International Review of Financial Analysis 90 (2023) 102903

Contents lists available at ScienceDirect

International Review of Financial Analysis

journal homepage: www.elsevier.com/locate/irfa

Debt financing of SMEs: The certification role of R&D Subsidies

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ARTICLE INFO

JEL classification:
G30
H25
O31
O38
R58

Keywords:
Debt financing
Debt structure
Finance gap
Certification effects
Resource effects
R&D subsidies

ABSTRACT

This study investigates the (unintended) effects of public subsidies for research and development (R&D) on the debt financing of small and medium-sized enterprises (SMEs) by examining a public program implemented in the Marche region of Italy during the 2005–2012 period. The study combines matching methods with a difference-in-differences estimator to examine whether receiving public subsidies affects total indebtedness and the structure and cost of debt of awarded firms. The results indicate that R&D subsidies are associated with a modification of firm debt structure (especially for young, high-tech, and risky firms) in favor of long-term maturities and help firms limit the average cost of debt. Subsidies also foster the use of bank financing and reduce trade debt, but they do not affect the overall level of debt. Taken together, these findings suggest that the public funding of SME innovation projects plays a certification role in the access to external financial resources for firms receiving subsidies.

1. Introduction

In the Modigliani and Miller (1958) world of perfect capital markets, the debt-financing decisions of firms are unbound, and finance is not a constraint on business investment plans. In practice, financial markets are imperfect and plagued by information asymmetries, agency problems, and bankruptcy costs. This is especially true for innovative small and medium-sized enterprises (SMEs). Innovation and research and development (R&D) are characterized by a high degree of uncertainty, private knowledge, and *non-disclosable* information, as well as investment in intangible and non-redeployable assets, which make the monitoring costs for banks and other investors high and access to pledgable collateral low compared to traditional investments. Similarly, SMEs are generally more informationally opaque than large companies — for which information disclosure requirements are stricter and public information is more readily available — and they are less able to provide collateral to banks. As a result, raising external finance is typically more expensive and problematic for innovative enterprises compared to non-innovative ones (Aghion, Bond, Klemm, & Marinescu, 2004; Hall & Lerner, 2010), and especially among SMEs, for which information asymmetries and the financial gap are larger, as well as for long-term debt maturities (Accetturo, Canzian, Cascarano, & Stefani, 2019; Alessandrini, Presbitero, & Zazzaro, 2010; Bond, Harhoff, & Van Reenen, 2005; Brown, Martinsson, & Petersen, 2012; Himmelberg & Petersen, 1994; Magri, 2009; Neville & Lucey, 2022; Wellalage & Fernandez, 2019).

Based on similar arguments, public subsidy programs are widely used by governments to support R&D and innovation investment by SMEs (OECD, 2011). The relevance of this policy tool has been extensively studied in the literature in terms of R&D input and output additionality, i.e., from the point of view of the goal of supplementing the R&D investments that the subsidized firms would have made in the

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https://doi.org/10.1016/j.irfa.2023.102903
Received 27 January 2023; Received in revised form 27 June 2023; Accepted 30 August 2023
Available online 1 September 2023

absence of the subsidy.[1] However, the awarding of public financial support may also have further — unintended — effects on the financial decisions of recipient firms and their ability to access private financial funding. First, R&D subsidies represent an additional source of finance that reduces the "funding gap" of recipients, allowing them to carry out their development plans and prove their quality to external investors (*resource effect*).[2] In addition, being awarded with a competitive public subsidy is a positive signal of the quality of the beneficiary firm that reduces information asymmetries and selection costs for private investors (*certification effect*).

In this paper, we consider an R&D subsidy program launched and implemented by the government of the Marche region of Italy in the 2005–2012 period. We explore the role of certification effects and resource effects arising from the allocation of public R&D subsidies by analyzing how the debt structure, cost of debt and commercial debt reliance of the SMEs benefiting from the subsidy change after its allocation.

Previous literature has illustrated the role of public subsidies in mitigating the financial constraints of awardees. First, without distinguishing between resource and certification effects, Czarnitzki, Hanel, and Rosa (2011) and Colombo, Croce, and Guerini (2013) find that the receipt of public subsidies reduced the sensitivity of firm investments in research and new technology to internal funds. However, Han, Zhang, Bi, and Huang (2019) find that public subsidies lead firms to invest more than the expected level, while they do not have any significant mitigating effect on underinvestment. Second, a number of studies have analyzed firm access to venture capital funding and external equity, confirming the existence and importance of both the certification effect and the resource effect of subsidy awards. On the one hand, there is evidence that SMEs receiving competitive grants under government programs in support of innovation are significantly more likely to attract venture financing and external equity in subsequent years as well since they are subject to lower interest rates, in line with the hypothesis that passing the selection process for access to subsidies certifies the quality of awardees to external investors (Bellucci, Borisov, Giombini, & Zazzaro, 2023; Feldman & Kelley, 2006; Islam, Fremeth, & Marcus, 2018; Lerner, 1999; Söderblom, Samuelsson, Wiklund, & Sandberg, 2015; Wei & Zuo, 2018). On the other hand, consistent with a direct resource effect of R&D subsidies, Feldman and Kelley (2006) find that recipient firms are less likely to apply for additional funding, while Howell (2017) shows that only access to early-stage grants for proof-of-concept technology prototypes improves the ability to raise subsequent venture capital funds, while winning later-stage grants has no significant effect on venture capital. In a similar vein, Santoleri, Mina, Di Minin and Martelli (2022) show that firms receiving an R&D subsidy under the European Union's "Small and Medium Enterprise Instrument" are more likely to raise private equity financing (and in greater amounts) than firms not receiving the subsidy; in line with the resource channel, this effect is broadly driven by firms receiving the largest grants and increasing their patenting activity.

Closer to our paper, other studies have considered the cost and structure of the debt of awardees. Meuleman and De Maeseneire (2012) looked at a panel of SMEs applying for subsidies from the public Institute for the Promotion of Innovation by Science and Technology of Flanders in Belgium. They found that firms receiving the subsidy were more likely to increase their financial debt in the following year than rejected firms and non-applying firms, and especially regarding the long-term debt. Consistent with the certification role of subsidies, the effect on debt was independent of the amount of the subsidy; however, consistent with the resource effect, they also found that the increase in long-term debt was limited to firms receiving subsidies devoted to financing the setting up of technological knowledge and the creation of prototypes. Similar results have been found by Hottenrott, Lins and Lutz (2018) for Germany, Martí and Quas (2018) for Spain, Li, Chen, Gao, and Xie (2019), Li, Lee, and Wan (2020), Wu, Liu, Chen, and Liao (2021) and Guo et al. (2022) for China), Srhoj, Škrinjarić, and Radas (2021) for Croatia and Chiappini, Montmartin, Pommet, and Demaria (2022) for France, where firms receiving public grants or participation loans for R&D tended to increase their bank debt, and especially long-term maturities, after the allocation of a subsidy. These studies confirm the primary importance of the certification effect by showing that the increase in bank debt is more likely and consistent for awardees that are informationally more opaque, i.e., small and young firms (Chiappini et al., 2022; Li et al., 2020; Martí & Quas, 2018; Srhoj et al., 2021), unlisted or illiquid firms (Li et al., 2019; Li et al., 2020), firms operating in high-tech or knowledge-intensive service sectors (Hottenrott, Lins, & Lutz, 2018; Martí & Quas, 2018) and, in China, regions where intellectual property rights protection is weaker or where the role of markets in the local economy is stronger (Guo et al., 2022; Li et al., 2019; Wu et al., 2021). However, Guo et al. (2022) and Moon (2022) also document a role for the resource effect. The former finds that the firms that increase their bank debt are those receiving larger subsidies and obtaining the highest number of patents. Moon (2022) find that Korean firms raise less funding from external financial institutions for innovation activity after receiving R&D grants.

Finally, Hottenrott and Demeulemeester (2017) find that the average cost of debt is lower for firms receiving a public R&D grant. On average, this effect is activated by the award of the subsidy regardless of its size, consistent with the certification hypothesis; however, for young firms, the amount of subsidy further decreases the cost of debt, supporting a role for the resource effect.[3]

We contribute to this literature by analyzing a regional subsidy program for R&D investments by local SMEs and its impact on the external debt of recipient firms in Italy. This program is an ideal setting to evaluate the effects of public funding on firm indebtedness for several reasons. First, the funding scheme consisted of a direct monetary grant, which was a source of fresh, low-priced financial capital for subsidized firms. Second, the subsidy program required submitted projects to be preliminarily evaluated by experts from a commercial bank, who decided on their financial feasibility and merit, and this makes it relevant for looking at the possible certification effects of public subsidies (Puri, 1996). Third, the program was aimed at SMEs, for which, as mentioned above, access to external finance is more problematic. Fourth, eligible firms must be headquartered in a single region. Public support for private R&D and innovation at a regional scale has assumed growing importance in recent years. The innovation literature has embraced the concept of regional innovation systems, emphasizing the systemic and local nature of knowledge creation and

[1] The impact-evaluation literature on public subsidies for R&D is not conclusive. Some studies support the view that public funding produces additionality in R&D expenditures and innovation by private firms (Aerts & Schmidt, 2008; Czarnitzki & Lopes-Bento, 2013; Gonzalez & Pazo, 2008; Mateut, 2018), while others provide evidence that public intervention crowds out private R&D investments (Busom, 2000; Hall & Lerner, 2010; Marino, Lhuillery, Parrotta, & Sala, 2016) or that the effectiveness of public subsidies varies with the context (Heijs, Guerrero, & Huergo, 2021; Hud & Hussinger, 2015; Klette, Møen, & Griliches, 2000; Zuniga-Vicente, Alonso-Borrego, Forcadell, & Galan, 2014) and the design of the subsidy program (Bellucci, Pennacchio, & Zazzaro, 2019).

[2] Alternative labels used to refer to the resource effect include grant effect (Howell, 2017), funding effect (Guo, Guo, & Jiang, 2022) and liquidity effect (Hottenrott & Demeulemeester, 2017).

[3] The role of public certifications in firms' access to external finance and the cost of debt has also been analyzed in other contexts such as the adoption of external audits, loss of analyst coverage, litigation, modification in disclosure regulations, and public ratings for excellence and legality (e.g., Acconcia, Alfano, Baraldi, & Cantabene, 2022; Bonfim, Custódio, & Raposo, 2023; Derrien, Kecskés, & Mansi, 2016; Kim, Simunic, Stein, & Yi, 2011; Minnis, 2011; Ni & Yin, 2018).

dissemination (Braczyk, Cooke, & Heidenreich, 1998; Cooke, 1992), and policymakers have placed regions at the heart of innovation strategies, as agents of change that can identify new opportunities for technological progress in knowledge-based economies (European Commission, 2010; OECD, 2011). In addition, the local dimension of the subsidy program means that all firms share the same economic environment, including banking and financial markets, which mitigates unobserved heterogeneity in the institutional and cultural environment and improves the quality of matching between funded and non-funded firms.[4]

We add to the previous literature by considering a richer set of outcome variables measuring changes in the amount, maturity, composition and cost of external debt. We distinguish the effects of the subsidy program on total external debt and bank debt in both the short and medium term. We also check whether these effects vary according to certain dimensions that capture the potential relevance of certification effects (distinguishing subsidized firms by age, innovativeness, and credit risk) or the role that access to additional financial resources may play (distinguishing subsidized firms by the amount of subsidy received). In this way, we aim to provide a comprehensive and reliable picture of the potential resource and certification effects of public subsidies on firm debt capacity. In addition, for the first time in the literature, we study the effects of the subsidy-award credit restrictions of recipient firms by looking at changes in the use of trade credit. Finally, we adopt a matching difference-in-differences identification strategy to isolate the causal impact of subsidy awards on external debt.

As a preview, our results show that R&D subsidies did not affect the overall level of indebtedness of recipient SMEs, either in the short or medium term. However, subsidies allowed firms (i) to modify the structure of their debt towards long-term financing, (ii) to increase access to bank debt, (iii) to reduce the average cost of debt, and (iv) to reduce trade debt. These effects were more pronounced in the medium term and for young, high-tech, and risky firms, while the results were no different for large and small subsidies, which, if anything, were statistically and economically more significant than the former. Overall, our diff-in-diffs analysis supports the view that public funding primarily plays a certification role for recipient finance, signaling the quality of subsidized firms to private lenders who are then prepared to provide more long-term credit at a lower cost.

The rest of the paper is organized as follows. Section 2 sets out the main research hypotheses. Section 3 describes the public subsidy program. Section 4 describes the data and the empirical strategy used to identify the effects of the subsidy program. Section 5 presents the empirical results and a robustness analysis, and Section 6 offers some concluding remarks.

2. Resource and certification effects

2.1. Resource effects

Public subsidies for investments in R&D are an important source of low-cost external finance for SMEs, bridging a possible finance gap that prevents funding socially valuable innovation projects (Feldman & Kelley, 2006). Access to additional financial resources may have different repercussions for the debt structure of recipient firms that reflect the impact of subsidies on their investment choices. To the extent that public subsidies are non-refundable (and recorded as revenue in income statements), their direct impact on the total debt of recipient firms can be either negative or positive, depending on whether obtaining the subsidy has input additionality effects or not (Hottenrott & Demeulemeester, 2017). If subsidized investments substitute other non-subsidized R&D expenditures, public subsidies automatically and immediately reduce the total amount of external debt needed to implement R&D projects (*debt-substitution channel*). By contrast, if subsidies have an additionality effect on R&D expenditure, their receipt may leave the total debt of recipient firms unaffected or may even increase it. This occurs if the subsidized investment is part-funded by additional financial resources provided by banks and other external private investors (*debt-additionality channel*; see Czarnitzki, 2006) or if the award of the subsidy allows recipients to develop proof-of-concept prototypes or other investments proving their future growth potential and opening up new investment opportunities requiring additional external finance (*prototyping channel*; see Howell, 2017).

The resource effects of public R&D subsidies on the total indebtedness of recipients can be accompanied by other effects on the maturity structure and cost of debt. When subsidies replace private debt, recipient firms are expected to reduce their reliance on forms of debt that are more costly and readily accessible again in the future. Therefore, the debt-substitution channel of R&D subsidies is expected to be associated with an immediate decrease in both short-term debt and the average cost of debt. By contrast, the long-term debt of recipients should be largely unaffected both in the short and medium run. Similarly, the resource effects of subsidies operating through the debt-additionality channel should, for the most part, be reflected immediately in the financial statements of recipient firms, but unlike the debt-substitution effect they determine an increase in the short-term debt of recipient firms without causing significant reduction in the cost of debt. Both the debt-substitution and debt-additionality channels should mainly affect bank debt, which is more immediately responsive to changes in firm financing needs than other sources of external finance such as venture capital, open-end funds, bond markets, or even trade credit.

On the other hand, the prototyping channel is expected to operate in the medium run, after the awardee firms have successfully realized the proof-of-concept prototype funded by the subsidy. To the extent that successful prototype investments open up new long-term investment opportunities, the resource effect due to prototyping should lead subsidized firms to increase their long-term debt, possibly driving up the average cost of debt. In addition, the prototyping channel is also expected to affect the non-bank debt of firms receiving the R&D subsidy, which is provided by investors who are generally less informed than banks and who may therefore be particularly sensitive to proof-of-concept results.

Finally, all resource effects are expected to be largely independent of the degree of information opaqueness and the riskiness of recipients, while they should be stronger for larger subsidies.

2.2. Certification effect

Besides increasing the availability of financial resources, the award of a subsidy under a public program using competitive allocation criteria can have a certification effect by acting as a positive signal of the quality of subsidized projects and the creditworthiness of recipient firms to private investors (Hall, Moncada-Paternò-Castello, Montresor, &

[4] It is worthwhile to note that in principle the geographic scale, whether regional or national, of the R&D subsidy program may have mixed influence on the relevance of certification effects and resource effects for the debt of the subsidized firms. On the one hand, the regional scale of the program strengthens the certification effect, as firms operate in a smaller and more homogeneous context where signals about the quality of recipients are less noisy and easier to detect. On the other hand, information available locally on companies operating in the area is greater and this reduces the impact of an additional quality certification. Similarly, the involvement of a local bank in the assessment of the financial feasibility of projects can make the certification provided by the allocation of the subsidy more reliable, but it can also strengthen the role of resource effects, as the assessing bank itself can supply new credit to awardees, for which it can save on screening costs, or can restructure the maturity of the debt that they have with the bank.

Vezzani, 2016). The conditions for signaling being feasible are generally met (Kleer, 2010; Lerner, 2002; Takalo & Tanayama, 2010; Tirole, 2006).[5] First, the application process for an R&D program entails both monetary and non-monetary costs of preparing the required documentation. Second, the public agency that evaluates the research projects generally has a reputation at stake because it manages many programs and repeated calls over time and is subject to the supervision of other public offices interested in the efficient use of scarce public resources. Third, the public agency has informational advantages over external investors in that it is typically called on to evaluate a large number of R&D projects and is often assisted by a panel of independent experts in the field. Fourth, the allocation of the subsidy is usually made public through the publication of the results of the call by the awarding agency, so that the signal is publicly observable by private investors.

Receiving the "seal of quality" of the subsidy award allows firms to obtain additional debt from private investors or to rebalance their debt structure. Therefore, unlike resource effects, the impact of certification effects on the total indebtedness of recipients cannot be negative, whatever the degree of additionality of subsidies on R&D investments.

The impact of the certification effects of R&D subsidies on the maturity structure of the debt of subsidized firms is also different from that of resource effects. According to the standard corporate finance literature, information asymmetries and agency costs are key determinants of the debt maturity structure of corporate debt and the low reliance of SMEs on longer-term financing.[6] Banks and investors tend to prefer short-term lending because this allows repeated reviews of loan contract terms and mitigates moral hazard incentives for borrowers (Diamond, 1991, 1993). When reassured by the positive results of a government agency's screening for subsidy allocation, banks and investors may be more willing to provide long-term debt. The certification effect is therefore expected to produce a rebalancing of the debt structure of subsidized firms towards longer maturities. Similarly, the positive signal of a subsidy award allows recipients to negotiate new debt and/or renegotiate outstanding debt at lower rates, thus decreasing the average cost of debt. Furthermore, the creditworthiness-signaling role of subsidy awards is expected to result in a reduction of trade debt for subsidized firms. Whether deferring payments to suppliers acts as a costly source of financing for credit-constrained SMEs that cannot rely on bank loans (Petersen & Rajan, 1997) or whether it acts as a costly signal sent to less informed external investors (Biasis & Gollier, 1997), the reduction in the cost of debt and the increase in the share of long-term bank debt of firms receiving a subsidy due to certification effects should be accompanied by a reduction in trade account payables.[7]

The certification effect of R&D subsidies is expected to show up gradually in the financial statements of recipient firms and to be prolonged over time. In addition, it is expected to be stronger for young and risky firms, which are more dependent on external finance and informationally more opaque than old and safe ones, and it should be independent of the amount of the subsidy received.

2.3. Identification and hypotheses

Empirically identifying the resource effect and certification effect of R&D subsidies on the debt of recipient firms using real data is challenging. The two effects are not mutually exclusive, they do not always have a univocal sign, and while in some respects they both operate in the same direction, for others they operate in opposite directions. For this reason, we propose a "comprehensive approach" to the identification of certification effects and their prevalence over resource effects, which encompasses the overall consistency of the changes in the amount, maturity, and composition of debt, of the time horizon along which these variations occur, and the differences between subsidized firms.

Based on the discussion in Sections 2.1. and 2.2., in Table 1 we summarize the expected impacts of the certification effect of subsidy award on the amount, maturity structure, composition, and cost of external debt of subsidized firms, the expected time horizon and the expected sign of firm-specific moderators (see column 1). We then compare these with those that should characterize the resource effect through the debt-substitution, debt-additionality, and prototyping channels (see columns 2 to 4). Therefore, we can formulate the following proposition.

Proposition. (Testing for certification effects). *The allocation of R&D subsidies produces a certification effect for recipient firms, which could possibly also add to a resource effect, when the following hypotheses are not statistically rejected: (H1) the total debts of firms receiving an R&D subsidy increase or remain unchanged; (H2) their short-term debts reduce; (H3) their long-term debts increase; (H4) the share of long-term debt over total debt increases; (H5) the share of bank debt over total debt increases; (H6) the share of long-term bank debt over total bank debt increases; (H7) trade debts reduce; (H8) the average cost of debt decreases; (H9) the effects in (H1)–(H8) appear mainly in the medium run; (H10) the effects (H1)–(H8) are stronger for young, more innovative, and risky firms; (H11) the effects in (H1)–(H7) are independent of the amount of subsidy.*

Although some of the hypotheses are consistent with some of the resource-effect channels, evidence of their simultaneous validity indicates that subsidies are not only an additional source of financing for the recipient firms but also, and especially for firms that are more informationally opaque, a public signal of creditworthiness that is transmitted to external lenders to rebalance the maturity and composition of their debts and reduce their cost.

3. The subsidy program

To investigate the effect of R&D subsidies on firm indebtedness, we examined the 2005 and 2007 rounds of "Intervento 1.1.1.4.1. - Promozione della ricerca industriale e sviluppo sperimentale nelle PMI" (Intervention 1.1.1.4.1. - Promotion of Industrial Research and Experimental Development in SMEs, hereafter PIREDS), a public program implemented by the government of the Marche region in central Italy.[8] The subsidy program aimed to promote private R&D and innovation investment by SMEs, supporting industrial research projects and pre-competitive development activities. The research projects had to foster product and process innovation and the transfer of knowledge between university and industry, as well as increase the level of human capital through the assimilation of specialized knowledge and competencies. Eligible firms had to have fewer than 250 employees and either a turnover below €50 million or total assets below €43 million. The main

[5] The importance of certification effects produced by access to financial resources has been extensively illustrated in the literature on corporate finance, mainly in the context of initial public offerings (IPOs) and the role of rating agencies, auditors, and independent analysts (Booth & Smith, 1986; James, 1987; Megginson & Weiss, 1991; Sufi, 2009; Titman & Trueman, 1986).

[6] Wu, Opare, Bhuiyan, and Habib (2022) provide a comprehensive review of the theoretical and empirical literature on the debt maturity structure of private corporates. Accetturo et al. (2019) analyze the debt maturity structure of Italian SMEs and examine the role of a public credit guarantee scheme introduced to expand the use of long-term bank debt by local firms in the Italian province of Trento.

[7] A large empirical literature has analyzed the relation between bank credit and trade credit, confirming both the substitution and the signaling hypotheses (Love, Preve, & Sarria-Allende, 2007; Garcia-Appendini, 2011; Atanasova, 2012; Garcia-Appendini and Montoriol-Garrica, 2013; Carbó-Valverde, Rodríguez-Fernández, & Udell, 2016); for Italy, see Agostino and Trivieri (2014), Deloof and La Rocca (2015), Bertrand and Murro (2022), Dottori, Micucci, and Sigalotti (2022), and Murro and Peruzzi (2022).

[8] Data on these two rounds of the Intervento 1.1.1.4.1 has been previously used to examine the input and additionality of this R&D subsidy program (see Bellucci et al., 2019).

Table 1
Expected effects of R&D subsidies on the outcome variables.

	Certification effects	Resource effects		
		Debt-substitution channel	Debt-additionality channel	Prototyping channel
Outcome variables				
Change in total debt	≈0/+	−	+	+
Change in short-term debt	−	−	+	≈0
Change in long-term debt	+	≈0	≈0	+
Long-term debt over total debt	+	+	−	+
Change in total bank debt	+	−	+	≈0/+
Long-term bank debt over total bank debt	+	≈0	−	+
Trade debt	−	≈0/+	≈0/+	≈0/+
Cost of debt	−	−	−	≈0/+
Time and firm moderators				
Short run	*	**	**	^
Medium run	**	^	*	**
Firm age	−−	≈0	≈0	≈0
Firm risk	++	≈0	≈0	≈0
Subsidy amount	≈0	++	++	++

Notes. + the expected impact of subsidies is positive and statistically significant; − the expected impact of subsidies is negative and statistically significant; ≈0 the expected impact of subsidies is statistically not different from zero; ** very significant in the time horizon considered; * significant in the time horizon considered; ^ not significant in the time horizon considered; −− negative moderator; ++ positive moderator.

unit of applicants also had to be located in the region, and they had to implement the research project within the region and operate in an industry considered to be strategically important for the local economy, such as food, clothing, ICT, nanotechnology, building automation, and new materials.

The projects could last at most eighteen months, starting within 30 days of the notification of acceptance. The cost had to range between €100,000 and €2,000,000. Permitted outlays included personnel (researchers and technicians), machinery, equipment, raw materials, consulting, and non-material goods such as patents, licenses, and software. All outlays had to be explicitly linked to research activities.

The funding scheme consisted of a non-refundable capital contribution of 35% of eligible expenditure and an interest rate subsidy that, upon request, might cover up to 10% of the total cost. The interest subsidy could be requested only by medium-sized firms (firms with between 50 and 250 employees) that simultaneously integrated the public capital contribution with a bank loan of a greater amount to be signed within two months of the notification of the subsidy award decision. Given the stringency of these eligibility criteria, only seven firms took advantage of the interest rate option.[9]

The contribution was granted to firms in two tranches: the first within three months of the acceptance of the application and the second (at least 30% of the total grant) after completion of the project and a positive evaluation by a committee of experts appointed by the Region. Firms could, however, ask for up to 50% of the capital contribution in advance.

Firms could apply for only one research project per call and could not receive other public subsidies—from regional, national or international public institutions — for the same research activities. Additionally, using the database of the regional agency we checked that public grants awarded in 2005 and 2007 were univocal or overlapped with other public subsidies for R&D in the same timeframe of our analysis. This ensured that the effect of the subsidy program was not confounded by the impact of other public programs, helping us in the evaluation.

The submissions were assessed by a local commercial bank assisted by a committee of independent experts in the field of innovation who were registered on lists held by the Ministry of Education, Universities, and Research. After preliminary screening designed to discard applications that did not meet the requirements of the call, the bank considered the financial feasibility of the projects and, together with the experts, the merit of the research idea. Across the two rounds, there were 441 applications, of which 282 were accepted (64%) and 159 were rejected (36%). A total of €57 million was granted to firms, with an average project cost of €202,120.

4. Data and identification strategy

4.1. Data

To evaluate the effects of the regional subsidy program, we drew on three sources of data. The list of firms receiving subsidies under the PIREDS program was extracted from a database held jointly by the regional agency for innovation (Marche Innovazione) and the Department of Information Engineering (DIIGA) at Marche Polytechnic University in Ancona. Unfortunately, this database only provides information on firms that received the subsidy and not firms that applied for the subsidy and were rejected. Therefore, we cannot compare the debt performance of subsidized firms with that of rejected firms. Balance sheet data and other information on regional firms were drawn from ORBIS, published by Bureau van Dijk. Lastly, as a measure of firm innovativeness we included patent data from REGPAT, the OECD database reporting information on patent applications to the European Patent Office.

By merging data from ORBIS with the list of subsidized firms, we obtained the treatment group. In this process, we lost 79 observations that were missing in ORBIS. To build the matched control group of unsubsidized firms, from the ORBIS database we also selected all firms headquartered in the Marche region that were in the same industries as the subsidized firms and which met the dimensional criteria imposed by the subsidy program under scrutiny.

We evaluated the effects of the subsidies from the year of the call for applications until five years later. To ensure the reliability of impact-evaluation analyses, it is important to rule out the possibility that any factors other than the program of interest explain the observed impact on the outcome. Specifically, when analyzing the causal effect of R&D subsidies, a critical point is whether subsidized and non-subsidized firms received other types of public funds in the same period. This might bias the identification of the causal effect of the specific PIREDS subsidy program on firm outcomes. On the one hand, a fraction of the firms in the treated group, i.e., a fraction of firms that received the subsidy, may have been subject to multiple treatments. On the other hand, a fraction of firms assigned to the control group, i.e., a

[9] To check for potential confounding effects of these supplementary private loans on the certification and resource effects of public subsidies, we check the robustness of our results to the exclusion of firms that also benefited from the interest rate subsidy.

Table 2
Subsidized firms by sector of activity.

NACE Rev. 2 code	Description	Round 2005 ($n = 78$)	Round 2007 ($n = 98$)
CA	Manufacture of food products, beverages and tobacco products	–	4.08
CB	Manufacture of textiles, apparel, leather and related products	7.79	4.08
CC	Manufacture of wood and paper products, and printing	1.30	3.06
CE	Manufacture of chemicals and chemical products	–	8.16
CG	Manufacture of rubber and plastics products, and other non-metallic mineral products	9.09	9.18
CH	Manufacture of basic metals and fabricated metal products, except machinery and equipment	15.59	11.24
CI	Manufacture of computer, electronic and optical products	12.99	5.10
CJ	Manufacture of electrical equipment	5.19	5.10
CK	Manufacture of machinery and equipment	23.36	11.24
CL	Manufacture of transport equipment	1.30	1.02
CM	Other manufacturing, repair and installation of machinery and equipment	9.09	11.22
D	Electricity, gas, steam and air-conditioning supply	1.30	–
E	Water supply, sewerage, waste management and remediation	1.30	1.02
F	Construction	3.90	5.10
G	Wholesale and retail trade, repair of motor vehicles and motorcycles	1.30	7.14
JA	Publishing, audiovisual and broadcasting activities	–	1.02
JC	IT and other information services	2.60	11.22
L	Real estate activities	1.30	1.02
MA	Legal, accounting, management, architecture, engineering, technical testing and analysis activities	1.30	–
MB	Scientific research and development	1.30	–
	Total	*100*	*100*

fraction of firms that did not receive the subsidy under consideration, could have been subject to treatment if they received a different subsidy. A similar concern is also relevant to our study, but two elements make it less so. First, as specified in Section 3, access to a subsidy under the PIREDS program is conditional on a ban on receiving other public subsidies for the same research activities. Second, taking advantage of a database by Marche Innovazione and DIIGA that provides information on all regional public programs for local firms, we discarded from our dataset any firms funded by other programs besides PIREDS. This resulted in a unique dataset of 176 regional SMEs that had only received R&D subsidies from the PIREDS program (78 in the first round and 98 in the second round) and 5127 SMEs headquartered in the region that did not receive any public support from the regional government in the 2003–2012 period. Finally, in the two rounds of the PIREDS programs that we analyze, no firm refused or renounced the subsidy granted, thus excluding the problem of non-compliance with treatment.

Table 2 provides a description of firms subsidized in the two rounds by sector of activity. It shows that most subsidized firms operated in manufacturing industries, including sectors such as “Machinery and Equipment”, “Computer”, “Rubber and Plastic Products” and “Basic Metals and Metal Products”. The most common services industry was “IT and other information services”. Several firms belonged to traditional industries such as the “Manufacture of Textiles, Apparel and Leather”, “Manufacture of Food, Beverages and Tobacco”, and “Construction”.

4.2. Outcome variables

To evaluate the impact of the public subsidy program on firms' access to external finance, we considered first total debt, both in the short and medium term, and then concentrated on bank financing and its maturity structure. This focus is justified because the positive signal associated with the awarding of competitive public subsidies may be especially relevant for other banks, which can take advantage of the positive evaluation expressed by the local bank assessing the applications. Lastly, we also considered the impact of the subsidy on trade debt, a type of debt that is particularly important for SMEs.

For overall firm indebtedness, we considered five variables: (i) the annual growth rate of total debt, *change in total debt*; (ii) the annual growth rate of short-term debt, *change in short-term debt*; (iii) the annual growth rate of long-term debt, *change in long-term debt*; (iv) the ratio of long-term to total debt, *long-term debt over total debt*; and (v) the average cost of total debt, *cost of debt*. For bank financing, we considered two variables: (vi) the ratio between bank debt and total debt, *bank debt over total debt* and (vii) the ratio of long-term bank debt to total bank debt, *long-term bank debt over total bank debt*. For trade debt, we considered (viii) the ratio between trade debt and total debt (*trade debt over total debt*).

Table 3 shows descriptive statistics in the year before the start of the program (2004) for subsidized firms and other regional firms that did not receive the subsidy, as well as mean difference tests between the two types of firms. Looking at total debt and bank debt, firms receiving R&D subsidies were more indebted than other firms. Indebtedness, a measure of a firm's leverage computed as the ratio between total assets and equity, suggests the opposite conclusion, however, and the debt-to-equity ratio shows similar values for the two groups of firms. With a mean value of 5.1%, the cost of debt was lower for subsidized firms than unsubsidized companies (5.8%). The evidence for cash flow is mixed: It was significantly higher in firms receiving public funds in terms of level, but it was not significantly different when considering the ratio of cash flow to total assets. Trade debt was similar for subsidized and unsubsidized firms.

With regard to other firm characteristics, firms funded under the R&D subsidy program were significantly older and larger than unsubsidized firms in terms of sales, value added, total assets and number of employees. Return on equity (ROE) was higher for unsubsidized firms, but earnings before interest, taxes, depreciation and amortization (EBITDA) over sales was not significantly different. Subsidized firms applied for more patents than unsubsidized firms, but differences in R&D intensity were not statistically significant from zero. A similar picture emerged when using median values instead of means, and differences between subsidized and unsubsidized firms were even less pronounced. More details on the definitions of variables, as well as the correlation matrix for the outcome and matching variables, can be found in the Appendix (Tables A1 and A4),

4.3. Methodology

Our empirical strategy to identify the effect of the subsidy program relies on a matched difference-in-differences approach. This methodology has been used in several previous policy evaluation studies because

Table 3
Descriptive statistics and mean comparison tests before the program for subsidized and unsubsidized firms.

	Subsidized			Unsubsidized			Mean difference test t-statistic
	Mean	Median	Std. dev.	Mean	Median	Std. dev.	
Variables for firms' debt							
Total debt†	5684	3924	5997	2754	1146	6601	5.6***
Short-term debt†	4747	1130	4824	2167	978	4081	7.9***
Long-term debt†	937	345	1800	587	147.6	4018	1.1
Total bank debt†	2106	1765	3514	1724	1362	3262	1.5
Short-term bank debt†	1433	997	2140	1138	849	2082	1,8*
Long-term bank debt†	673	409	1388	586	102	4715	0.1
Indebtedness	8.9	5.5	14.8	13.2	5.8	49.2	−3.1***
Debt-to-equity ratio	2.9	1.3	5.9	2.8	1.1	26.9	0.1
Cost of debt (%)	5.1	4.4	3.2	5.8	5.0	4.5	−1.5
Trade debt	2239	1386	2453	1442	242	8560	1.3
Variables for firms' characteristics							
Cash flow†	485.5	251.6	841.8	181.1	59.9	577.9	6.4***
Cash flow over total assets	0.055	0.047	0.056	0.051	0.042	0.110	0.5
Age	18.6	18	11.6	8.1	5	12.4	11.1***
Sales†	8946	5606	8420	3900	1935	6.069	10.3***
Value added†	2460	1609	2355	837	410.3	1468	13.5***
Employees	55.3	45	48.3	31.1	15	59.3	4.4***
Total assets†	7601	4780	7436	3636	1578	7662	6.5***
EBITDA/sales	12.8	7.6	45.1	9.3	7.3	34.1	1.2
Return on equity (ROE)	3.6	3.8	26.1	8.2	5.6	26.7	−2.3**
Tangible assets†	1266	758	1331	1012	199.3	4898	0.5
Intangible assets†	173.5	32.4	528.8	45.5	6.6	399.9	3.1***
R&D intensity (%)	0.5	0.04	1.4	0.3	0.02	4.1	0.5
Wages†	1087	814.7	1006	679.6	186.3	896.5	5.7***
Patents	0.06	0.01	0.3	0.02	0.01	0.05	7.6***

Notes: † Thousands of euros. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. The table shows descriptive statistics for the year before the program (2004).

it is a valuable way to overcome endogeneity in the allocation of public subsidies.[10]

Firms that received a public subsidy and non-recipient firms are not randomly distributed, and a raw comparison of the two groups can therefore yield biased results (Cowling, 2016; Klette et al., 2000). In our sample, for example, this is a relevant issue because subsidized and unsubsidized firms were highly heterogeneous in terms of many characteristics. When randomized experiments cannot be conducted, matching methods are helpful to evaluate the causal effects of a program (Khandker, Koolwal, & Samad, 2010). The aim of matching is to identify a counterfactual or control group that is as similar as possible to the group of treated units in terms of observed characteristics. In our setting, the R&D subsidy program is the treatment, subsidized firms are the treated units, and the control group is formed by firms not receiving the R&D subsidies but that, based on their characteristics, could have applied for the subsidy.[11]

The first step in our estimation procedure consisted of using a propensity score matching (PSM) model to build the statistical control group for subsidized firms. In PSM, a control group is identified by modelling the probability of participating in the program using observed characteristics that are unaffected by the program. Based on this probability, or propensity score, treated units are matched with similar untreated units.

In our PSM model, we considered firm characteristics in the baseline year or the year before the receipt of public subsidies (2004 for the first round and 2006 for the second round of the program). The matching between observations was based on nearest neighbors (NN) matching, one of the most used techniques in matching, where each observation is matched to the control unit with the closest propensity score. For robustness purposes, we conducted PSM using NN with 3 nearest neighbors and kernel matching.

The validity of PSM depends on three main assumptions. The conditional independence assumption (CIA), or unconfoundedness, assumes that subsidy allocation was independent of the potential outcomes conditional on the observed pre-treatment matching covariates (Rosenbaum & Rubin, 1983). CIA implies that the uptake of the program is based exclusively on observables. This is a strong assumption that is often difficult to defend. Our analysis uses a rich set of pre-program and observed firm-specific covariates, which helps to support the CIA. Combining PSM with difference-in-differences (DID) also relaxes this assumption by allowing for unobserved time-invariant heterogeneity.

The common support (or overlap) condition (CSC) requires a comparable unsubsidized firm with a similar propensity score for each subsidized firm. This therefore implies that a substantial area of common support exists between the two types of observations. This assumption is plausible in our empirical setting because the control group was drawn from a very large population of regional firms that did not receive a PIREDS subsidy or other regional subsidies during the 2005–2012 period.[12] To further improve comparability between treatment and control groups, we also imposed the common support option, which means we dropped both subsidized and unsubsidized firms without similar counterparts (Heckman, Ichimura, & Todd, 1997; Ravallion, 2008).

Finally, the stable unit treatment value assumption (SUTVA) postulates the absence of spillovers, that is, that R&D subsidies did not have any effects on the outcomes of unsubsidized firms. This assumption also appears to be credible in our setting because the number of subsidized

[10] For example, Lach (2002) and Cannone and Ughetto (2014) used a difference-in-differences estimator, Almus and Czarnitzki (2003), Czarnitzki et al. (2011), Bernini and Pellegrini (2011), Pennacchio (2014), and Antonioli, Marzucchi, and Montresor (2014) applied matching and other non-parametric methods, and Engel, Rothgang, and Eckl (2016) and Bellucci et al. (2019) combined the two methods.

[11] A similar approach has been frequently adopted in the literature (e.g., Bergström, 2000; Almus & Czarnitzki, 2003; Busom and Ribas, 2008; Czarnitzki and Lopes-Bento, 2014; Bellucci et al., 2019; Dottori & Micucci, 2019; Guo, Guo, & Jiang, 2016; Vanino, Roper, & Becker, 2019; Srhoj et al., 2021).

[12] Before creating control groups, we removed from the population of firms headquartered in the Marche region those that received an R&D subsidy to avoid that firms funded in the first (second) round enter the control group of the second (first) round.

firms was low compared to the total number of regional firms. In addition, funded firms were small, and the R&D grants were on average not particularly large. Lastly, even if some spillover effects arose from the receipt of R&D subsidies, they would probably have required a longer period to develop fully (Bernini & Pellegrini, 2011).

In the second step of the estimation procedure, we used the DID method to estimate the causal effect of the R&D subsidy program. DID measures the changes in the outcome variables between the subsidized and control (unsubsidized) firms identified by PSM, before and after subsidies were awarded. The DID estimator has the major advantage of allowing for heterogeneity in unobservable and time-invariant factors. It therefore relaxes the assumption of PSM that the selection in the program is based only on observable firm characteristics and takes into account the possibility that different performance in subsidized and unsubsidized firms may be driven by time-invariant characteristics (Heckman et al., 1997). These might include individual fixed effects, human capital, and managerial competences, as far as they can be considered time-invariant, which is plausible in short time periods (Engel et al., 2016). The reliability of DID relies on the parallel-trend assumption, which requires that in the absence of the program the trends in the outcomes for subsidized and unsubsidized firms would have moved in tandem (Gertler, Martinez, Premand, Rawlings and Vermeersch, 2016). This assumption is also empirically tested. The estimated equation is as follows:

$$y_{it} = \beta_0 + \beta_1 post_t + \beta_2 Subsidy_i + \beta_3 (post_t \bullet Subsidy_i) + \delta_t + \delta_t \bullet \gamma_i + \delta_t \bullet \lambda_i + \alpha_i + \varepsilon_{it}, \quad (1)$$

where i and t index firms and years and $y_{it}$are the firm outcomes described in Section 4.2. $post_t$ is a dummy variable equal to 1 for the period after the receipt of the subsidy and 0 for the baseline year. We assessed the impact of the program in two different periods to capture the short- and medium-term average effects. With t as the year of funding and $t-1$ as the pre-treatment or baseline year, the first period, which we consider to be the short-term, includes years t and $t+1$, while the second period, which we consider to be the medium term, includes years $t+2$, $t+3$, and $t+4$.[13] $Subsidy_i$ is a dummy variable equal to 1 for firms receiving the subsidy under the PIREDS program and 0 for control firms, δ_t is a set of time fixed effects to control for unobserved cyclical variations of the credit market, γ_i is a set of industry fixed effects that control for time-invariant industry characteristics, λ_i is a set of province fixed effects that account for the different characteristics of the local credit markets, and ε_{it} is the random error term. Industry and province fixed effects are interacted with the time fixed effects because Eq. (1) includes also firms fixed effects (α_i). The model is estimated by the fixed effects estimator.

In the baseline estimates, we consider the effect of the subsidies both separately for the 2005 and 2007 rounds and for the two rounds together. This can be viewed as a consistency check because we expect similar results for the two rounds. For the sake of space, we present results only for the overall sample.

5. Results

5.1. Matching

PSM was the first step in our estimation strategy, to identify comparable groups of subsidized and unsubsidized firms. We used the following matching variables for PSM: *indebtedness*, *turnover growth*, *cash flow*, *age*, *total assets*, *intangible assets over total assets*, *EBITDA/sales*, *ROE*, *wages*, *patents* and industry dummies. When difference-in-differences is combined with matching, a problem of regression to the mean can bias the estimated impact of a program. The bias is severe when *i)* matching variables and outcomes are strongly correlated, *ii)* the mean differences at baseline between treated and untreated units are high, and *iii)* the serial correlation of matching variables is low (Daw & Hatfield, 2018). In our analysis, matching variables and outcomes showed moderate correlations, as shown by the correlation matrix in Table A4, and high serial correlation. We are therefore confident that regression to the mean is a minor issue in our empirical setting.

Table 4
Balancing test for propensity score matching.

	Mean for subsidized firms	Mean for control firms	Mean difference test t-statistic
Indebtedness	8.5	8.3	0.09
Cash flow†	536.1	520.2	0.22
Age	19.6	20.5	−0.43
Total assets†	8344	9309	−0.15
EBITDA/sales	9.3	7.9	1.10
Return on equity (ROE)	2.05	2.3	−0.13
Turnover growth	9.63	11.06	−0.69
Intangible assets over total assets	0.034	0.047	−1.38
Wages†	1177	1242	−0.74
Patents	0.05	0.06	−0.48

Notes: † Thousands of euros. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. The table shows the mean values in the year before the two rounds, that is 2004 for Round 2005 and 2006 for Round 2007.

To improve comparability between the two groups of firms, we undertook matching with the common support option. This ensured that subsidized firms (treated units) had similar control firms (untreated units) close to them in the distribution of propensity scores, in terms of observed characteristics unaffected by subsidies (Heckman, Lalonde, & Jeffrey, 1999). This option is particularly important in our sample because several firms in both groups lie outside the common support area. The number of these firms depends on the outcome variable. For *change in total debt*, for example, the common support option identified four subsidized firms in the 2005 round and six in the 2007 round that did not have similar comparison observations among firms not receiving the subsidy. There were more unsubsidized firms — around 35% and 17% in the two rounds — that did not have a similar counterpart in the subsidized group. In line with Heckman et al. (1997), who noted that inferences about the causal effect of a treatment can only be made in the area of common support, we dropped these observations.

This procedure led to a good balance between subsidized and unsubsidized firms. Balancing tests assessing the quality of matching (Table 4) showed that after matching, subsidized firms were undistinguishable from the untreated firms included in the control group.[14] The differences between the two groups of firms in terms of the mean values of the variables used in the matching procedure were small and not statistically significant. We can therefore conclude that our matching procedure provided a good balance between the two groups of firms.

5.2. Main results

After identifying comparable groups of subsidized and unsubsidized firms using PSM, we used DID to estimate the causal effect of R&D subsidies. Table 5 shows the average treatment effects on treated units for the two rounds of the subsidy program separately (columns 1 and 2) and together (column 3). The impact on *Change in total debt* was

[13] Looking, for example, at the first round of the program, the year of funding was 2005 and the baseline year was 2004, so the short-term period included the years 2005 and 2006 and the medium-term period the years 2007, 2008, and 2009.

[14] Descriptive statistics reported in Table 4 are slightly different from those in Table 3. Table 3 refers to the year 2004 for both rounds of the program, while Table 4 refers to 2004 for round 2005 and to 2006 for round 2007.

Table 5
DID estimates on the effects of R&D subsidies.

	Round 2005	Round 2007	Both Rounds
Change in total debt (%)			
Short-term average effect	−0.153***	−0.085	−0.049
	(0.057)	(0.061)	(0.049)
Medium-term average effect	−0.050	−0.020	−0.032
	(0.061)	(0.065)	(0.044)
Number of treated firms	73	89	162
Change in short-term debt (%)			
Short-term average effect	−0.140*	−0.216***	−0.159***
	(0.074)	(0.082)	(0.053)
Medium-term average effect	−0.166**	−0.220***	−0.184***
	(0.076)	(0.082)	(0.052)
Number of treated firms	73	89	162
Change in long-term debt (%)			
Short-term average effect	0.384*	0.457	0.463
	(0.208)	(0.425)	(0.493)
Medium-term average effect	0.415**	0.659*	0.486**
	(0.190)	(0.390)	(0.213)
Number of treated firms	73	89	162
Long-term debt over total debt			
Short-term average effect	0.005	0.030*	0.008
	(0.014)	(0.017)	(0.012)
Medium-term average effect	0.045**	0.038*	0.043*
	(0.019)	(0.023)	(0.022)
Number of treated firms	73	89	162
Bank debt over total debt			
Short-term average effect	0.123	0.147	0.160
	(0.167)	(0.153)	(0.117)
Medium-term average effect	0.187*	0.181**	0.177*
	(0.098)	(0.101)	(0.103)
Number of treated firms	51	65	116
Long-term bank debt over total bank debt			
Short-term average effect	0.026	0.085*	0.044
	(0.047)	(0.051)	(0.033)
Medium-term average effect	0.064*	0.102*	0.182**
	(0.038)	(0.057)	(0.082)
Number of treated firms	51	65	116
Cost of debt			
Short-term average effect	−0.173	−0.317**	−0.240
	(0.178)	(0.130)	(0.250)
Medium-term average effect	−0.293*	−0.375**	−0.321*
	(0.170)	(0.180)	(0.186)
Number of treated firms	51	77	128
Trade debt over total debt			
Short-term average effect	−0.028	−0.017	−0.020
	(0.026)	(0.027)	(0.015)
Medium-term average effect	−0.052*	−0.044*	−0.052***
	(0.022)	(0.021)	(0.013)
Number of treated firms	37	45	82

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. Heteroskedasticity-robust standard errors in parentheses.

significant only in the short term and for the first round of the program. However, the statistical significance disappeared in the second round and when the two rounds were considered separately. This suggests that receiving R&D subsidies had no effect on the overall indebtedness of firms and that there was no resource effect. Other results show that public subsidies encouraged subsidized firms to use banks as a source of funding. The variable *Bank debt over total debt* was positively and significantly related to the receipt of subsidies in the medium term, i.e., from two to four years after the award of the public subsidy. To the extent that banks pay special attention to the positive signals linked to the passing of a bank-type screening and the obtaining of public subsidies, the significant increase in bank debt for subsidized firms reflects a certification effect.

This was confirmed by the changes in the debt structure of subsidized firms, which reduced short-term borrowing and increased long-term financing. There was a significant decline shown by *Change in short-term debt* in both rounds of the program and both time horizons. By contrast, the coefficients for *Change in long-term debt* were positive and larger, especially in the medium term. These changes in the maturity structure of debt were reflected in a significantly higher ratio between long-term debt and total debt in the medium term (*Long-term debt over total debt*) and in a higher long-term exposure with banks (*Long-term bank debt over total bank debt*).

Looking at the average cost of debt (*Cost of debt*), the DID estimates were negative and statistically significant in the three estimations, and especially in the medium term. This finding is consistent with the presence of a certification effect of R&D subsidies, which allowed firms to reduce their average cost of debt compared to matched firms.[15] Lastly, public subsidies induced firms to reduce trade debt (*Trade debt over total debt*) in the medium term.

Summing up, the R&D subsidy program had a mixed and statistically insignificant impact on overall indebtedness but allowed SMEs to reduce short-term borrowing and increase long-term financing. The program also reduced the average cost of debt in SMEs. Focusing on bank financing, subsidized firms increased their use of loans from banks in the short and medium term, but especially in the long term. Finally, subsidized firms reduced trade debt in the medium term. The estimates were consistent across the two rounds of the subsidy program and when these were considered jointly, with only small differences in the size and statistical significance of the coefficients.

Taken together, these results are consistent with the certification hypothesis. The effects on the structure and costs of debt for subsidized firms were persistent over time and both statistically and economically stronger in the medium term, which further confirms that R&D subsidies had a positive and long-lasting certification effect on the structure and cost of debt. This effect goes beyond the implementation of the research project and the presence of a resource effect. This is especially true for the maturity structure of debt, which in the years after the projects became much more long-term oriented. By contrast, the influence of a resource effect on firm debt was unclear and would be expected to appear immediately after the receipt of subsidies. The increasing use of bank debt provides qualified support for the certification role of public subsidies and, at the same time, reduces the plausibility of a resource effect.

The impact of the subsidy program was sizeable. We have information on the amount of the awarded grant for about 72% of recipient firms. The comparison between subsidized and control firms provides useful information on the average effects. Column 3 of Table 5 shows that the short-term debt of subsidized firms decreased by approximately 16% two years after receiving the subsidy and by 18% in the following three years. The increase in long-term debt was stronger, at approximately +48% in the medium run. The estimates for *bank debt over total debt* also suggest an important effect on bank debt, which increased by about 18% of total debt. Trade debt decreased by 5.2% of total debt in the medium term.

As for the average cost of debt, in the medium-term subsidized firms paid 32 basis points less than firms that did not receive the subsidy. Considering the average value of total debt reported in Table 3 (€5684,000), the certification effect produced by the subsidy award allowed recipients to save about €18,250 per year.

5.3. Robustness analysis

To confirm the validity of our main results, we tested the validity of the parallel-trend assumption for the two rounds of the program. By combining matching with DID, we could account for observable heterogeneity between subsidized and control firms and time-invariant unobserved characteristics that differed between the two groups.

[15] Across both roudns, only seven firms requested the interest rate subsidy. To assess whether these firms drive the effect of R&D subsidy on the cost of debt, we re-estimated the model without them. The DID estimates are reported in Table A3 of the Appendix and show that the impact on the cost of debt is not affected by these firms.

Table 6
Test on the parallel-trend assumption of DID.

	DID estimate
Total debt	20.3 (122.1)
Short-term debt	−136.7 (161.6)
Long-term debt	52.2 (61.7)
Bank debt over total debt	0.023 (0.085)
Long-term bank debt over total bank debt	−0.001 (0.068)
Cost of debt	−0.057 (0.208)
Trade debt over total debt	−0.024 (0.019)

Notes: the table shows the DID estimate in the two years before the PIREDES program starts. Both rounds of PIREDS are considered in this test.

However, the reliability of this empirical strategy crucially depends on the assumption that there were no time-varying differences between subsidized and control firms. This parallel-trend assumption could not be demonstrated because it was impossible to assess whether the outcomes of subsidized and control firms would have moved in tandem in the absence of the program. A good check to evaluate its plausibility, however, is to compare the changes in the outcomes for the two groups of firms in the years before the implementation of the subsidy program (Gertler, Martinez, Premand, Rawlings, & Vermeersch, 2016). If the outcomes had the same trends before the program started, it is reasonable to conclude that without the subsidy they would have continued to move in tandem during the study period.

We therefore replicated the empirical strategy used in the main analysis by estimating Eq. (1) in the two years before the program: 2003 and 2004 for the 2005 round and 2005 and 2006 for the 2007 round. For 2003, we could not compute the growth rates of the outcome variables, so we used their level. The results are summarized in Table 6 and show that the outcomes were not significantly different for subsidized and control firms before the receipt of the subsidy, supporting the plausibility of the parallel-trend assumption. This robustness test also suggests that we can reasonably exclude the presence of an anticipation effect, also known as Ashenfelter's dip, for the various outcomes.[16]

In the main analysis, we used nearest neighbor (NN) matching, which identified one control firm for each subsidized firm in the sample. A possible drawback of this type of matching is that it uses only a small subset of untreated units, discarding some potentially useful information. Therefore, as a further sensitivity check we replicated the main analysis using two alternative algorithms: nearest neighbor with 3 nearest neighbors for each treated firm and kernel matching. The latter is a non-parametric matching estimator that uses a weighted average of all unsubsidized firms to build the counterfactual match for subsidized firms. A major advantage of kernel matching is that it uses all available information, while other algorithms such as nearest-neighbor matching use only a subset of untreated units to build the control group.[17]

Table A2 in the Appendix shows the results. Despite the coefficients being lower in absolute magnitude, the signs of the coefficients and the statistical significance were in line with the main results and were robust to the use of alternative matchings.

In addition, we assessed whether the main results are confirmed if we adopt a matching procedure that constrains control firms to be headquartered within the same province or to operate in the same industrial sector of the matched subsidized firm. Comparing firms in the same province, we are confident that the results are not driven by the different characteristics of the local credit markets, while comparing firms in the same industry rules out potential bias due to asymmetric shocks between sectors. The results are reported in Table A5 of the Appendix and generally confirm the main estimates.

5.4. Subsample analysis

To obtain more information about the empirical relevance of the certification hypothesis, we replicated the analysis distinguishing between different subsamples of firms based on age, credit risk, size of the grant received, and degree of innovativeness. To ensure the comparability of the control and treated firms, we repeated the PSM procedure for each subsample using the belonging to that subsample as the eligibility criterion for common support.

5.4.1. Firm age

Assuming that young firms are more informationally opaque than mature firms, they are expected to benefit more from the positive signal of a subsidy award. By contrast, for mature firms R&D subsidies primarily act as a source of fresh and low-priced external finance. We therefore tested whether the effects of the R&D subsidy on debt structure were stronger for young firms and whether the effects of debt reduction were more obvious for mature firms.

In our sample, the distribution of subsidized firms by age showed a mean of 18.6 years and a median of 18 years. We therefore used 18 years as the threshold to identify the two groups of firms: firms under 18 years of age were "young", and those 18 and over were "mature".[18] Our subsample analysis confirmed that the signal given by R&D subsidies was particularly effective in certifying the quality of young firms, helping them to access external financing (Table 7). First, compared to mature firms, young firms significantly reduced their use of short-term debt while they increased long-term financing. For the latter, the coefficients of *Change in short-term debt* were negative and statistically significant while those of *Change in long-term debt* and *Long-term debt over total debt* were positive and significant. This implies that for young firms, the shift in the structure of the debt towards the long term was due to a greater use of this form of indebtedness. For mature firms, the coefficients had the same sign as for young firms but were smaller and showed a lack of statistical significance.

Similar results emerged for bank debt and the cost of debt. Young firms increased their use of bank financing (*Bank debt over total debt*), especially in the form of long-term bank debt, as shown by the coefficients of *Long-term bank debt over total bank debt*, which were positive and significant in the medium term. Therefore, further support for the certification role of R&D subsidies was provided by bank financing. It seems likely that subsidized firms obtained more financing from banks and that they re-balanced their bank debt, increasing the weight of long-term debt to total bank debt. This effect was more pronounced and robust for young firms. Similarly, the average cost of debt (*Cost of debt*) and trade debt (*Trade debt over total debt*) decreased for all firms, but the

[16] To further verify the robustness of our identification strategy, we performed a placebo test by applying the empirical model to a fake outcome, or a firm variable that a priori should not be affected by the PIREDS program. Considering total credit as a fake outcome, we found that it was not affected by PIREDS subsidies. The point estimates are available upon request to the authors.

[17] Other studies using the kernel matching procedure before DID in a similar context of R&D subsidies include, for example, Lööf and Heshmati, (2007), Alecke, Reinkowski, Mitze, and Untiedt (2012), and Moon (2022), while Dottori and Micucci (2019) use the same methodology to analyze the impact of earthquakes that occurred in the Marche region at the end of 2016 on firm investments.

[18] We recognize that the group of firms under 18 years of age included some well-established firms that cannot exactly be considered "young". However, using lower age thresholds would have resulted in unbalanced samples because of the small number of younger firms. Only 26 of the subsidized firms (15%) were under 5 and 46 (26%) were under 10.

Table 7
DID estimates on the effects of R&D subsidies by firms' age and *Z*-score.

	Age < 18 years	Age ≥ 18 years	Z-score < 3	Z-score ≥ 3
Change in total debt (%)				
Short-term average effect	−0.003	−0.005	−0.046	0.165
	(0.092)	(0.072)	(0.058)	(0.126)
Medium-term average effect	−0.077	−0.029	−0.038	−0.048
	(0.111)	(0.062)	(0.045)	(0.081)
Change in short-term debt (%)				
Short-term average effect	−0.254***	−0.119*	−0.186**	−0.047
	(0.090)	(0.065)	(0.094)	(0.127)
Medium-term average effect	−0.292**	−0.246	−0.171*	−0.111
	(0.119)	(0.165)	(0.089)	(0.108)
Change in long-term debt (%)				
Short-term average effect	0.244	0.272	0.139	0.121
	(0.356)	(0.307)	(0.159)	(0.205)
Medium-term average effect	0.523*	0.275	0.244*	0.222
	(0.304)	(0.396)	(0.138)	(0.941)
Long-term debt over total debt				
Short-term average effect	0.057*	−0.040	0.005	0.002
	(0.031)	(0.030)	(0.020)	(0.015)
Medium-term average effect	0.097***	0.023	0.055*	0.027
	(0.026)	(0.046)	(0.031)	(0.045)
Bank debt over total debt				
Short-term average effect	0.241	0.169	0.992	0.194
	(0.279)	(0.323)	(0.919)	(0.462)
Medium-term average effect	0.206***	0.048	0.197*	0.668*
	(0.061)	(0.074)	(0.109)	(0.402)
Long-term bank debt over total bank debt				
Short-term average effect	0.037	0.038	0.076**	0.001
	(0.063)	(0.052)	(0.039)	(0.023)
Medium-term average effect	0.135*	0.001	0.113*	0.068*
	(0.071)	0.071	(0.067)	(0.36)
Cost of debt				
Short-term average effect	−0.236	−0.126	−0.096	−0.114
	(0.293)	(0.139)	(0.116)	(0.173)
Medium-term average effect	−0.257*	−0.143	−0.247*	−0.067
	(0.136)	(0.176)	(0.135)	(0.132)
Trade debt over total debt				
Short-term average effect	−0.032	−0.029	−0.025	−0.043
	(0.067)	(0.021)	(0.47)	(0.46)
Medium-term average effect	−0.085*	−0.045	−0.067*	−0.052**
	(0.037)	(0.036)	(0.035)	(0.023)

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. Heteroskedasticity-robust standard errors in parentheses.

effect was statistically significant only for young firms in the medium term.

5.4.2. Firm credit risk

To the extent that obtaining competitive public subsidies for R&D certifies the creditworthiness of recipients and diminishes the perceived risk of potential external investors, the impact on debt composition, maturity structure, and cost should be especially prominent for firms with higher credit risk.[19] By contrast, although subsidies can act an injection of liquidity strengthening the solvency position of recipients (Chiappini et al., 2022), the role of resource effects through the debt-substitution, additionality, and prototyping channels can be expected to not systematically depend on the credit risk of the recipient firm.

As a measure of firm credit risk, we used the Altman *Z*-score model (Altman, 1968). The original formulation of the score was based on five financial ratios accounting for profitability, leverage, liquidity, solvency, and operating activity to predict whether a firm has a high probability of becoming insolvent. Given that most firms included in our sample were private, we used the modified accounting-based indicator presented in Altman (1983), which basically considers the book value of equity instead of the market value of equity.

Values of the Altman Z-score higher than 3 suggest that a firm is in a solid financial position. Therefore, we used this threshold to identify the two subsamples of "solid" and "risky" firms. If R&D subsidies had a certification effect, they were expected to be more effective for risky firms. However, regardless of firm riskiness R&D subsidies did not affect the total debt of subsidized firms. Nevertheless, risky firms showed a significant change in the structure of total debt towards the long term. They reduced short-term borrowing and increased long-term borrowing both in the short and medium term. The latter effect was confirmed by the coefficient of *long-term debt over total debt,* which was positive and significant. Small firms tend to use more short-maturity debt than long-maturity debt because they are perceived as riskier (Wu et al., 2022). Public subsidies steer firms towards more long-term debt, and this effect is stronger for riskier firms.

This effect was also relevant for bank financing, at least in the medium term, where we found a positive coefficient of *bank debt over total debt*. Also in this case, risky firms re-balanced their indebtedness towards long-term debt, as shown by the coefficients for *long-term bank debt over total bank debt*. Firms with a solid financial position did not change the maturity structure of their debt, although they showed a certain rebalancing towards bank debt, and especially long-term bank debt. The impact of the subsidy program on the cost of debt was stronger and statistically significant only for risky firms. Once again, these results

Table 8
DID estimates on the effects of R&D subsidies by amount of subsidy.

	Grant <200,000	Grant ≥200,000	High-tech firms	Low-tech firms
Change in total debt (%)				
Short-term average effect	−0.028	−0.026	0.129	−0.065
	(0.072)	(0.063)	(0.119)	(0.053)
Medium-term average effect	−0.048	0.001	0.042	−0.042
	(0.161)	(0.054)	(0.149)	(0.046)
Change in short-term debt (%)				
Short-term average effect	−0.142***	−0.090*	−0.131*	−0.124***
	(0.038)	(0.053)	(0.071)	(0.043)
Medium-term average effect	−0.248*	−0.120	−0.249*	−0.173***
	(0.141)	(0.075)	(0.138)	(0.063)
Change in long-term debt (%)				
Short-term average effect	0.011	0.291	0.081*	0.201
	(0.121)	(0.392)	(0.436)	(0.370)
Medium-term average effect	0.400*	0.340	0.391*	0.291
	(0.221)	(0.533)	(0.221)	(0.358)
Long-term debt over total debt				
Short-term average effect	0.046*	−0.021	0.010	0.017
	(0.025)	(0.026)	(0.013)	(0.020)
Medium-term average effect	0.081*	0.013	0.094*	0.016
	(0.049)	(0.039)	(0.053)	(0.021)
Bank debt over total debt				
Short-term average effect	0.102***	0.414	0.467	0.385
	(0.020)	(0.693)	(0.526)	(0.269)
Medium-term average effect	0.718*	0.701*	0.715*	0.549
	(0.400)	(0.411)	(0.410)	(0.450)
Long-term bank debt over total bank debt				
Short-term average effect	0.076*	0.022	0.033	0.049
	(0.044)	(0.065)	(0.051)	(0.046)
Medium-term average effect	0.039	0.001	0.162*	0.035
	(0.023)	(0.087)	(0.095)	(0.069)
Cost of debt				
Short-term average effect	−0.910	−0.176	−0.036	0.216
	(0.777)	(0.251)	(0.164)	(0.145)
Medium-term average effect	−0.209**	−0.136	−0.134*	−0.090
	(0.102)	(0.247)	(0.071)	(0.098)
Trade debt over total debt				
Short-term average effect	−0.055	−0.029	−0.027	−0.043
	(0.045)	(0.021)	(0.024)	(0.033)
Medium-term average effect	−0.059**	−0.041	−0.064**	−0.040
	(0.025)	(0.027)	(0.027)	(0.035)

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. Heteroskedasticity-robust standard errors in parentheses.

[19] Consistent with this conjecture, Bonfim et al. (2023) analyze the certification role of the government guarantee *SME-Leader Program* in Portugal and find that riskier firms benefit more from the certification of "excellence" in that they show a larger increase in loans and reduction in interest rate.

are consistent with the certification hypothesis, especially when considering the structure of debt, and support the conclusions of the main analysis.

5.4.3. Subsidy amount

To further investigate whether being awarded a subsidy plays a certification role for recipients, we split our sample according to the amount of subsidy received. This information is available for 127 firms (72% of the subsidized firms in our sample). The idea is that the certification effect is largely independent of the level of financial resources received by the firm, while resource effects should be more evident for firms receiving large subsidies.

Therefore, we considered the two subsamples of firms receiving subsidies below and above the median value. Consistent with the certification hypothesis, our results are not stronger for firms receiving large subsidies, while they are statistically significant for the group of firms with small R&D subsidies (Table 8). These firms are likely to exploit the certification provided by succeeding in the competition for the public funds to rebalance their debt towards longer maturities and reduce the cost of debt.

5.4.4. Firm innovativeness

Lastly, we assessed whether the degree of firm innovativeness affected the main results of the analysis. To this aim, we used the European Commission classification that breaks down the manufacturing and services industries by their technological intensity to split our sample into two groups: a group of high-tech firms that includes high technology industries and knowledge-intensive services and a group of low-tech firms that includes medium- and low-technology industries and less knowledge-intensive services. We expect that firms operating in high-technology sectors benefitted more from the receipt of the R&D subsidy because of their information opacity and information asymmetries with external lenders (Hottenrott et al., 2018; Martí & Quas, 2018).

The estimates reported in Table 8 show that both high-tech and low-tech firms reduced their short-term debt after receiving the subsidy. However, only high-tech firms increased their long-term debt and bank financing, decreased trade debt, and experienced a reduction in the cost of debt. These findings support the view that R&D subsidies play a certification role of SME awardees for external lenders.

6. Concluding remarks and policy implications

R&D and innovation are crucial to firm success and competitiveness. The literature has emphasized that firms may face difficulties in financing their innovation activities and that this problem is exacerbated for SMEs. An extensive literature has analyzed the role of R&D subsidies as a policy tool to foster R&D investments and to enhance innovation and performance in the private sector (e.g., Dimos & Pugh, 2016; Marino et al., 2016). However, little attention has been paid to the *unintended* effects of R&D subsidies on other organizational and economic choices of subsidized firms. This study extends our knowledge of the behavioral effects of public funding for private R&D, which go beyond the desired goals of supporting private R&D investments or improving the innovation performance of subsidized firms. Specifically, we focused on the effects of R&D subsidies on the amount, structure, and cost of debt for subsidized firms.

We used a unique sample of firms from the Marche region of Italy to assess the effects of a regional subsidy program designed to support private R&D projects. The program provides an ideal setting for analysis because a commercial bank evaluated the financial aspects of the research projects of applicants. Our empirical findings show that receiving an R&D subsidy had three major effects on the debt of firms. First, after receiving subsidies firms modified the maturity structure of their debt, increasing the proportion of long-term financing. Second, subsidized firms used bank debt more extensively than other types of highly priced debt, such as trade credit. Third, the average cost of debt tended to be lower for subsidized firms in both the short and medium term. These effects were independent of the amount of subsidy received and were more pronounced for the firms expected to suffer most from asymmetric information and access to credit problems (i.e., firms that are younger, riskier, and operate in high-tech sectors),

Our results suggest that passing the screening process of the R&D subsidy program provided a positive certification effect for awardee SMEs, which helped them overcome or mitigate financing constraints. The certification role of subsidies may be more pronounced if the screening process is carried out by commercial banks, as in the subsidy program in this paper. In this case, external investors know that the firms awarded by R&D grants were positively evaluated by an informed agent. This provides a credible, positive signal about the quality of a firm and its research project and reduces the risk of financing in the eyes of external investors.

Of course, to the extent that certifying the credit quality of subsidized firms is not one of the intended goals of an R&D subsidy program, it would be purposeless to assess the welfare effects stemming from its effects on corporate debt without considering its impact on R&D expenditures and outcomes of firms receiving the subsidies. From this point of view, Bellucci et al. (2019) find that the same subsidy program grants analyzed in this paper had an additionality impact on both R&D expenditure and patents, thus suggesting a possible welfare-enhancing role of the subsidies that is potentially augmented by the certification effects on access to credit.

Whatever the input and output additionality of public R&D subsidies, if the seal of credit quality certification is an important effect linked to their granting that provides subsidized SMEs wider and less expensive access to credit regardless of the amount of the subsidy received, it is relevant to explore the possibility of designing explicit credit-quality certification policies for SMEs, acting as a sort of public credit rating agency. However, while the informativeness of the rating assigned by a private rating agency is guaranteed by the value of its reputational capital, in the case of public ratings it would be necessary to design potentially costly mechanisms capable of guaranteeing the reliability of the signal to private investors. Therefore, although in principle (and in fact, as our evidence demonstrates) the certification effects deriving from the awarding of an R&D subsidy are independent of the money granted to the company, the credibility for external investors of the signal of recipients' creditworthiness depends on the resources and costly procedures of implementing the grant program. Our estimates show that for each euro of subsidy, the recipients save approximately 0.45 euros on the cost of debt in the following five years. This suggests that the program we analyzed may have been effective in providing a signal of the recipients' quality but not efficient, that there may be room for public rating policies and that analyzing their efficient design and implementation is an important topic for future research.

Data availability

The authors do not have permission to share data.

Acknowledgements

We are especially grateful to Professor Brian Lucey (the Editor) and to three anonymous referees for their constructive suggestions. We also thank participants at the conferences on “Innovation, Competitiveness and Public-Private Partnerships”, United Nations; COMPIE 2018 “Counterfactual Methods for Policy Impact Evaluation”, Humboldt University; “Entrepreneurship and Economic Development”, University of Bari, “SMEs, Banks, Finance, Innovation and Growth”, University of Urbino; “Capital Markets Union: Unlocking Europe’s economic potential”, European Commission, Brussels; SIEPI Workshop 2019; and seminars at the University of Naples Parthenope; Roma Tre University, University of Insubria and the European Commission JRC Unit B1 Finance and Economy for helpful comments. A working paper version of

this paper circulated with the title "R&D subsidies and firms' debt financing" CSEF WP, No. 527 and MoFiR WP, No. 153, 2019. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix

Table A1
Definition of variables used in the empirical analysis.

Variable	Definition
Total debt	Short-term debt + Long-term debt
Short-term debt	Short-term borrowing (< 12 months)
Long-term debt	Long-term borrowing (> 12 months)
Total bank debt	Short-term bank debt + Long-term bank debt
Short-term bank debt	Short-term bank borrowing (< 12 months)
Long-term bank debt	Long-term bank borrowing (> 12 months)
Cost of debt	Cost of debt (%)
Trade debt	Trade debt
Indebtedness	Total assets / Equity
Cash flow	Cash flow
Cash flow over total assets	Cash flow / Total assets
Age	Number of years since the establishment of the firm
Sales	Total sales
Turnover growth	Percentage change of total sales
Value added	Value added
Employees	Number of employees
Total assets	Total assets
EBITDA/sales	(Operating profit + Depreciation expenses + Amortization expense) / Sales
Return on Equity (ROE)	Profit / Equity
Tangible assets	Tangible assets
Intangible assets over total assets	Ratio between intangible assets and total assets
R&D intensity	Expenditure in R&D / Sales
Wages	Amount of wages paid to employees
Patents	Number of patent applications to the European Patent Office

Table A2
DID estimates on the effects of R&D subsidies with NN (3) and kernel matching.

	NN (3)	Kernel Matching
Change in total debt (%)		
Short-term average effect	−0.041	0.006
	(0.186)	(0.016)
Medium-term average effect	−0.094	−0.008
	(0.206)	(0.019)
Change in short-term debt (%)		
Short-term average effect	−0.244*	−0.030*
	(0.141)	(0.018)
Medium-term average effect	−0.287*	−0.032*
	(0.171)	(0.016)
Change in long-term debt (%)		
Short-term average effect	0.216	0.192*
	(0.281)	(0.110)
Medium-term average effect	0.381**	0.230*
	(0.185)	(0.121)
Long-term debt over total debt		
Short-term average effect	0.0013	0.013
	(0.024)	(0.007)
Medium-term average effect	0.103**	0.015**
	(0.047)	(0.007)
Bank debt over total debt		
Short-term average effect	0.055	0.222*
	(0.038)	(0.132)
Medium-term average effect	0.084***	0.242*
	(0.027)	(0.144)
Long-term bank debt over total bank debt		
Short-term average effect	0.042	0.014
	(0.031)	(0.018)
Medium-term average effect	0.069*	0.035**
	(0.358)	(0.017)
Cost of debt		
Short-term average effect	−0.075***	−0.109*
	(0.019)	(0.063)
Medium-term average effect	−0.124**	−0.110**
	(0.053)	(0.055)

(*continued on next page*)

Table A2 (*continued*)

	NN (3)	Kernel Matching
Trade debt over total debt		
Short-term average effect	−0.025	−0.009
	(0.036)	(0.012)
Medium-term average effect	−0.105**	−0.048**
	(0.044)	(0.023)

Table A3
Robustness check for the effect of R&D subsidies on the cost of debt.

	Round 2005	Round 2007	Both Rounds
Cost of debt			
Short-term average effect	−0.043	−0.274	−0.115
	(0.312)	(0.125)	(0.142)
Medium-term average effect	−0.371*	−0.375*	−0.368*
	(0.190)	(0.180)	(0.210)

Table A4
Correlation matrix for the outcome and matching variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1) Change in total debt																	
(2) Change in short-term debt	0.75																
(3) Change in long-term debt	0.02	0.01															
(4) Long-term debt over total debt	0.00	−0.08	−0.00														
(5) Bank debt over total debt	0.06	0.01	0.01	0.02													
(6) Long-term bank debt over total bank debt	−0.02	−0.05	−0.00	0.64	−0.01												
(7) Cost of debt	−0.03	0.00	−0.00	−0.00	−0.04	0.04											
(8) Trade debt	0.11	0.15	−0.00	0.02	−0.00	0.01	0.01										
(9) Total assets	0.01	−0.00	0.00	0.12	0.01	0.07	−0.00	0.00									
(10) Wages	−0.00	−0.01	0.00	0.02	−0.00	0.05	0.01	−0.00	0.86								
(11) Patents	0.00	0.00	−0.00	−0.01	−0.00	0.01	−0.04	−0.00	0.15	0.24							
(12) Cash flow	−0.01	−0.00	−0.00	−0.03	0.00	0.08	−0.04	0.00	0.03	0.05	0.03						
(13) Indebtedness	0.01	0.01	−0.00	−0.06	−0.00	−0.07	0.06	−0.00	−0.04	−0.04	−0.02	−0.06					
(14) Intangible assets	0.14	0.11	0.05	−0.00	−0.00	−0.00	0.00	0.01	−0.01	−0.01	−0.00	0.01	0.00				
(15) Age	−0.03	−0.03	−0.00	0.04	0.05	0.05	−0.01	0.02	0.15	0.14	0.07	−0.04	−0.08	0.01			
(16) EBITDA over sales	0.01	0.02	−0.00	0.24	−0.00	0.12	−0.01	0.01	0.07	0.00	0.00	0.35	−0.03	0.00	−0.03		
(17) ROE	0.02	0.04	−0.00	−0.12	0.00	−0.04	−0.03	0.00	0.01	0.01	0.01	0.39	−0.05	0.00	−0.10	0.18	
(18) Firm growth	0.05	0.05	0.00	−0.05	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.07	0.00	0.01	0.01	−0.05	0.07

Table A5
DID estimates with constrained matching.

	By province	By industry
Change in total debt (%)		
Short-term average effect	−0.019	−0.014
	(0.048)	(0.053)
Medium-term average effect	−0.015	−0.058
	(0.029)	(0.027)
Change in short-term debt (%)		
Short-term average effect	−0.030	−0.017
	(0.053)	(0.061)
Medium-term average effect	−0.131***	−0.094**
	(0.033)	(0.044)

(*continued on next page*)

Table A5 (*continued*)

	By province	By industry
Change in long-term debt (%)		
Short-term average effect	0.176***	0.086
	(0.006)	(0.064)
Medium-term average effect	0.885*	0.521*
	(0.487)	(0.279)
Long-term debt over total debt		
Short-term average effect	0.016**	0.024
	(0.008)	(0.021)
Medium-term average effect	0.033**	0.035**
	(0.013)	(0.014)
Bank debt over total debt		
Short-term average effect	0.112	0.020
	(0.162)	(0.014)
Medium-term average effect	0.132*	0.294**
	(0.075)	(0.123)
Long-term bank debt over total bank debt		
Short-term average effect	0.014	0.046
	(0.021)	(0.034)
Medium-term average effect	0.107**	0.087*
	(0.054)	(0.048)
Cost of debt		
Short-term average effect	−0.150	−0.188
	(0.240)	(0.246)
Medium-term average effect	−0.415**	−0.352**
	(0.190)	(0.142)
Trade debt over total debt		
Short-term average effect	−0.015	−0.014
	(0.028)	(0.028)
Medium-term average effect	−0.700*	−0.511**
	(0.397)	(0.243)

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. Heteroskedasticity-robust standard errors in parentheses.

Appendix. The regional context and the program under scrutinyr

The regional context

The public program under analysis has been implemented in the Marche region of Italy. The Marche region is located in the center of Italy and represents one of the twenty NUTS2 regions in the country. The regional model of development is based on small and medium-sized enterprises (SMEs). Through value chain connections and other formal and informal networks, SMEs are connected in an integrated territorial system that strikes a unique balance between inter-firm competition and collaboration. According to the Italian Institute of Statistics (ISTAT), in the Marche region there are 19 industrial districts that employ 70% of the regional labor force, with approximatively 75% of workers in the manufacturing sector. According to the survey on "Industry and Services" conducted by ISTAT in 2011, 79% of the labor force is employed in SMEs with fewer than 10 employees and 19% in firms with between 10 and 49 employees, only the remaining 2% work in firms with >50 employees.

Historically, the industrial system has focused on traditional industries with low-to-medium technological intensity, such as food, footwear and leather, furniture, equipment, and textiles. However, in recent years more technologically advanced companies in fields such as ICT and domotics have grown in significance in the regional economy (Alessandrini, 2015; Iacobucci, Micozzi, & Micozzi, 2015).

The Marche region had the lowest level of specialization in high-tech industries in 2008 (2.1%, as opposed to the national average of 3.3%). But in 2013 the region outperformed all others, increasing this from 2.1% to 2.7%, although the degree of specialization was still below the national average (3.4%) (see Table A6).

The fraction of manufacturing companies that have introduced product/process innovations is much lower and declining (24.5%) compared to the Italian average (33.5%), confirming the low propensity of local SMEs for innovation. Most businesses with product/process innovations have only introduced process innovations (16%), while a small percentage have only introduced product innovations (5%); for Italy as a whole, the corresponding figures are 16% and 5%, respectively. Local businesses are also relatively more likely to introduce process innovations than product innovations. Similar indications can be found in the ratio of R&D spending to GDP, which is consistently lower than the Italian average, particularly for private businesses. In 2012, the Marche region fell short of the Italian average in terms of both the proportion of researchers to the entire workforce (2‰ and 3‰ in the Marche and Italy, respectively) and the number of employees engaged in R&D activities (3.1 per thousand workers, compared to an average of 4 for Italy). These numbers support an innovation model based on a widespread innovative capability produced by learning-by-doing processes, the acquisition of existing knowledge from external sources, and localized knowledge spillovers in industrial districts and value chain networks but a weak propensity for internal R&D (Favaretto & Zanfei, 2007). Hence, the program analyzed here aimed to finance R&D investments for local SMEs in the Marche region to promote the introduction of radical and incremental product/process innovations.

Table A6
Descriptive statistics for Marche regional innovation systems in selected years (%).

	2008		2012	
	Marche	Italy	Marche	Italy
Specialization in sectors with high knowledge intensity*	2.1	3.3	2.6	3.3
Rate of innovation of manufacturing firms**	29.7	30.7	24.5	33.5
R&D expenditure of the private sector on GDP, total***	0.35	0.62	0.41	0.69

Source: our calculations based on ISTAT and Eurostat data.
Notes: * percentage of employees in high-tech manufacturing and service industries on total workforce, ** share of manufacturing firms introducing product and/or process innovations, *** total intramural R&D expenditure (all expenditure for R&D performed within a sector) on GDP.

The regional program

To look at the causal impact of R&D subsidies on firm debt, we analyzed two rounds (2005 and 2007) of a public regional subsidy program named "Intervento 1.1.1.4.1. - Promozione della ricerca industriale e sviluppo sperimentale nelle PMI" (Intervention 1.1.1.4.1. - Promotion of Industrial Research and Experimental Development in SMEs, or PIREDS), run by the Marche Region in Italy. The regional subsidy program under scrutiny is funded by the European Regional Development Fund and implemented and managed by the Marche Region through its Regional Authority for Innovation. The purpose of this program is to support local SME R&D expenditures, which should result in the introduction of both radical and incremental product/process improvements and innovations. The program provides monetary subsidies to SMEs to begin experimental activities and industrial research. Eligible businesses are from a select group of industries considered strategically significant to the regional economy. Traditional industries such as food or clothing are included in the eligible categories, as well as more technologically advanced ones like ICT, nanotechnology, building automation, and novel materials.

The initiative is aimed at companies that meet the European Union's definition of SME[20] and are headquartered in the region. A company can apply for the subsidy if it has fewer than 250 employees and either a turnover under €50 million, or total assets under €43 million. Additionally, no other public subsidies (regional, national, or European) for R&D may be received by the applying companies. This criterion is very beneficial to our research because it eliminates a significant confounding element and aids in determining the causal relationship between the regional program under examination and the R&D input and output of recipient enterprises. Upon acceptance, funded projects must begin within one month and must be completed within 18 months. The costs of machinery, equipment, raw materials, software, patents, licenses, salaries for hired researchers, and fees for consulting services are all eligible for financial subsidization. The project must have a minimum budget of €200,000. The maximum amount of the non-repayable grant is 35% of the project's total expenses, while the maximum interest rate on the repayable subsidy is 10%.

The regional government appoints a committee of independent experts to evaluate applications and make approval decisions. The research projects are evaluated using a number of criteria, with a focus on competitiveness and innovativeness as well as the ability to enhance the employment of highly qualified employees. Table A7 provides some descriptive statistics for the two program waves.

Project size ranged between €100,000 and €1,000,000 for the first rounds of the program and between €200,000 and €2,000,000, for the second wave. However, the average grant amount throughout the two rounds was relatively comparable, coming in at an average of €202,120 for a total of €57 million in granted subsidies. Across the two rounds there were 441 applications, of which 282 were accepted (64%) and 159 were rejected (36%). The amount of subsidies granted seems quite substantial given the small dimensions of the targeted businesses.

Table A7
Descriptive statistics for the regional program.

	Round 2005	Round 2007
Total amount of grants (millions of euros)	15.3	28.4
Projects funded	103	179
Projects not approved	90	69
Admissible amount of projects		
Min.	0.1	0.2
Max.	1	2
Average amount of funded projects	0.185	0.212

Note: Amount is in millions of euros.

The number of submissions indicates that the majority of proposals were accepted and funded. There were 193 and 248 applications submitted in each round of program, respectively, of which 103 (54%) and 179 (72%) were approved. Looking at the distribution of SMEs by industry, it is worth noting that subsidized companies operated in both the traditional sectors of the local economy and more technology-intensive industries (e.g., computer and electronic products, machinery and equipment). It is also worth noting that the distribution of SMEs across industries was homogeneous between the two rounds.

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[20] The definition of small and medium-sized enterprises adopted by the Regional Agency for Innovation follow the European Commission's definition adopted in its Recommendation of May 6, 2003 (GUCE L 124/36 of 20/5/2003).

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