check, we also exploit the limited information on innovation collaboration available in the VII UniCredit survey by pooling the 2010-2011 waves and leveraging the small panel of firms observed in both waves.

<sup>2</sup> 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), investigating the effect of bank support on firms' export (Bartoli et al., 2014), and analyzing family firms' access to credit (Peruzzi, 2024).

is located. The 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 with strong material infrastructures. Finally, our analysis provides suggestive evidence on the positive impact of open innovation adoption on medium-term firm profitability, especially under credit constraints.

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 hypothesis to be tested. Section 4 describes the dataset and the empirical strategy. Sections 5 and 6 discuss the empirical results. Section 7 presents a suggestive analysis of the potential implications of adopting open innovation strategies on firms' future profitability. Section 8 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 level of R&D intensity. In 2010, business formal R&D spending relative to the GDP was 1.2%, compared to 2.3% in the OECD countries and 1.9% in the European Union (World Bank, 2010). In spite of that, a significant percentage of firms appear to be engaged in innovation activities. Minetti et al. (2015), by relying on the Survey on Italian Manufacturing Firms, provide evidence that in the period 1997–2006, 51.2% of firms (mostly small- and medium-sized) introduced a product or process innovation. More recent data from the EU Community Innovation Survey (CIS) confirm that 51.9% of Italian enterprises with at least ten employees engaged in innovation activities between 2010 and 2012, with 35.5% of all enterprises focusing on product and process innovations (ISTAT, 2014).<sup>3</sup> Large enterprises were the most active (69.2%), followed by medium and small businesses (respectively, 54.8% and 32.7%). Unfortunately, only a small number of innovators chose to cooperate with other enterprises or institutions (12.5% of all the product 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., 2021). 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 consists of bank credit constraints. A relevant feature of the Italian banking system is its delimitation within provinces (Guiso et al., 2004; Presbitero et al., 2014), 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; Presbitero et al., 2014).

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 hypothesis 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 (Sections 3.1 and 3.2) and develop the hypothesis to be tested empirically (Section 3.3).

<sup>3</sup> These figures are in line with the percentage of innovating firms in our sample.

### 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; Giebel and Kraft, 2020). 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.

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.

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. 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. More recently, Giebel and Kraft (2020) analyze the change in firms' innovation behavior during the last financial crisis and highlight that innovation activities are affected by bank credit shocks.

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 (2003)'s 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 few years, given the relevance of this topic and its managerial implications, scholarly awareness of open innovation has substantially improved (Obradović 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 innovation 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 (Wassmer and Dussauge, 2012). In this regard, innovation cooperation allows them to maximize firm value through the combination of partners' resources and the exploitation of complementarities (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 (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 (Obradović et al., 2021). Since the 1970s, it has been recognized that customers are relevant 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; Obradović et al., 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. De Faria et al. (2010), by using the Portuguese Community Innovation Survey, provide evidence 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. Kleine et al. (2022), by analyzing a small sample of small and medium-sized enterprises in the United Kingdom, show that public subsidies promote firms' reliance on open innovation.

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 hypothesis

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 partners, 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 influence the adoption of open innovation strategies. For instance, in 2005, the NASA human research and development program faced a 45% reduction on its budget. While this resulted in the loss of some essential capabilities, including personnel, contracts and grants, the Human Health and Performance Directorate (HH&P) leadership responded by creating a new strategy based on collaborations to advance their mission, improve organizational performance, and enhance efficiency. This involved establishing strategic relationships to leverage external resources 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) managed to maintain the vitality of its R&D activities by exploiting some external opportunities. In particular, CRF selectively chose what knowledge to keep private and what to expose, and then shared non-core technologies with external partners to generate additional income. They also established long-term strategic partnerships with customers and new partners to diversify the exploitation of their complementary assets. These open approaches helped FIAT to avoid substantial reduction of R&D and innovation capabilities that would have negatively impacted the firm in the long term. More recently, Piccola Industria Confindustria, the main association representing Italian manufacturing

and services SMEs, has established an observatory on open innovation. The aim is to identify and provide visibility to concrete and replicable models of open innovation (Confindustria, 2016). Among the success stories, we find Arti Grafiche Boccia, a company founded in 1961 in the printing and typography sector; Immergas, operational since 1964, specializing in the design and manufacturing of domestic gas boilers; and Reda, a wool mill established in 1865. In all of these cases, it has been highlighted how access to open innovation has effectively facilitated innovation and research despite limited internal resources and budget constraints. In spite of this “positive” evidence of open innovation adoption in bad times, cooperation for innovation can be extremely costly for some firms. In fact, a survey on small Italian firms found that the most challenging factor for exploiting the opportunities associated to open innovation practices is the search and coordination costs that come with them (UniCredit, 2012).

Based on the theories described above, we propose the following hypothesis to be tested empirically:

*Hypothesis:* A priori, it is unclear whether firms with limited access to bank credit are more or less inclined to adopt open innovation strategies. Firms that are more exposed to credit rationing may have more incentives to cooperate for innovation in order to share the costs and risks associated with innovative activities, especially when they lack the necessary technological and human resources. However, they may find it more difficult to sustain the transaction and opportunity costs related to innovation collaborations. In this case, the existence of credit restrictions may reduce firms’ reliance on open innovation strategies.

## 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 on the previous year 2010. Each year, this survey collects data from a sample of Italian firms that are UniCredit’s customers. The sample is always representative of the bank’s portfolio, which is well diversified by sector due to the bank’s large scale in terms of loans, deposits, and branches.<sup>4</sup> In 2011, the survey targeted 7433 small and medium-sized enterprises, that were selected with a stratified sampling procedure in order to ensure the representativeness of the findings at the level of company size, individual sectors, as well as provinces. 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. Therefore, the uniqueness of our dataset relies on the provision of measures of access to credit and innovation activities that are based directly on firms’ responses to survey questions, rather than being indirectly inferred from balance sheet statements.

Employing data on self-reporting firms might raise concerns about firms misreporting their propensity to innovate and to collaborate on innovation activities. We do not believe this to be the case. First, 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. Second, respondents were provided with exhaustive instructions about the interpretation of the questionnaire, and special attention was devoted to make the questions understandable and to minimize measurement errors.<sup>5</sup> Third, a pure measurement error in the dependent variable would only affect the result if it were systematically related to one or more of the explanatory variables.

Table A1 reports a detailed description of all the variables employed in the empirical analysis. Table 1 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.

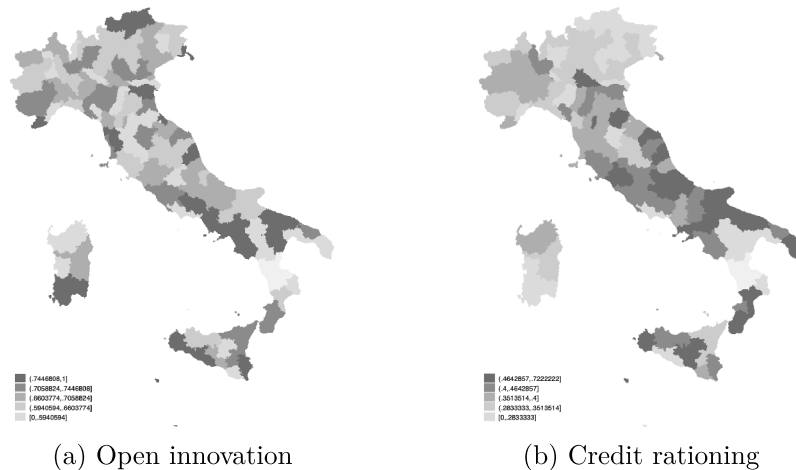
### 4.2. Measurement

#### 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 strictly adheres to this definition and is based on firms’ answers to the following question of the UniCredit survey: “Who is the main partner with whom

<sup>4</sup> Given the prominent position of UniCredit, the second largest bank in Italy with a market share of 13% in 2011, it is reasonable to expect that the sample used in this survey accurately represents the segment of small and medium-sized enterprises within the Italian economy.

<sup>5</sup> For instance, to prevent any ambiguity among the firms being interviewed, the survey questionnaire includes clear definitions of both product and process innovation. Product innovation is described as the introduction of a technologically new (or significantly improved) product or service compared to those previously available, in terms of technical and functional features, performance, ease of use, etc., excluding the sale of new products or services purchased from other companies. Similarly, process innovation is defined as the implementation of technologically new (or significantly improved) production processes or techniques compared to those previously adopted by the company, in terms of technical and functional features, performance, and ease of use.



**Fig. 1.** Credit constraints and open innovation adoption across Italian provinces (NUTS-3). Notes: The figures show the percentage of open innovation adoption and credit rationing for the firms in our sample.

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 as those who answered (i)-(vi). As the question on cooperation agreements was only asked to 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.<sup>6</sup>

As reported in Table 1, of the 5225 firms identified as innovative businesses, 67% (3,502 firms) claimed to adopt an open innovation strategy by collaborating on technological innovation activities with external partners.<sup>7</sup> 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%).<sup>8</sup> Fig. 1a 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), Minetti et al. (2019), Murro and Peruzzi (2019), we define credit rationed firms those ones that gave a positive response to this question.<sup>9</sup>

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. Fig. 1b draws the distribution of credit rationed firms across Italian provinces. The figure indicates that rationed firms are not clustered in few provinces. Although

<sup>6</sup> The reader could wonder whether this could bias our results. Hence, as a robustness check, we estimate a Heckman selection model. The results, available upon request, are consistent with the baseline findings discussed in Section 5.1.

<sup>7</sup> The share of firms engaging in open innovation (67%) may appear relatively high, but it is broadly consistent with evidence from other studies. For instance, Tether (2002), using data on UK enterprises for 1997, finds that about 49.5% of firms innovate and that roughly 45% of those innovators collaborate with external partners. Given that our data refer to 2010, the higher figure we observe is consistent with the increasing diffusion of open innovation practices over time. In addition, Italian small and medium-sized enterprises often operate within dense national and global supply chains (Murro and Peruzzi, 2025), where collaboration with suppliers and customers is frequent and may contribute to the relatively high share of open innovation observed in our data.

<sup>8</sup> See Table A2.

<sup>9</sup> In this paper, we focus on the impact of bank credit constraints on firms’ open innovation strategies by neglecting the role of other sources of financing, such as equity. Although this could represent a limitation of the paper, as equity is known to be an important source of financing for R&D activities, it is rather a minor concern in our context. In fact, as discussed in Section 2, the nature of the Italian financial system and the size of the firms in our sample make bank credit the most used source of external financing (Minetti and Zhu, 2011). The financial information provided by the survey suggests that bank credit represents more than 68% of external financial resources for the firms under analysis.

**Table 1**  
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.	
<i>Dependent variables:</i>													
Open innovation	0.670	0.470	5225						0.719	2047	0.644	3050	-5.685
<i>Independent variables:</i>													
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
<i>Control variables:</i>													
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
<i>Instrumental variables:</i>													
Share UniCredit group	0.148	0.079	7433	0.147	3502	0.148	1723	0.477	0.149	2731	0.148	4516	-0.361
<i>Other variables:</i>													
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
Innovation	0.703	0.457	7433					0.749	2731		0.675	4516	-6.847
Open vs. No Innovation	0.613	0.487	5710					0.682	2155		0.572	3429	-8.398
Closed vs. No Innovation	0.438	0.496	3931					0.457	1260		0.426	2553	-1.833
<i>Geographical areas:</i>													
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
<i>Industry sectors:</i>													
Agriculture	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 A1.

**Table 2**  
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

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 an 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 (Berger and Udell, 1995; Guiso and Minetti, 2010). 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; Bartoli et al., 2013). 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 2).

#### 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).<sup>10</sup> 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. 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 (Chesbrough, 2003; Brockman et al., 2018). 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, 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, typically reluctant to invest in unfamiliar technology classes, may be incentivized to form strategic alliances and profit from collaborations (Brockman et al., 2018). By contrast, family owned businesses may be reluctant to disclose information with other parties and cooperate (Murro and Peruzzi, 2019; Peruzzi, 2026). 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 (Benfratello et al., 2008; D'Onofrio et al., 2019). 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),<sup>11</sup> based on the area where the firm is located, and sector dummies according to the one-digit NACE classification.<sup>12</sup>

#### 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:

$$P(\text{Open innovation}_i = 1) = \Phi(\alpha_1 + CR_i\beta_1 + Z_i\gamma_1) \quad (1)$$

where  $\Phi$  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 Eq. (1) by maximum likelihood probit regressions.<sup>13</sup>

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 Eq. (1) and the following probit equation for firms' access to credit:

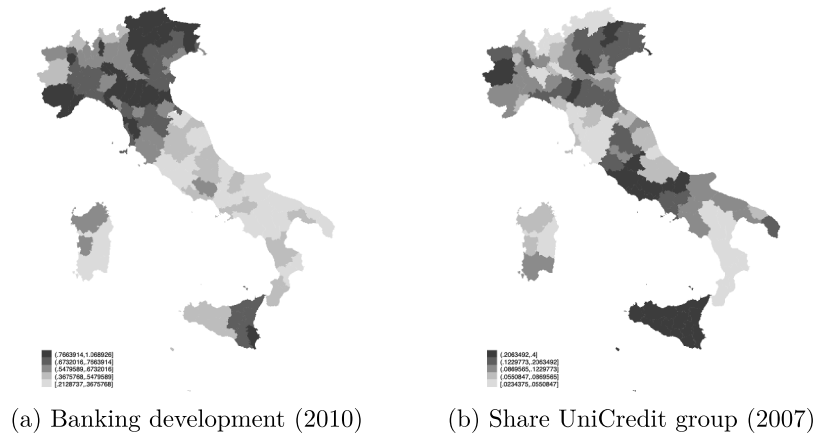
$$P(CR_i = 1) = \Phi(IV_i\delta_1 + Z_i\lambda_1) \quad (2)$$

<sup>10</sup> The log transformation of the two variables reduce the skewness of their distributions and mitigate the influence of extreme values. Moreover, it allows for diminishing marginal effects, consistent with the notion that the incremental impact of an additional year of age or one more employee decreases as firms grow older or larger (see, e.g., Herrera and Minetti, 2007; Murro and Peruzzi, 2019; Peruzzi, 2024).

<sup>11</sup> The NUTS classification (Nomenclature of territorial units for statistics) is a hierarchical system for dividing up the economic territory of the European Union with the objective to collect and develop European regional statistics, perform economic analyses, and frame regional policies. According to the first level of classification (NUTS-1) the European territory is classified in major socio-economic regions. In Italy, that is the country under analysis, this implies having five major areas: North East, North West, Center, South, Isles.

<sup>12</sup> The survey asks each firm to indicate its activity sector based on the following categorization: Agriculture, Manufacturing, Services, Trade, Tourism, and Construction. However, as a robustness check, we reestimate our regressions using the two-digit NACE classification, which is available only for a subsample of firms.

<sup>13</sup> In all the regressions, standard errors are heteroskedasticity robust, clustered at the regional level.



**Fig. 2.** Banking development and share of UniCredit group across Italian provinces (NUTS-3). Notes: The figures show bank branches per 100,000 inhabitants in the provinces for 2010 (left) and the share of provincial branches of UniCredit and Capitalia for 2007 (right).

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 Eq. (1).<sup>14</sup>

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. In particular, following Minetti et al. (2019), we construct our instrument by exploiting the merger that occurred in 2007 between two major Italian banking groups, UniCredit and Capitalia, which in turn comprised Banca di Roma, Banco di Sicilia, and Bipop-Carire.<sup>15</sup> The banking literature has widely documented that mergers between major banking groups can affect firms' credit access through two competing channels. On the one hand, mergers may improve credit availability, by enhancing banks' efficiency in loans origination and management, and by fostering informational gains through the integration of databases and monitoring systems (Shaffer, 1993; Peek and Rosengren, 1998). On the other hand, mergers can also reduce local competition, potentially leading to tighter credit conditions (Sapienza, 2002). The net effect on credit supply therefore depends on which of these two mechanisms dominates. The report prepared by UniCredit to explain the merger and the documents of the Italian regulatory agencies and of the Bank of Italy assessing the merger indicated that important benefits were expected from the merger of UniCredit and Capitalia in terms of information sharing, economies of scale and scope, and improvements in loan origination and management (Minetti et al., 2019).<sup>16</sup> In particular, as instrumental variable, we use the provincial share of branches of the merging banking groups over the total number of branches in the province (*Share UniCredit group*). This variable captures the intensity of the merger shock in the provincial credit market. Although these banks operated nationwide, their branch presence differed markedly across provinces before the merger. We thus expect a different effect of the merger on credit access depending on the importance of the merged banks, relative to other banks, in the local credit market at the time of the merger.

In order to be valid, the instrument must be exogenous, that is, it must not be correlated with unobservable variables that could also influence firms' adoption of open innovation strategies, and it must be relevant, that is, correlated with our measures of credit rationing and relationship length. With respect to the exogeneity condition, we have strong reasons to believe that, at the time of the merger, the relative branch presence of the two banking groups across provinces was not correlated with the economic features of the provinces. As discussed by Minetti et al. (2019), this presence was largely determined by the historical evolution of the Italian banking sector under the 1936 banking regulation, as well as by the long-standing geographical roots and community ties of each bank (see Fig. A1). For example, Banco di Sicilia (belonging to the Capitalia banking group), founded in 1849 in the southern region of Sicily, was particularly important in the Sicilian provinces due to its traditional vocation to serve local markets. In the North, Bipop-Carire (also part of Capitalia) had a strong presence in the province of Reggio Emilia, but a very weak one in the nearby provinces of Lucca and Pisa, despite similar levels of GDP per capita and banking development. In these latter provinces, the bank Monte dei Paschi di Siena had deep historical roots dating back to the Middle Ages, which explains its extensive presence there. Fig. 2 displays the relative branch presence of the merged banks in the provinces before the merger became effective, alongside a measure

<sup>14</sup> Eqs. (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 Eq. (1). Although  $CR_i$  enters Eq. (1) as an endogenous variable, Eqs. (1) and (2) can be estimated using a standard bivariate probit software (Greene, 2002).

<sup>15</sup> In May 2007, UniCredit bought Capitalia for more than \$29 billion in shares. The merger strengthened UniCredit's position as Italy's largest bank by market value, with branches extending from Sicily to Eastern Europe and with operations in four core markets (Italy, Germany, Austria, and CEE, with a presence in 17 countries). The group resulting from the merger adopted a business model consistent with the previous divisional structure of UniCredit, and Capitalia's activities were integrated within the existing UniCredit divisions.

<sup>16</sup> See, for example, the documents of Consob on the merger of UniCredit and Capitalia drafted on the basis of Consob directive no. 11971, the report on the merger presented by UniCredit in response to Consob, and the related documents of the Italian Competition Authority.

of local banking development (the number of bank branches normalized by provincial population). As the maps show, there appears to be very little correlation between the two measures. In fact, the correlation coefficient is -0.17 and the rank correlation coefficient across provinces equals -0.07. This evidence supports the view that our instrument is unlikely to capture contemporaneous economic or innovation-related factors.<sup>17</sup>

Turning to the relevance condition, the impact of bank mergers on credit supply can, as discussed above, reflect a trade-off between efficiency and competition effects. In our context, we expect the informational-efficiency effect to dominate. Italian small and medium-sized enterprises rely heavily on bank financing, and their relevant credit market is the provincial one. The small size and informational opacity of these firms imply that any merger-driven improvements in banks' information sharing and screening processes could translate into better credit availability. Moreover, as noted earlier, UniCredit and Capitalia had limited branch overlap across provinces prior to the merger, so the transaction did not materially reduce local competition. Instead, it mainly produced informational and organizational synergies, such as the integration of databases and credit-rating systems, which are particularly beneficial in a context characterized by informational opacity and relationship lending. Consistent with this interpretation, Fig. A2 shows a clear negative relationship between the share of credit-rationed firms across provinces and the provincial share of branches of the merged banks. Provinces where the merging groups were more represented before the merger display lower levels of credit rationing, in line with the view that the merger improved credit provision. The first-stage regressions confirm this descriptive pattern: the larger the pre-merger share of branches of the merged banks in a province, the smaller the probability of firms being credit constrained. These results support the relevance of our instrument and indicate that, in our setting, the efficiency and information-sharing gains of the merger clearly outweighed any potential loss of competition.

## 5. Main results

This section presents the baseline findings (5.1) and discusses some preliminary insights into the underlying mechanisms (5.3).

### 5.1. Credit constraints and open innovation

Table 3 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 instrumented bivariate probit model specified in Eqs. (1) and (2).<sup>18</sup> 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 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.<sup>19</sup> As discussed in Section 3 when framing our hypothesis, we interpret this finding as suggesting that credit constrained firms are more incentivized to cooperate for innovation to share the costs and risks associated with innovative activities, and to overcome any internal shortfalls in technological and human resources. The bottom of column (1) reports the marginal effect of the instrument from the 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 consistent with the notion that, in our setting, the positive efficiency and information-sharing effects of the merger outweighed the potential negative effect of reduced competition. The two banks had limited branch overlap across provinces prior to the merger, so the transaction did not significantly decrease local competition. Instead, it improved screening and monitoring efficiency and facilitated the diffusion of internal credit information across branches, ultimately expanding credit availability to firms.<sup>20</sup> The estimated marginal effects 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).

<sup>17</sup> It is not possible to completely rule out the possibility that there may be some unobserved provincial characteristics correlated with both the initial presence of the merged banks and firms' innovation behavior. To alleviate this concern, as discussed in Section 4.2.3, we include a variety of province-level controls in our regression analyses.

<sup>18</sup> The non-instrumented probit estimates of Panels A and B of Table 4 are reported in Table A3.

<sup>19</sup> When compared with the marginal effect obtained with the probit model reported in Table A3, the marginal effect of credit rationing from the bivariate probit appears to be particularly large. One interpretation 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.

<sup>20</sup> The Kleibergen-Paap Wald F-statistic from the first stage, equal to 5.23 and 21.55 for the variables *Credit rationing* and *Relationship length*, respectively, suggests that we do not face an issue of weak instruments. However, it is important to stress here that the literature on weak instruments is less developed with regard to diagnostics for nonlinear IV models (see, e.g., Mikusheva (2013), for a survey). Thus, the often used cutoff values for the first-stage F-statistics are derived using a linear model under the assumption that the model is homoskedastic (Stock and Yogo, 2005).

Panel B reports the estimations of a set of robustness checks. In column (2), 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 IV probit model highlight a negative and statistically significant association between the length of the firm's main lending relationship and the reliance on open innovation strategies. 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: firms with shorter credit relationships, that means higher financial constraints, are more likely to cooperate with external partners on innovation projects. In column (3), we reestimate our baseline regression by employing a different classification of open innovation strategies. More specifically, we remove from the definition of open innovation the innovation done with firms belonging to same business group and consider it as a closed innovation activity. As reported in Table A2, in our sample, 7.33% of firms declare to perform innovation activities with this type of partner. The results carry through.

The reader may wonder whether credit constraints affect firms' overall propensity to innovate, or whether they primarily shape the way innovation is organized. If credit rationing does not reduce the likelihood of innovating per se, but instead influences firms' choice between closed and open innovation models, this would suggest that open innovation represents an adjustment margin through which financially constrained firms can sustain their innovative activity. To investigate this issue, Table A4 adopts a two-layered approach. In Panel A, column (1), we estimate the effect of credit rationing on firms' overall decision to innovate, using as dependent variable the dummy *Innovation*, which is equal to one if the firm introduces either product or process innovations, and zero otherwise. The marginal effect of credit rationing is not statistically significant, indicating that credit constrained firms are not less likely to innovate in general.

We then move to the second layer and examine how credit constraints affect the mode of innovation. In columns (2) and (3), we distinguish between firms that rely on open innovation and firms that rely exclusively on closed innovation, relative to non-innovating firms. Specifically, we construct two outcomes: *Open vs. No Innovation*, equal to one if the firm relies on open innovation strategies, and zero if the firm does not innovate; *Closed vs. No Innovation*, equal to one if the firm innovates without external partners, and zero if the firm does not innovate. The bivariate probit estimates show that credit rationing is negatively associated with the likelihood of adopting purely closed innovation, while it is positively and significantly associated with engaging in open innovation. This pattern indicates that financially constrained firms are less likely to innovate only internally, but more likely to involve external partners in their innovation activities.

To further strengthen this interpretation, Panel B of Table A4 reports results from an ordered probit model that jointly considers three innovation outcomes: no innovation, (only) closed innovation, and open innovation. The marginal effects indicate that credit rationing significantly reduces the probability of both no innovation and closed innovation, while it increases the probability of open innovation. This ordered framework confirms that credit constraints do not simply operate at the extensive margin of innovation, but rather shift firms toward organizational forms that rely on external collaboration.

Overall, these findings suggest that credit constraints do not necessarily suppress innovative activity, but instead influence how firms innovate. Firms facing financial limitations appear to reorganize their innovation process by leveraging external knowledge and resources, rather than abandoning innovation altogether. This interpretation is consistent with recent evidence showing that financial pressure or adverse economic conditions can induce firms to search for alternative strategies and organizational arrangements, leading to heterogeneous and sometimes proactive innovation responses (Archibugi et al., 2013; Brzozowski et al., 2019; Cucculelli and Peruzzi, 2020b; Minetti et al., 2025). In this perspective, open innovation emerges as a strategic response that allows credit-constrained firms to remain innovative despite limited internal financial resources.

### 5.1.1. More on the identification strategy

Panel C of Table 3 reports a set of additional robustness tests aimed at further addressing endogeneity issues. A first concern with our identification strategy is related to omitted variables. To assuage this concern, in column (4), we reestimate our baseline regression by including three other firm-level variables, i.e., the return 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.<sup>21</sup> As shown at the bottom of Table 3, 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 effect for the bivariate probit model is positive and statistically significant. Then, in column (5), we rerun the baseline estimate by adding the two-digit industry dummies for manufacturing firms, while retaining the broader industry dummies for non-manufacturing businesses. As noted, also in this regression 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. A second concern regards potential violations of the exclusion restrictions associated with our instrument. We do not have any reasons to expect that our instrumental variable impacts on firms' adoption of open innovation through channels other than their experience of credit rationing. Nonetheless, the reader may be concerned that our instrument captures province-specific characteristics that could directly influence innovation collaborations. Although we have already included a set of province-level controls in our baseline regression, in column (6) we make additional efforts to address these concerns, by adding industry by region fixed effects. Once again, our results closely align with those obtained from the baseline analysis.

<sup>21</sup> This information is drawn from Centrale dei Bilanci database, which gathers yearly financial data on approximately 35,000 Italian businesses. These data include balance sheets, income statements, and other relevant metrics. The database is managed by a consortium of banks and utilizes information from sources like the Italian Chambers of Commerce. It is representative of the Italian business sector and has a very comprehensive coverage of small and medium-sized firms (Minetti et al., 2019).

**Table 3**  
Credit constraints and open innovation.

Dependent variable	Panel A: Baseline results		Panel B: Robustness on measurement		Panel C: More on the identification strategy							
	Bivariate probit		Excluding OI within groups		Additional controls		2-digit NACE FE		Region × Industry FE		Propensity score matching	
	Open innovation	IV Probit	Open innovation	Bivariate probit	Open innovation	Bivariate probit	Open innovation	Bivariate probit	Open innovation	Bivariate probit	Open innovation	Probit
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	
Credit rationing	0.264*** (0.031)	-0.061*** (0.018)	0.256*** (0.013)	0.251*** (0.017)	0.252*** (0.031)	0.245*** (0.075)	0.073*** (0.012)					
Relationship length												
Age (log)	-0.015*** (0.004)	0.279*** (0.104)	-0.008** (0.004)	-0.021** (0.010)	-0.015*** (0.004)	-0.016** (0.006)	-0.029*** (0.010)					
Size (log)	0.007 (0.005)	0.029 (0.026)	0.002 (0.003)	-0.009** (0.004)	0.003 (0.004)	0.011 (0.007)	0.004 (0.012)					
Graduates	-0.033*** (0.008)	-0.115*** (0.047)	-0.021*** (0.007)	-0.008 (0.007)	-0.032*** (0.008)	-0.049*** (0.014)	-0.022 (0.025)					
Corporation	-0.005 (0.010)	0.001 (0.076)	0.001 (0.009)	-0.023** (0.011)	-0.010 (0.011)	-0.010 (0.011)	0.041 (0.032)					
Family firm	0.008 (0.010)	0.036 (0.046)	0.009 (0.006)	0.004 (0.010)	0.014 (0.009)	0.006 (0.008)	0.016 (0.014)					
Local banking development	0.018 (0.033)	0.407*** (0.172)	0.018 (0.028)	0.026 (0.037)	0.034 (0.027)	0.001 (0.050)	0.118* (0.070)					
Judicial inefficiency	0.026*** (0.007)	0.117*** (0.032)	0.017*** (0.007)	0.018** (0.009)	0.028*** (0.006)	0.055*** (0.016)	0.040*** (0.010)					
Trust	0.133** (0.056)	0.870*** (0.290)	0.110*** (0.040)	-0.021 (0.106)	0.138*** (0.046)	0.155** (0.071)	0.231* (0.126)					
ROI				-0.077* (0.045)								
Sales growth				-0.001 (0.006)								
Intangibles				0.067 (0.057)								
<i>Instrumental variables:</i>												
Share UniCredit group	-0.139*** (0.047)	11.881*** (1.776)	-0.113*** (0.036)	-0.115 (0.081)	-0.367*** (0.087)	-0.129*** (0.039)						
Area dummies	Yes	Yes	Yes	Yes	Yes	No	Yes					Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	No	Yes					Yes
Region × Industry dummies	No	No	No	No	No	Yes	No					No
Observations	4360	4432	4360	1926	3884	3850	2,988					

Notes: The table reports marginal effects for the bivariate probit, IV probit, and probit regressions. Three, two and one star (\*, \*\*, \*\*\*) mean, respectively, a 99, 95 and 90 percent level of significance. Standard errors clustered at the regional level are in parentheses. All of the variables are defined in Table A1.

In column (7), we further account for endogeneity concerns by following a propensity score matching (PSM) approach (Murro and Peruzzi, 2022). 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<sup>22</sup> and requires a tolerance level for the maximum propensity score distance (caliper) between the treatment and the control group equal to 0.0001.<sup>23</sup> Once obtained the treatment and control groups, we end the procedure by rerunning our baseline regression as in Eq. (1). Estimation results are reported in column (7) and are fully consistent with the baseline regressions discussed above.

As an additional robustness check, we complement our baseline estimates by exploiting the limited information on collaboration available in the 2010 wave of the UniCredit survey and pooling the 2010–2011 waves. While the survey is conducted annually, questions explicitly capturing innovation collaborations are not systematically collected across waves. The 2010 wave only includes a more indirect question, which provides a proxy of openness that is not fully comparable to our baseline 2011 measure.<sup>24</sup> Despite these measurement differences, using the closest available proxy in each wave we estimate a repeated cross-section specification pooling 2010 and 2011. The results, reported in Table A5, remain consistent with our baseline evidence. We also exploit the small panel component of firms observed in both waves and estimate a panel fixed effects specification. Although the panel sample is necessarily limited, the estimates continue to point to a positive association between credit constraints and open innovation.

## 5.2. Innovation quality and bargaining power

The baseline results indicate that firms facing credit constraints are more likely to adopt open innovation strategies. A natural question is why external partners are willing to collaborate with firms that experience limited access to finance. One possibility is that credit constrained firms possess particularly valuable or high-quality innovative projects, which make collaboration attractive despite financial frictions. An alternative explanation is that firms under financial pressure may rely on their bargaining power, especially vis-à-vis suppliers, to shift part of the innovation costs onto their partners, raising the concern that such collaborations may reflect cost shifting rather than genuine open innovation. In this subsection, we provide suggestive empirical evidence to assess the relevance of these two mechanisms.

We first investigate whether the relationship between credit constraints and open innovation depends on the quality of the innovation being introduced. The UniCredit survey allows us to distinguish between firms that introduced innovations that are new to the market and firms that introduced innovations that are new only to the firm.<sup>25</sup> The former are generally considered more ambitious and knowledge-intensive, and therefore more likely to generate spillovers and attract external partners (Cucculelli and Peruzzi, 2020a). In Table 4, Panel A, we re-estimate our baseline specification separately for these two subsamples. The results show a clear asymmetry. Credit constraints are positively and significantly associated with the adoption of open innovation strategies only among firms introducing innovations that are new to the market. By contrast, for firms whose innovations are new only to the firm, the effect of credit rationing on open innovation is not statistically significant. This evidence suggests that open innovation by credit constrained firms is not merely a mechanical response to financial scarcity. Instead, it appears to be concentrated among firms undertaking higher-quality projects, for which collaboration can provide access to complementary knowledge. These findings support the interpretation that external partners engage in collaboration because the underlying innovation projects are valuable, rather than because financially constrained firms are simply offloading costs.

We then turn to the role of bargaining power, with particular attention to collaborations with suppliers. If credit constrained firms rely on open innovation primarily to shift financial pressure onto their partners, the effect of credit constraints on collaboration should be stronger for firms with greater bargaining power. To test this hypothesis, in Table 4, Panel B, we exploit additional information from the survey. First, we distinguish firms that self-report being leaders of their supply chain from those that do not.<sup>26</sup> Supply chain leadership can be interpreted as a proxy for stronger bargaining power in vertical relationships (Minetti et al., 2019). The results show that the positive effect of credit constraints on open innovation is present among firms that are not leaders of their supply chain, while it is not statistically significant among supply chain leaders. This pattern runs counter to the cost-shifting hypothesis, as firms with weaker bargaining positions are precisely those for which collaboration increases in response to credit constraints.

<sup>22</sup> The control variables included in the estimation are: Age, Size, Graduates, Corporation, Family firm, Local banking development, Judicial efficiency, Trust.

<sup>23</sup> Fig. A3 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.

<sup>24</sup> The 2010 UniCredit survey asks: “To foster innovation activities, did the firm develop relationships with other local actors? (i) research centers; (ii) customers or suppliers; (iii) other firms; (iv) trade associations.”

<sup>25</sup> The UniCredit survey asks: “The product or service innovations introduced in the last three years are: (i) products or services that are technologically new (or significantly improved) for the reference market; (ii) products or services that are technologically new (or significantly improved) only for the firm.”

<sup>26</sup> The UniCredit survey asks: “Who makes the decisions within the supply chain in which the firm operates that affect its activity? (e.g., quality standards, major product changes) (i) leading firm in the supply chain (other than the interviewed firm); (ii) decisions are jointly agreed upon among supply chain participants; (iii) interviewed firm itself.” We define a firm as a supply chain leader if it reports that decisions affecting its activity are taken by the interviewed firm itself.

**Table 4**  
Innovation quality and bargaining power.

Dependent variable	Panel A: Innovation quality		Panel B: Bargaining power			
	Inno. new to the market	Inno. new to the firm	Supply chain leader	Supply chain non-leader	Local partners	National/ Foreign partners
	Open innovation	Open innovation	Open innovation	Open innovation	Open innovation	Open innovation
	(1)	(2)	(3)	(4)	(5)	(6)
Credit rationing	0.290*** (0.019)	0.206 (0.237)	0.093 (0.185)	0.260*** (0.012)	0.043 (0.120)	0.091*** (0.010)
+ 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	1980	1246	715	3645	4360	4,360

Notes: The table reports marginal effects for the bivariate probit model. In Panel A, firms are split according to the quality of innovation, distinguishing between innovations that are new to the market and those that are new to the firm but already existing in the market. In Panel B, firms are classified using proxies for bargaining power in the supply chain, distinguishing between supply-chain leaders and non-leaders, and between firms collaborating mainly with local partners and those collaborating with national/foreign partners. Three, two and one star (\*) mean, respectively, a 99, 95 and 90 percent level of significance. Standard errors clustered at the regional level are in parentheses. All of the variables are defined in [Table A1](#).

Second, we distinguish collaborations based on the geographical scope of the partner, separating firms that collaborate mainly with local partners from those collaborating with national or foreign partners.<sup>27</sup> Collaborations with more distant partners are typically associated with weaker bargaining power and higher coordination costs (Peruzzi, 2026). Consistently with the previous result, we find that the positive relationship between credit constraints and open innovation is driven by firms collaborating with national or foreign partners, whereas no significant effect emerges for firms collaborating only with local partners.

Taken together, these results indicate that bargaining power is unlikely to be the main driver of the observed relationship between credit constraints and open innovation. Rather, credit constrained firms seem to be more likely to engage in open innovation precisely when they have less ability to impose terms on their partners. This further supports the interpretation that open innovation represents a strategic response to financial constraints aimed at accessing external knowledge and sharing innovation risks, rather than a mechanism to transfer costs onto suppliers.

### 5.3. Heterogeneous effects

The impact of credit constraints on firms’ reliance on open innovation strategies may vary depending on some firm characteristics. In this section, we provide further insights into the relationship between credit rationing and innovation collaborations by examining whether the effect differs across firms of different size and age. Estimation results are reported in [Table 5](#).

Panel A re-estimates the baseline regression of [Table 3](#) for the subsamples of micro, small, and medium-sized businesses. Following the European Commission’s definition, we classify firms with fewer than 10 employees as micro enterprises, those with fewer than 50 employees as small, and those with fewer than 250 employees as medium. The marginal effects of the bivariate probit regressions in columns (1)-(3) show that credit constraints are positively and significantly associated with firms’ probability of cooperating for innovation only for small and medium-sized enterprises. Among these, firms facing credit rationing are, respectively, 30.4 and 14.2 percentage points more likely to rely on open innovation strategies than non-rationed businesses. Conversely, for micro enterprises, the estimated coefficient is not statistically significant. This result likely reflects a weaker responsiveness of very small firms to credit rationing in terms of innovation collaborations.

Panel B presents the results when the sample is divided by firm age. 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 mainly driven by younger firms. Among businesses with less than 7 years, credit rationed firms are 33.9 percentage points more likely to engage in innovation agreements than non-rationed ones. Similarly, among firms operating for 7–15 years, those experiencing credit restrictions are 19.5 percentage points more likely to rely on open innovation than non-restricted businesses. These findings are consistent with the idea that younger firms are typically more flexible and resource-seeking, which makes them more likely to translate credit constraints into opportunities for cooperation.

Although firm size and age are positively correlated, in the Italian context many older firms remain micro or small. Hence, the two dimensions capture partially overlapping but distinct aspects of firm heterogeneity. The age-related heterogeneity reflects differences

<sup>27</sup> The UniCredit survey asks: “Where is the main partner with whom the firm has developed relationships or cooperation agreements to support innovation activities located? (i) in the same province where the firm’s administrative headquarters are located; (ii) in the same region where the firm’s administrative headquarters are located; (iii) elsewhere within the national territory; (iv) abroad.” Firms are classified as collaborating with local partners if the main innovation partner is located in the same province or region (options i-ii), and with national/foreign partners if the partner is located elsewhere in the country or abroad (options iii-iv).

**Table 5**  
Heterogeneous effects.

Dependent variable	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
	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 (0.178)	0.304*** (0.041)	0.142* (0.078)	0.339*** (0.012)	0.195** (0.079)	0.148 (0.152)	0.210 (0.178)
+ Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Area dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1234	2145	981	1059	995	1055	1251

Notes: The table reports marginal effects for the bivariate probit model. In Panel A, 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 (the 25th, 50th, and 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 regional level are in parentheses. All of the variables are defined in [Table A1](#).

**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*** (0.033)	−0.086*** (0.023)	0.261*** (0.040)	0.230*** (0.066)	0.147 (0.209)	0.219*** (0.072)	0.049 (0.561)	0.025 (0.107)	0.306*** (0.029)
+ Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Area dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3226	2198	2922	3660	1678	1631	1860	1605	2257

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 regional level are in parentheses. All of the variables are defined in [Table A1](#).

in firms' dynamism and openness to change, whereas the size-based heterogeneity relates to differences in the extent to which firms' behavior responds to financing constraints.

## 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

A large body of research highlights that product and process innovations differ systematically in their objectives, knowledge characteristics, and exposure to transaction and opportunity costs ([Herrera and Minetti, 2007](#)). Product innovations typically aim at introducing or substantially modifying market offerings, and therefore involve higher degrees of technological and commercial

**Table 7**  
Open innovation partners.

Dependent variable	Open innovation with research centers/universities (1)	Open innovation with customers and clients (2)	Open innovation with suppliers (3)	Open innovation with firms in the same business group (4)	Open innovation with competitors (5)	Open innovation with trade associations (6)
Credit rationing	-0.040 (0.051)	0.014 (0.047)	0.112*** (0.005)	0.014 (0.023)	-0.204 (0.969)	-0.140 (0.145)
+ 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	4360	4360	4360	4360	4360	4,360

Notes: The table reports marginal effects for the bivariate probit model. The dependent variables are six dummy equal to one if the firm collaborates for innovation with a given type of partner, and zero otherwise: (1) Open innovation with research centers / universities; (2) Open innovation with customers and clients; (3) Open innovation with suppliers; (4) Open innovation with firms in the same business group; (5) Open innovation with competitors; (6) Open innovation with trade associations. Three, two and one star (\*) mean, respectively, a 99, 95 and 90 percent level of significance. Standard errors clustered at the regional level are in parentheses. All of the variables are defined in Table A1.

**Table 8**  
The innovation environment.

Panel A: Obstacles to innovation activity						
Dependent variable	No partners available (1)	Low technological knowledge (2)	No qualified personnel (3)	Low market demand (4)	Highly concentrated market (5)	Very expensive innovation (6)
Credit rationing	-0.134*** (0.007)	0.336** (0.166)	0.293*** (0.101)	0.344*** (0.030)	-0.111*** (0.009)	0.066 (0.128)
+ 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	1034	1717
Panel B: Obstacles to collaborations (not for innovation purposes)						
Dependent variable	No autonomy limitations (1)	No trust among firms (2)	Potential partners far away (3)			
Credit rationing	-0.032 (0.905)	0.021 (0.209)	-0.081* (0.037)			
+ Control variables	Yes	Yes	Yes			
Area dummies	Yes	Yes	Yes			
Industry dummies	Yes	Yes	Yes			
Observations	2090	599	126			
Panel C: Information sources for innovation activity						
Dependent variable	Internal sources (1)	Firms of the same business group (2)	Competitors (3)	Suppliers (4)	Customers and clients (5)	Research centers/ Universities (6)
Credit rationing	0.169 (0.183)	0.344*** (0.080)	0.277*** (0.064)	0.228** (0.108)	0.284*** (0.044)	0.186 (0.132)
+ 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	1020	1605	1546	2892	2616	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 regional level are in parentheses. All of the variables are defined in Table A1.

**Table 9**  
The socio-economic environment.

Dependent variable	Panel A: Trust		Panel B: Judicial efficiency		Panel C: Material infrastructures	
	Low trust	High trust	Low judicial efficiency	High judicial efficiency	Low infrastructures	High infrastructures
	Open innovation		Open innovation		Open innovation	
	(1)	(2)	(3)	(4)	(5)	(6)
Credit rationing	-0.113*** (0.032)	0.190*** (0.040)	-0.082** (0.037)	0.280*** (0.006)	0.200 (0.151)	0.273*** (0.033)
+ 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	2103	2257	2359	2001	1693	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) 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 regional level are in parentheses. All of the variables are defined in Table A1.

novelty. As emphasized by Cohen and Klepper (1996) and Cassiman and Veugelers (2002, 2006), this greater novelty increases the appropriability problem, because collaboration exposes firms to risks of information leakage, imitation, and dilution of the potential rents from innovation. Openness is therefore costlier for product innovation, especially when entirely new products are developed. By contrast, process innovations primarily target cost reductions or efficiency improvements within the production or organizational system. Their knowledge base is often more codified, more embedded in routines, and less directly market-facing. As a result, process innovation generally entails lower risks of knowledge dissipation and weaker appropriability concerns (Laursen and Salter, 2006). Consistent with this view, firms can more easily rely on external partners for process-related improvements, particularly when these partners already play a role in the supply chain.

These differences imply that credit constraints may influence the openness of product and process innovation in distinct ways. For process innovation, collaboration can help constrained firms share costs and access specialized complementary knowledge. For new product innovation, instead, financial constraints may exacerbate the perceived opportunity costs of collaboration: constrained firms may be less willing to risk knowledge dissipation or share future returns, and therefore may prefer a closed innovation strategy even if this requires bearing a larger share of development costs internally. In what follows, we exploit the detailed information provided by the UniCredit survey to distinguish between firms introducing completely new products and those improving existing ones, as well as between different types of process innovation. This allows us to test whether the relationship between credit constraints and openness differs across innovation categories.

In Table 6, we classify the surveyed firms as being product or process innovators.<sup>28</sup> 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 are consistent with the theoretical mechanisms discussed above. The negative effect of credit constraints on open innovation for firms introducing entirely new products reflects the central

<sup>28</sup> 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.”.

role of appropriability concerns and opportunity costs in highly novel innovation activities. New product development typically entails substantial technological and market uncertainty, together with a higher risk of information leakage and imitation. When firms are financially constrained, these concerns become even more relevant: sharing knowledge with external partners may compromise the expected returns from the innovation project, making a closed approach relatively more attractive despite the higher internal financial effort it requires. In contrast, for firms focused on improvements of existing products, the threat of knowledge dissipation is considerably lower, and the innovation process is more modular and easier to coordinate with external collaborators. In this case, credit constrained firms can more safely rely on open innovation to access complementary expertise, share development costs, and reduce the financial burden associated with internal investments. As a result, financial constraints push firms toward less openness in the context of highly novel product innovation, but greater openness when innovation is incremental.

Concerning process innovators, our data allow us to distinguish among different areas for 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 the interpretation that logistics and IT are activities characterized by relatively low secrecy concerns and a high potential for outsourcing or external collaboration. When facing credit constraints, firms can more easily rely on external partners to develop innovations in these areas, sharing costs and accessing specialized know-how. By contrast, process innovations related to production or purchasing are typically more specific to the firm's internal operations and technological assets, and are therefore less easily opened to external collaboration. Although maintenance shares several features with logistics and could in principle be outsourced, this pattern does not appear to emerge significantly in our data, possibly due to sample-specific factors or the smaller number of firms reporting maintenance-related innovations.

## 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 A2](#), suppliers and customers are the most widely engaged cooperation partners, but a non-negligible share of firms also collaborate with companies belonging to the same business group, trade associations, and research centers or universities. Cooperation with competitors is comparatively rare, as expected. To explore whether the impact of credit constraints on open innovation varies across different types of partner, we use the information provided by the UniCredit survey to construct partner-specific dependent variables. In particular, we create six binary indicators that take the value one if the firm collaborates for innovation with a given type of partner, and zero otherwise: (i) *Open innovation with research centers / universities*; (ii) *Open innovation with customers and clients*; (iii) *Open innovation with suppliers*; (iv) *Open innovation with firms in the same business group*; (v) *Open innovation with competitors*; (vi) *Open innovation with trade associations*.<sup>29</sup> Separate regressions are then estimated for each partner type, while keeping the overall sample of innovative firms constant. The estimation results reported in [Table 7](#) 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.<sup>30</sup> The

<sup>29</sup> As an example, the variable *Open innovation with suppliers* takes the value one if the firm declares to collaborate with suppliers on innovation activities, and zero otherwise, that is, when the firm collaborates with other partner types or does not engage in innovation collaborations at all.

<sup>30</sup> The UniCredit survey specifically asks: "Which are the main obstacles to the innovation activity?".

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.<sup>31</sup> 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 information sources they employ in the innovation process.<sup>32</sup> 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 adaptation, reduce coordination frictions, and enhance collaborative efficiency (Brockman et al., 2018; Ellis et al., 2020). The relevance of these mechanisms intensifies when firms suffer from credit constraints. In such cases, firms face tighter internal resources and stronger concerns about opportunism, information leakage, and coordination difficulties. Whether these firms can rely on external partners therefore depends not only on their internal characteristics, but also on the broader environment in which they operate.

For these reasons, in this section, we examine how three key provincial characteristics, i.e., societal trust, judicial efficiency, and material infrastructures, shape the relationship between credit constraints and the adoption of open innovation strategies. These dimensions are particularly relevant for financially constrained firms. First, societal trust reduces perceived relational risks. High-trust environments facilitate cooperation because firms expect greater honesty, reciprocity, and reliability from potential partners. This mitigates concerns about opportunism and the misappropriation of knowledge, concerns that are especially relevant for firms with limited resources to monitor collaborators. Second, judicial efficiency lowers the expected costs of enforcing contracts. In provinces with slow or inefficient courts, disputes are costly, lengthy, and uncertain. For credit constrained firms, already facing limited liquidity, this risk can severely discourage entering cooperative innovation agreements, which often involve incomplete contracts and implicit commitments. Conversely, efficient legal systems reduce the need for costly monitoring and strengthen the credibility of collaborative arrangements. Third, material infrastructures influence the logistical feasibility of collaboration. Good transport networks, digital connectivity, and business services reduce the costs of identifying, coordinating with, and monitoring external partners. These infrastructural advantages are crucial for firms under financial stress: if coordination frictions are low, constrained firms can substitute toward open innovation more easily; if frictions are high, collaboration becomes prohibitively costly. Taken together, these three dimensions capture complementary mechanisms through which the local environment can either alleviate or amplify the transaction and opportunity costs associated with relying on external partners for innovation.

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 local judicial efficiency, measured by the number of days provincial courts take to complete a first-degree trial (Guiso et al., 2004). Finally, in Panel C, firms are classified according to the provincial level of material infrastructures, based on a synthetic index considering road network, railways, ports, airports, energy systems, broadband services, and business structures.<sup>33</sup> 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 trust and judicial efficiency are particularly low (i.e. below the median provincial value). In these contexts, opportunism risks, relational uncertainty, and enforcement problems heighten the transaction and opportunity costs of collaboration. As a result, financially constrained firms, already facing limited internal resources, are unable to afford the additional risks and coordination burdens required to engage in external innovative activities. By

<sup>31</sup> The UniCredit survey asks: "Which are the main obstacles to collaborations with external partners (not for innovation purposes)?"

<sup>32</sup> The UniCredit survey asks: "Which are the information sources used for the innovation activity?"

<sup>33</sup> 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.

contrast, when firms operate in provinces characterized by high levels of trust (Panel A, column 2) or judicial efficiency (Panel B, column 4), the baseline result is confirmed: credit rationing is positively associated with the adoption of open innovation strategies. In these environments, socio-institutional mechanisms reduce relational frictions and facilitate coordination, thereby enabling financially constrained firms to substitute toward external collaborations as a way to access knowledge and share the costs and risks of innovation.

Results for material infrastructures reinforce this interpretation. The marginal effect reported in Panel C column (6) shows that credit constrained firms are 27.3 percentage points more likely to rely on open innovation when located in provinces with high-quality infrastructures. This pattern is consistent with the transaction cost perspective: when communication, transport, and digital connectivity reduce search and coordination costs, constrained firms find it easier to engage in external innovation partnerships.

## 7. Medium-term effects of open innovation adoption

To complement the analysis presented above, we consider it crucial to offer suggestive evidence on the medium-term impact of open innovation strategies on firms' profitability. Recognizing the implications of adopting open innovation can yield insights into how these strategies translate into tangible economic outcomes in the medium run, particularly in presence of credit constraints.

To this end, in [Table A6](#), we conduct OLS regressions to examine the relationship between the adoption of open innovation strategies by firms and their future profitability. We focus on two primary indicators of firm performance: return on equity (RoE) and return on sales (RoS), both computed as average values over the period 2011–2015.<sup>34</sup> Panel A of [Table A6](#) features regressions on the full sample of firms, while Panel B focuses exclusively on the subsample of firms that experienced credit constraints in 2010. This distinction aims to reveal how credit constraints may influence the relationship between open innovation and medium-term profitability. Estimation results indicate that open innovation adoption is positively associated with future profitability, as measured by the return on equity indicator, independently of firms' experience of credit rationing. Conversely, relying on open innovation strategies is positively associated with firms' return on sales only for the subsample of businesses that were credit restricted in 2010.

Overall, these findings are indicative of the strategic value of open innovation, especially for firms navigating financial constraints. Open innovation not only aids in mitigating immediate financial challenges but also contributes positively to the medium-term performance of the firm.

## 8. 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 analysis also extends to the medium-term impact of open innovation strategies on firm profitability. The suggestive evidence we have gathered indicates a positive association between open innovation adoption and future profitability, particularly for firms that faced credit constraints. This underscores the potential of open innovation as a viable strategy for sustained growth, especially under financial limitations.

### Data availability

The authors do not have permission to share data.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

<sup>34</sup> Further tests also consider average values over the period 2011–2013, yielding qualitatively similar results.

Appendix A.

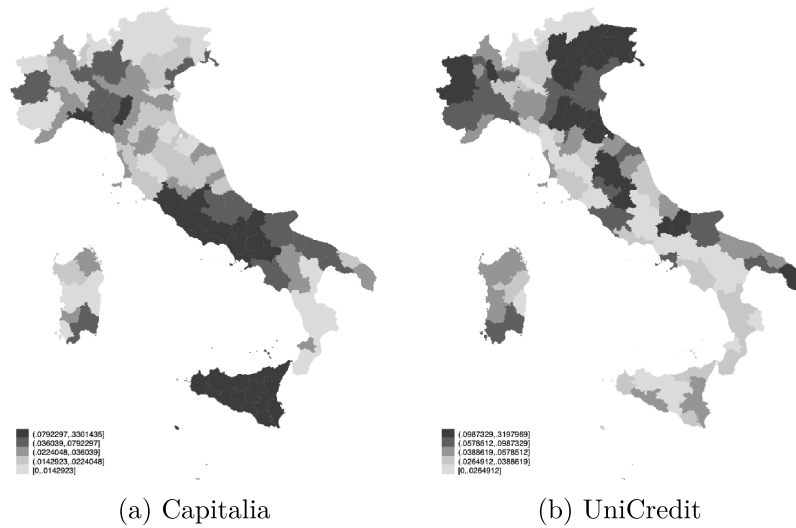


Fig. A1. Share of UniCredit and Capitalia before the merger across Italian provinces (NUTS-3). Notes: The figures show the share of provincial branches of UniCredit and Capitalia for 2007 (before the merger).

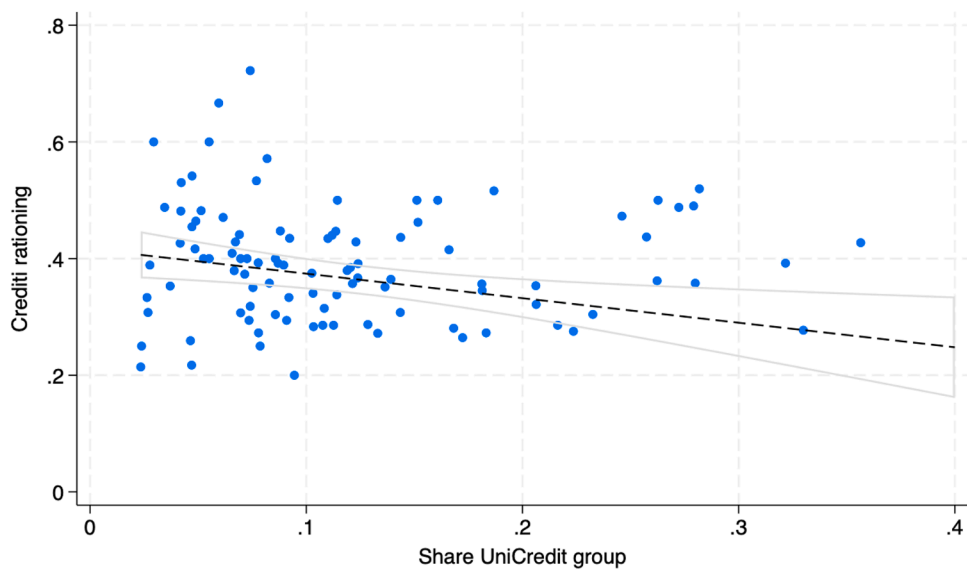
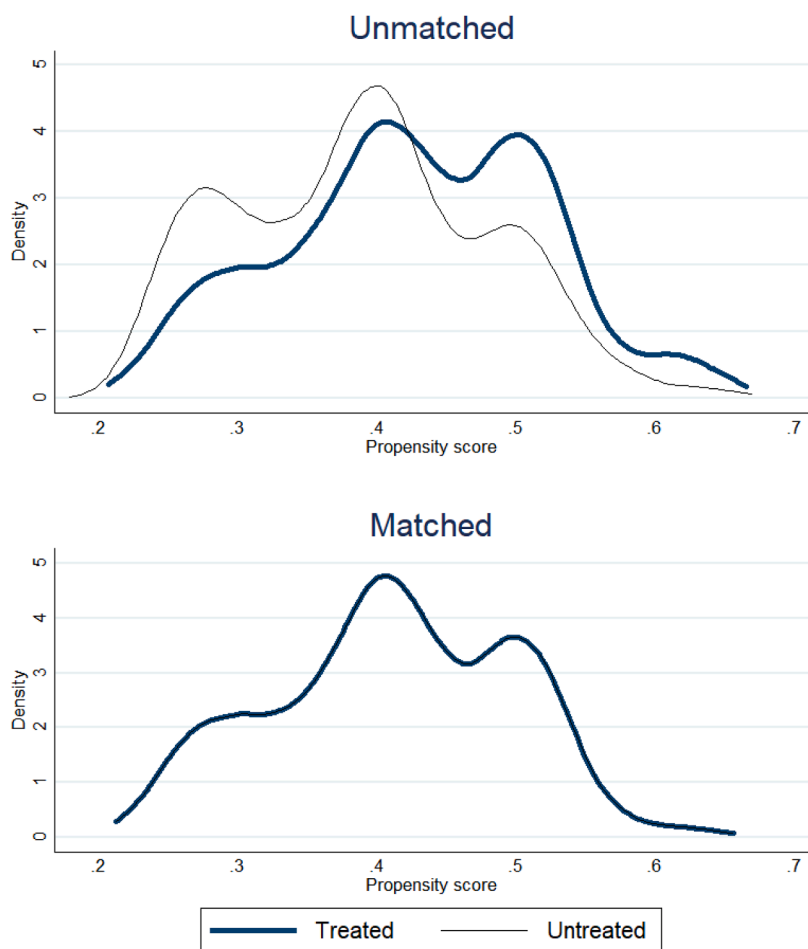


Fig. A2. Share of UniCredit group and credit rationing in Italian provinces (NUTS-3). Notes: The figure plots the share of credit rationed firms in Italian provinces against the provincial share of branches of UniCredit group.



**Fig. A3.** 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**  
Variable definitions.

Variable	Description
<i>Dependent variables:</i>	
Open innovation	Dummy variable equal to one if the firm cooperates with external partners on technological innovation, and zero otherwise.
<i>Independent variables:</i>	
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).
<i>Control variables:</i>	
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.
<i>Instrumental variables:</i>	
Share UniCredit group	Share of branches of the merged banking groups in the province.
<i>Other variables:</i>	
ROI	Return on investments.
Sales growth	Growth rate of sales.
Intangibles	Intangible assets.
Innovation	Dummy variable equal to one if the firm undertakes innovation activities, and zero otherwise.
Open vs. No Innovation	Dummy variable equal to one if the firm cooperates with external partners in technological innovation, and zero if the firm does not innovate.
Closed vs. No Innovation	Dummy variable equal to one if the firm carries out innovation without external collaboration (closed innovation), and zero if the firm does not innovate.
<i>Geographical areas:</i>	
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.
<i>Industry sectors:</i>	
Agriculture	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.

Notes: The table reports the definitions for the main variables used in the regressions.

**Table A2**  
Main partner 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.

**Table A3**  
Credit constraints and open innovation: probit estimates.

Dependent variable	Panel A: Baseline results	Panel B: Robustness on measurement	
	Open innovation (1)	Relationship length Open innovation (2)	Excluding OI within groups Open innovation (3)
Credit rationing	0.071*** (0.008)		0.073*** (0.012)
Relationship length		-0.001* (0.001)	
Age (log)	-0.024*** (0.006)	-0.019** (0.009)	-0.014** (0.006)
Size (log)	-0.000 (0.009)	0.001 (0.009)	-0.008 (0.008)
Graduates	-0.027 (0.019)	-0.029 (0.020)	-0.021 (0.020)
Corporation	0.017 (0.022)	0.013 (0.022)	0.028 (0.023)
Family firm	-0.007 (0.017)	-0.008 (0.018)	0.004 (0.018)
Local banking development	0.111 (0.072)	0.120* (0.066)	0.116 (0.081)
Judicial inefficiency	0.038*** (0.010)	0.039*** (0.010)	0.028* (0.011)
Trust	0.306** (0.120)	0.289** (0.115)	0.336*** (0.097)
Area dummies	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes
Observations	4360	4432	4,360

Notes: The table reports marginal effects for the probit regressions. Three, two and one star (\*) mean, respectively, a 99, 95 and 90 percent level of significance. Standard errors clustered at the regional level are in parentheses. All of the variables are defined in [Table A1](#).

**Table A4**  
Credit constraints and innovation.

Panel A: Bivariate probit			
Dependent variable	Innovation	Open vs. No Innovation	Closed vs. No Innovation
	(1)	(2)	(3)
Credit rationing	0.052 (0.060)	0.240*** (0.089)	-0.033 (0.057)
+ Control variables	Yes	Yes	Yes
Area dummies	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes
Observations	6112	4688	3,176
Panel B: Ordered probit			
Dependent variable	Outcome 0 No Innovation	Outcome 1 Closed Innovation	Outcome 2 Open Innovation
Credit rationing	-0.083*** (0.007)	-0.014*** (0.002)	0.097*** (0.008)
+ Control variables	Yes	Yes	Yes
Area dummies	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes
Observations	6112	6112	6,112

Notes: The table reports bivariate probit and ordered probit marginal effects. In Panel A, the dependent variables are defined as follows: *Innovation* is a dummy equal to one if the firm reports having introduced either a product or a process innovation and zero otherwise; *Open vs. No Innovation* is a dummy equal to one if the firm innovates and cooperates with external partners on technological innovation, and zero if the firm does not innovate; *Closed vs. No Innovation* is a dummy equal to one if the firm innovates without external partners, and zero if the firm does not innovate. In Panel B, the dependent variable takes value 0 for no innovation, 1 for only closed innovation, and 2 for open innovation. Three, two and one star (\*) mean, respectively, a 99, 95 and 90 percent level of significance. Standard errors clustered at the regional level are in parentheses. All of the variables are defined in [Table A1](#).

**Table A5**  
Credit constraints and open innovation: repeated cross-section and panel evidence.

Dependent variable	Panel A: Repeated cross section	Panel B: Panel firms
	Bivariate probit Open innovation (1)	Panel FE Open innovation (2)
Credit rationing	0.264*** (0.033)	0.172* (0.095)
+ Control variables	Yes	No
Area dummies	Yes	Yes
Industry dummies	Yes	Yes
Survey dummies	Yes	Yes
Firm FE	No	Yes
Observations	6918	128

Notes: The table reports marginal effects for the bivariate probit regression and OLS regression coefficients. Panel A pools the two waves and estimates a repeated cross-section specification; the dependent variable is a harmonized proxy for open innovation constructed using the closest available question in each wave. Panel B focuses on the panel subsample of firms observed in both waves and includes firm fixed effects. Three, two and one star (\*) mean, respectively, a 99, 95 and 90 percent level of significance. Standard errors clustered at the regional level are in parentheses. All of the variables are defined in [Table A1](#).

**Table A6**  
Medium-term effects of open innovation adoption.

Dependent variable	Panel A: All firms		Panel B: Credit rationed firms	
	RoE (Avg. 2011–2015) (1)	RoS (Avg. 2011–2015) (2)	RoE (Avg. 2011–2015) (3)	RoS (Avg. 2011–2015) (4)
Open innovation	0.736** (0.280)	0.023 (0.045)	1.646* (0.863)	0.019** (0.008)
Age (log)	0.072 (0.136)	-0.107 (0.091)	-0.134 (0.116)	0.005 (0.003)
Size (log)	0.045 (0.108)	-0.005 (0.008)	0.284 (0.177)	-0.019** (0.007)
Graduates	-0.314 (0.292)	-0.089 (0.094)	-1.694* (0.871)	-0.011 (0.024)
Corporation	-0.508** (0.237)	-0.100*** (0.017)	-0.549* (0.263)	-0.077*** (0.012)
Family firm	0.326 (0.354)	-0.051 (0.068)	1.458 (0.895)	-0.010 (0.022)
Local banking development	-1.890 (1.342)	-0.408 (0.529)	-6.768** (2.692)	-0.141 (0.111)
Judicial inefficiency	-0.067 (0.201)	-0.040 (0.043)	-0.375 (0.406)	-0.005 (0.010)
Trust	3.202* (1.611)	-0.014 (0.157)	8.478* (4.369)	0.142 (0.146)
Area dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Observations	2170	2155	756	750

Notes: The table reports OLS regression coefficients. In Panel A, regressions are run on the full sample of firms. In Panel B, regressions are conducted on the subsample of firms that experienced credit rationing in 2010. In columns (1)-(3) the dependent variable is the return on equity (RoE), computed as the ratio between net income and equity. In columns (2)-(4) the dependent variable is the return on sales, computed as the ratio between net income and total sales. In both cases, the dependent variables are computed as average values over the period 2011–2015. Three, two and one star (\*) mean, respectively, a 99, 95 and 90 percent level of significance. Standard errors clustered at the regional level are in parentheses. All of the variables are defined in [Table A1](#).

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