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R&D Subsidies and Firms' Debt Financing

Andrea Bellucci, Luca Pennacchio and Alberto Zazzaro

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University of Naples Federico II

University of Salerno

Bocconi University, Milan

CSEF - Centre for Studies in Economics and Finance
DEPARTMENT OF ECONOMICS – UNIVERSITY OF NAPLES
80126 NAPLES - ITALY
Tel. and fax +39 081 675372 – e-mail: csef@unina.it
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Abstract

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

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

JEL Classification: G30; H25; O31; O38; R58.

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** Università di Napoli Parthenope. Corresponding author. Università di Napoli Parthenope, Department of Business and Economics, Via Generale Parisi 13, Naples, Italy. E-mail address: luca.pennacchio@uniparthenope.it.

*** Università di Napoli Federico II, CSEF and MoFiR. E-mail: alberto.zazzaro@unina.it

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1. Introduction

Public subsidy programs are widely used by national and regional governments to support private sector research and development (R&D) and innovation (OECD 2011). The effectiveness of these programs is typically assessed by measuring the additionality effects in terms of R&D inputs and outputs (Georghiou and Clarysse 2006). Input additionality assesses whether public funding supplements or crowds out R&D investments in recipient firms. Output additionality focuses on scientific and innovation performance of subsidized firms, such as patent applications or product and process innovations that the firms would not have achieved without public support.[1] This traditional view of additionality has recently been complemented by behavioral additionality, where a public intervention causes changes in firms' behavior in other business domains not immediately related to innovation, such as organization, finance and market strategy (Buisseret et al. 1995). This paper contributes to this literature on behavioral additionality by investigating the impact of public subsidies on financial decisions and capital structure of subsidized firms.

A common motivation for public support of private R&D is the "funding gap" for innovation investments (Hall and Lerner 2010). Innovation projects are characterized by a high degree of uncertainty, large amounts of private knowledge and non-disclosable information, and investment in intangible and non-redeployable assets. This makes the monitoring costs for banks and other investors especially high, and access to collateral especially low. As a result, raising external finance is typically more expensive and problematic for innovation than for more traditional investments, and it has a strong influence on the optimal capital structure and debt composition of innovative companies (Aghion et al. 2004).

Access to public R&D subsidies can have two non-mutually exclusive effects on debt financing of recipient firms. First, subsidies are an additional, low-priced source of finance that can reduce the "funding gap" of recipients, affecting the amount, structure and cost of debt (*resource effect*). Second, access to subsidies provides a positive signal about the quality and creditworthiness of beneficiary firms that reduces information asymmetries and costs for private investors (*certification effect*).

In this paper, we explored the effects of public subsidies for R&D projects on total amount, composition and cost of debt of recipient firms, relative to firms not receiving public subsidies. We examined a subsidy program running in the Marche region of Italy in the period 2005–2012, using a difference-in-differences approach, combined with matching methods to select control groups of (similar) firms not receiving subsidies. This program is an ideal setting to evaluate the effects of public funding on firms' indebtedness. First, the funding scheme consisted of a direct monetary grant, which was a source of fresh, low-priced financial capital for subsidized firms and the most suitable public instrument for R&D in small and medium-

[1] The impact evaluation literature is not conclusive (David el al. 2000; Dimos and Pugh 2016). Most studies support the view that public funding produces additionality in R&D investments and innovation of private firms (Aerts and Schmidt 2008; Gonzalez and Pazo 2008; Czarnitzki and Lopes-Bento 2013; Herrera and Sanchez-Gonzalez 2013; Hottenrott and Lopes-Bento 2014; Costantini et al. 2015; Hud and Hussinger 2015; Bellucci et al. 2016; Mateut 2018). Some, however, provide evidence that public intervention crowds out private R&D investments or is ineffective in increasing firm performance (Busom 2000; Hall and Lerner 2010; Marino et al. 2016). The effectiveness of public subsidies varies with the context of analysis (Klette et al. 2000; Zuniga-Vicente et al. 2014), the methodology used for evaluation (David el al. 2000; Cerulli 2010), and the design of public instruments (Bellucci et al. 2019).

sized enterprises (SMEs) (Busom et al. 2014; Radas et al. 2015). Second, the subsidy program required submitted projects to be evaluated by a commercial bank and a committee of independent experts from the Italian Ministry of Economic Development, which decided on their financial feasibility and merit. The in-depth banking screening required to secure access to public financial resources makes it possible to assess and compare the prominence of the resource and certification effects of public subsidies on firms' indebtedness. Third, the program was aimed at SMEs in a single region (Marche). The size of eligible firms is relevant because the innovation funding gap is particularly important for small to medium-sized firms. They also make up the backbone of the Marche economy. The local dimension of the subsidy program means that all the firms shared the same economic environment, including banking and financial markets, which improves the quality of matching between funded and non-funded firms.

Our results show that R&D subsidies did not affect the overall level of indebtedness of recipient firms, 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 banking debt; and (iii) to reduce the average cost of debt. These effects were more pronounced in the medium term and for young firms, supporting the view that public funding had a "certification effect" for subsidized firms, signaling their quality to private financers, who are then prepared to provide more long-term credit at lower costs.

A few recent studies have analyzed the effects of R&D subsidies on firms' access to specific external financial resources. However, the overall impact of public subsidies on firms' debt structure and cost is still relatively unexplored, and there is no systematic assessment of the relevance of the resource and certification effects. Consistent with the certification role of public subsidies, Lerner (1999) noted that SMEs receiving grants under the Small Business Innovation Research program in the United States were more likely to attract venture financing in the next few years. They also had higher growth rates than similar non-grant-receiving firms, regardless of the number of grants involved. Feldman and Kelley (2006) looked at a sample of US firms applying for a government program which supported early-stage research projects, and confirmed Lerner's results. They showed that funding recipients raised more funds from venture capitalists and other sources after the public grant than rejected applicants. Islam et al. (2018) found that US start-ups receiving research grants were 12% more likely to obtain subsequent venture capital funding. Wei and Zuo (2018) looked at the certification effect of R&D subsidies and analyzed whether the subsidies provided by different government agencies had an impact on access to external funds in a sample of Chinese listed companies. They found that receiving R&D subsidies from local governments positively signaled the quality of R&D projects, improving access to equity investments and bank loans. Subsidies from the central government, however, tended to worsen access to external capital. These results were confirmed by Li Li et al. (2019), who analyzed a sample of listed and unlisted Chinese innovative entrepreneurial firms from 2009 to 2013. They found that access to government R&D subsidies increased access to bank loans, especially for unlisted companies, where less information was publicly available. Similarly, based on a panel of newly funded start-ups in Germany interviewed between 2005 and 2009, Hottenrott et al. (2018) found that new

high-tech ventures receiving a public grant (not necessarily related to R&D investments) were more likely to use long-term bank loans and have a higher share of bank debt in their venture's financing mix.

Most closely related to our analysis, Meuleman and De Maeseneire (2012) and Hottenrott and Demeulemeester (2017) looked at a panel of Belgian firms applying for subsidies from the Institute for the Promotion of Innovation by Science and Technology. They investigated the effect of receiving subsidies on firms' debt capacity. They estimated fixed effects models showing that firms receiving subsidies were more likely to increase their debt with financial institutions, especially long-term debt (Meuleman and De Maeseneire 2012) and had a lower average cost of debt (Hottenrott and Demeulemeester 2017).

We contribute to this strand of literature in three major ways, on data, variables and methodology. First, we considered the case of Italy, looking at a regional program of financial grants for small and medium-sized local firms, in which applications were subject to screening by a local bank. This context makes our dataset particularly suitable for investigating the impact of public subsidies on the indebtedness of SMEs. It also enabled us to distinguish between resource and certification effects. Second, we considered four outcome variables measuring amount, time structure, composition and cost of debt, and disentangled the effects of the subsidy program on total debt and bank debt, short-term and medium-term, and in young and mature businesses, providing a comprehensive and reliable picture of the effects of public subsidies on firms' debt capacity. Third, our methodology used a matching difference-in-differences estimator that relied on large control groups of firms not applying for R&D subsidies, but sharing the same economic and financial environment.

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 gives the empirical results and the robustness analysis, and Section 6 the conclusion.

2. Resource and certification effects of public subsidies

In efficient capital markets, firms always find sufficient and appropriate financial resources to fund their investments. In this theoretical setting, a firm's decision on whether to use internal finance, equity or external debt is immaterial for its investment strategy and value (Modigliani and Miller 1958, Miller and Modigliani 1961).

In practice, however, financial markets are imperfect, characterized by information asymmetries, agency problems and bankruptcy costs, Firms' investment and value can depend on their capital structure and debt capacity. R&D projects and innovative activities are particularly associated with private, not easily verifiable information, volatile and long-term returns, and the disproportionally high use of intangible assets. Expected returns from these projects are therefore difficult for non-specialist investors to assess accurately, and related assets can seldom be used as collateral (Griliches 1986; Hall 2002; Freel 2007). This makes dilution costs and the issue of new equity shares especially expensive, but also makes credit constraints in debt markets more likely (Blass and Yosha 2003; Aghion et al. 2004). As a result, innovative firms often prefer to finance

their investments and innovation activities primarily from internal funds, such as generated cash flow or retained earnings. If internal funds are not sufficient to cover all the financial needs for R&D investments, firms have to obtain external financing, which is more expensive. The high costs of external finance reduce firms' innovation capacity below the optimal social level (Carpenter and Petersen 2002).

Within this general framework, small firms typically have access to fewer financial options than large firms, and suffer from a bigger finance gap (Berger and Udell 1998). Small and new enterprises may not generate sufficient cash flow to fund their R&D and innovative investments (Himmelberg and Petersen 1994). External finance and debt may also be an unsuitable way to finance an innovative business, for several reasons (Audretsch and Lehmann 2002; Hall 2002). First, the information asymmetries, risk and uncertainty perceived by investors are all exacerbated when innovative projects are implemented by SMEs. In many countries, these companies typically face quantity and price constraints in funding innovation through banks (Himmelberg and Petersen 1994; Magri 2009; Alessandrini et al. 2010; Brown et al. 2012). Second, SMEs have difficulties raising external equity from non-specialized financers. Firm owners tend to be reluctant to dilute their control, even partially, or share their operational activities with external financers (Holmes and Kent 1991). As a result, SMEs are especially likely to discard or scale down socially-valuable innovation projects (Feldman and Kelley 2006).

Public subsidies for investments in R&D activities are therefore an important and additional source of low-cost external finance for SMEs, bridging a possible financing gap in the markets for private credit. To the extent that public subsidies are non-refundable (and recorded as revenue in the income statement), the direct impact of this resource effect of R&D subsidies on total debt of recipient firms is negative, zero or even positive (Hottenrott and Demeulemeester 2017). If subsidized investments substitute for other non-subsidized R&D expenditures, public subsidies automatically reduce the amount of internal funds and external private debt needed to implement R&D projects. By contrast, if subsidies have an additionality effect on R&D expenditure, their receipt may leave the total debt of recipient firms unaffected or even increase it when the subsidized investment is part-funded by financial resources raised on the market (Czarnitzki 2006). In any event, whatever the additionality effects of subsidies, the resource effect of funding R&D investments by public subsidies decreases the ratio between total debt and total assets for recipient firms.

This resource effect of public R&D subsidies can be accompanied by other effects on the structure and cost of debt. When subsidies replace private debt, recipient firms are expected to reduce their reliance on forms of debt that are costlier and readily accessible again in the future. The resource effect of R&D subsidies is therefore expected to be associated with a decrease in both short-term debt and average costs of debt. By contrast, long-term debt of recipients should be largely unaffected. All the resource effects of public R&D subsidies on amount, composition and cost of debt are expected to be reflected immediately in the financial statements of recipient companies.

Besides increasing financial resources, a subsidy under a competitive public program can produce a certification effect, by acting as a signal to external, market-based financers that recipient firms are credit-

worthy. Takalo and Tanayama (2010) developed a theoretical model in which the allocation of monetary subsidies for research projects is based on ex-ante screening by government offices or the public agency responsible for managing the selection of applications. The evaluation process, and the subsequent granting of subsidies, may convey a positive signal to market-based financers about the quality of innovation projects implemented by the successful applicants.[2] Lerner (2002) argued that government officials may also have better information than private financers about firms and their fields of research, because of the large number of applications evaluated over time.

Unlike the resource effect, the certification effect of R&D subsidies on the overall indebtedness is always non-negative, independent of the degree of additionality on R&D investments. Due to the *certification effect*, both the growth rate of total debt and the ratio of total debt to total assets of recipient firms increase, if firms substitute equity for debt, or otherwise they remain unaffected. In the first case, it can be expected that the increase in total debt mainly concerns the debt towards banks, which is the major and most immediately responsive source of external financing, in particular for SMEs.

The positive signal linked to the receipt of public funds may help lenders to evaluate potential borrowers and their research projects (Narayanan et al. 2000), by reducing the cost of information collection and the perceived risk of research projects. Lenders tend to prefer short-term lending, because it allows stricter and repeated control over firms' strategies by providing the option to stop loans. It is also harder for short-term borrowers to defraud creditors, and short-term lending mitigates the conflict of interest between shareholders and debtholders (Diamond 1991, 1993). However, when a public subsidy has been awarded, banks and other financers are reassured by the positive screening of the government agency, and so are more willing to provide long-term debt. The certification effect can therefore be expected to produce a re-balancing of term structure of debt in favor of long-term debt: subsidized firms restructure their debt position by decreasing short-term and increasing long-term debt. This rebalancing of the term structure of debt towards longer maturities is expected to be particularly strong for bank debt, especially when the applications to the subsidy program are evaluated by a private bank (as in the program in this study).

The public agency effectively acts as a delegated monitor directly involved in the evaluation and co-financing of R&D projects. It can therefore help market-based lenders to reduce the related costs of information collection, by providing early evidence of the feasibility and risk of firms' subsidized R&D

[2] The pervasiveness and 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). Booth and Smith (1986) developed a theoretical model where the issuing firm selected a high-reputation underwriter to certify that the IPO price was consistent with inside information about the future prospects of the company held by the stockholders. Titman and Trueman (1986) extended the idea of certification to auditors, showing that the value of the issuing firm was an increasing function of auditor quality. Tirole (2006) generalized the model of Booth and Smith (1986), and argued that the value of the issuers can be certified by hiring both high-quality underwriters and through other well-informed agents. These agents, including rating agencies, auditors, independent analysts, and venture capitalists, have an incentive to become informed about the firm's value and convey their information to prospective investors. Venture capitalists, in particular, can reduce information asymmetries between the issuing firm and the market because of the reputational capital that they have earned bringing many firms to market over time (Megginson and Weiss 1991). Sufi (2009) analyzed the introduction of external ratings agencies and found that third-party debt certification increased the supply of available debt financing by banks, leading to real effects on firm investments.

investments. This is especially true if the screening for subsidies is carried out by a private bank. In this case, recipients can benefit from the positive signal provided by the subsidy, and negotiate new debts and/or renegotiate outstanding ones at lower rates. In contrast with the resource effect, the certification effect of R&D subsidies on firms' indebtedness is expected to be more prolonged over time and stronger for young firms that are less well-known to investors and more dependent on external finance than mature firms.

Table 1 summarizes the expected impact of the resource and certification effects. The presence of these effects of R&D subsidies and their relative predominance can be empirically identified by the simultaneous occurrence of specific effects on the amount, structure and cost of debt and their time-path. Specifically, a sufficient condition to conclude that R&D subsidies produce *certification effects* that add to the resource effect, eventually becoming more important, is that for subsidized firms: (i) changes in total debt (and total bank debt) will be non-negative, (ii) the ratio of total debt to total assets will increase; (iii) changes in short-term debt will be non-positive; (iv) changes in long-term debt will be positive; (v) the ratio between long-term (bank) debt and total (bank) debt will increase; (vi) the cost of debt will decrease; and (vii) effects (i)-(vi) will be medium term and clearer among young firms.

[Insert Table 1 about here]

3. The subsidy program

To investigate the effect of R&D subsidies on firms' indebtedness, we examined a public program implemented by the government of the Marche region, in central Italy. Public support for private R&D and innovation at regional scale has assumed growing importance in recent years. Innovation literature has embraced the concept of regional innovation systems, emphasizing the systemic and local nature of knowledge creation and dissemination (Cooke 1992; Brazyck et al 1998). Policy makers at national and supra-national level have placed innovation at the heart of growth strategies, giving a crucial role to regions as agents of change that can identify new opportunities for technological progress in knowledge-based economies (European Commission 2010; OECD 2011). Regions are therefore using a wide range of public instruments to foster innovation among local firms, including direct monetary subsidies. From the methodological point of view, the regional dimension of the program had the major advantage that it allowed us to avoid the unobserved heterogeneity in the economic and institutional environment that would have characterized a national or international program.

The subsidy program aimed to support projects of industrial research and precompetitive development by small and medium-sized firms, to promote private R&D and innovation investment. The research projects had to foster product and process innovation and transfer of knowledge between university and industry, and 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. Applicants also had to have a main unit in the region, implement the research project

within the region, and operate in an industry that was 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 the research activities.

The funding scheme consisted of a non-refundable capital contribution of 35% of eligible expenditure, and an interest rate subsidy that, on request, might cover up to 10% of the total cost. Only a few firms used the option on the interest rate. 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 the committee of experts. Firms could, however, ask for up to 50% of the capital contribution in advance.

During the study period, the program made two calls for applications, in 2005 and 2007. The effects of the subsidies were evaluated from the year of the call for applications until five years later, so over the time span 2005–2012. Firms could apply for just one research project per call, and could not receive other public subsidies—regional, national or from international public institutions—for the same research activities. 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 evaluated by a local commercial bank, helped by a committee of independent experts in the field of innovation who were registered on the lists held by the Ministry of Education, Universities and Research. After a 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, jointly with the experts, the merit of the research idea. Each project received a score between 0 and 100 and grants were made in score order. Across the two calls, there were 441 applications, of which 282 were accepted (64%), and 159 rejected (36%). A total of €57 million was granted to firms, with an average cost of projects 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. Information on the two rounds of the program were extracted from a database held jointly by the regional agency for innovation (Marche Innovazione) and the Department of Information Engineering (DIIGA) at the University Polytechnic of Marche in Ancona. This includes all regional programs supporting local firms. From this database, we selected only the study program, because it was specifically designed to support R&D in private firms, whereas other programs aimed to foster employment, human capital specialization and the creation of spin-offs. Balance sheet data and other information on regional firms were drawn from ORBIS,

published by Bureau van Dijk. Lastly, as a measure of firms' innovativeness, we included patent data from REGPAT, the OECD database reporting information on patent applications to the European Patent Office.

To build the dataset, we first merged data from ORBIS with the list of subsidized firms extracted from the database of Marche Innovazione and DIIGA. Some subsidized firms were in bankruptcy or liquidation, and others were missing from ORBIS because of their small size. We therefore lost some observations in this process. We used ORBIS to identify all the 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 study program. From this population, we removed any firms funded by other regional programs, using the database of Marche Innovazione and DIIGA, to improve the assessment of the R&D subsidy program.

This collection of data resulted in a unique dataset of 176 regional SMEs that had received R&D subsidies (78 in the first round and 98 in the second round of the program) and another 5,127 SMEs headquartered in the region that had not received any public support from the regional government in the period 2003–2012. Table 2 provides a description of subsidized firms by sectors of activity in the two rounds. It shows that most of subsidized firms operated in manufacturing industries, including sectors like "Machinery and Equipment", "Computer" and "Basic Metals and Metal Products". The most common services industry was "IT and other information services". Several firms belonged to more traditional industries, such as "Manufacture of Textiles, Apparel and Leather", "Manufacture of Food, Beverages and Tobacco", and "Construction".

[Insert Table 2 about here]

To evaluate the impact of the public subsidies program on firms' financial situation, we compared the overall indebtedness of subsidized firms with a matched control group of unsubsidized firms, distinguishing short- and medium-term debt. We then concentrated on bank financing and its time structure. This focus was 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.

For overall indebtedness, we considered six different outcome variables: (i) *Change in total debt*, or the annual growth rate of total debt; (ii) *Total debt over total assets*, or the ratio between total debt and total assets; (iii) *Change in short-term debt*, or the annual growth rate of short-term debt; (iv) *Change in long-term debt*, or the annual growth rate of long-term debt; (v) *Long-term debt over total debt*, or the ratio of long-term to total debt; and (vi) *Cost of debt*, or the ratio between total cost of debt and total debt. For bank financing, we considered two variables: (vii) *Change in total bank debt*, and (viii) *Long-term bank debt over total bank debt*.[3]

[3] Except for the variables computed as a ratio, all other outcomes were considered in terms of rate of growth to avoid size effects.

Table 3 shows descriptive statistics for subsidized firms and other regional firms that did not apply for the program, and mean difference tests between the two types of firms. Looking at total debt and bank debt, firms receiving R&D subsidies seemed to be more indebted than other firms. *Indebtedness*, however, a measure of firms' leverage computed as the ratio between total assets and equity, suggested the opposite conclusion, and debt-to-equity ratio showed similar values for the two groups of firms. The cost of debt was lower for subsidized firms, with a mean value of 5.1%, below that of unsubsidized companies (5.8%). The evidence was mixed for cash flow because it was significantly higher in firms receiving public funds if we considered its level, but not significantly different using the ratio to total assets.

Table 3 also shows information on other characteristics of firms. As expected, firms funded under the R&D subsidy program were significantly older and larger, in terms of sales, value added, total assets and number of employees, than unsubsidized firms. There were contrasting results for profitability and innovativeness. Return on equity was higher for unsubsidized firms but EBITDA over sales was not significantly different. Subsidized firms applied for more patents than unsubsidized firms, which suggests that they were more innovative. R&D intensity was also higher in subsidized firms but the difference was not statistically significant. Although the differences were less pronounced, a similar picture emerged using median values instead of means. More details on the definition of variables are shown in the Appendix (Table A1).

[Insert Table 3 about here]

4.2. Methodology

Our empirical strategy to identify the effect of the subsidy program relied on a matched difference-in-differences approach. This methodology has been used in several previous studies, because it is a valuable way to overcome endogeneity in the allocation of public subsidies.[4]

Firms receiving public funding and firms not applying for public subsidies are often not randomly distributed, and the raw comparison of the two groups can therefore yield biased results (Klette et al. 2000; Cowling 2016). In our sample, for example, this was a relevant issue because subsidized and unsubsidized firms were highly heterogeneous in terms of age, size and, partially, innovativeness. When randomized experiments cannot be used, matching methods are helpful to evaluate the causal effects of a program (Khandker et al. 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 was the treatment, subsidized firms were the treated units, and the control group was formed of firms not applying for the R&D subsidies. An alternative strategy could be to use firms that applied for the

[4] 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 et al. (2014) applied matching and other non-parametric methods, and Engel et al. (2016) and Bellucci et al. (2019) combined the two methods.

grant but that were rejected as the control group. We did not use this strategy for two reasons. First, we could reasonably expect rejected firms to be systematically different from subsidized firms in characteristics observable by the selection committee, but unobservable to the econometrician.[5] Second, some of the rejected firms were later given subsidies because of additional resources provided by the regional government, but we were unable to identify these firms.

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

Our PSM used 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 Kernel matching, a nonparametric matching estimator that used 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. Other algorithms such as nearest-neighbor matching use only a subset of untreated units to build the control group.

The validity of PSM depends on three main assumptions. The conditional independence assumption (CIA) or unconfoundedness (Rosenbaum and Rubin 1983) assumes that subsidy allocation was independent of the potential outcomes conditional on the observed pre-treatment matching covariates. 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 used a rich set of pre-program and observed firm-specific covariates, which helps to support 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 requires subsidized firms to have comparable unsubsidized firms with similar propensity scores. This therefore implies that a substantial area of common support exists between the two types of observations. The assumption was plausible in our empirical setting because the control groups were drawn from a very large population of regional firms not applying for the R&D subsidy program. We also imposed the common support option, which drops both subsidized and unsubsidized firms without similar counterparts to improve comparability (Heckman et al. 1997; Ravallion 2008).

Finally, the stable unit treatment value assumption (SUTVA) postulates the absence of spillovers, i.e. 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 firms was low compared to the total number of regional firms. Funded firms were also small and the amount of R&D subsidies was limited.

[5] We also had no information about the scores obtained by applicant firms at the end of the selection phase, and so could not apply a regression discontinuity design to compare the performance of subsidized and non-subsidized firms with scores close to the acceptance threshold (Bronzini and Iachini 2014).

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 and 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 groups of subsidized and control firms identified by PSM, before and after the receipt of subsidies. The years of matching varied by rounds of the program, so we estimated the effect of the subsidies separately for the two rounds. This was also a consistency check, because we expected similar results for the two rounds. Our estimation strategy consisted of a DID on repeated cross-sectional data with a weighted least squares regression, with observations weighted by their propensity scores. Hirano et al. (2003) showed that this procedure yields a fully efficient estimator.

DID has the major advantage that it allows for heterogeneity in unobservable and time-invariant factors. It therefore relaxes the assumption of PSM that the selection in the program was based only on observable firms' 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 et al. 2011). This assumption was also empirically tested.

5. Results

5.1. Matching

PSM was the first step of our estimation strategy to identify comparable groups of subsidized and non-applying firms. We used the following variables for PSM: *Indebtedness*, *Cash flow*, *Age*, *Total assets*, *Tangible assets*, *Intangible assets*, *EBITDA/sales*, *ROE*, *Wages* and *Patents*. To improve the comparability between the two groups of firms, we ran 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 et al. 1999). This option was particularly important in our sample because several firms in both groups lay outside the common support area. The number of these firms depended 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 applying for the program. There were more unsubsidized firms, around 35% and 17% for the two rounds, which 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 are shown in Table 4. For both rounds of the program, after matching,

subsidized firms were undistinguishable from the untreated firms included in the control groups. The differences between the two groups of firms in the mean values of the variables used in the matching procedure were very small and not statistically significant. Only one variable was different in one time period: tangible assets of subsidized firms were slightly higher than those of control firms in the 2005 round, and there were no differences in the 2007 round. We can therefore conclude that our matching procedure provided a good balance between the two groups of firms.

[Insert Table 4 about here]

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. The impact of the program was evaluated across different time horizons to capture short- and medium-term average effects. With t as the year of funding and $t-1$ as the pre-treatment or baseline year, the effects of the R&D subsidies were estimated over the period including the years during the projects, i.e. t and $t+1$, which we considered to be the short term, and over the period including years $t+2$, $t+3$, and $t+4$ after the projects, which we considered to be the medium term. 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 years 2005 and 2006, and the medium-term period years 2007, 2008, and 2009. Table 5 shows the average treatment effects on treated units for the two rounds of the subsidy program and the number of firms included in the treatment and control groups. Table A2 in the Appendix show the change in the outcomes for subsidized and control firms.

The impact on *Change in total debt* was not statistically different from zero in either the short- or medium-term and in both the 2005 and 2007 rounds, suggesting that receiving R&D subsidies had no effects on the overall indebtedness of firms. More importantly to our aim is that *Total debt over total assets* also did not decrease for subsidized firms: the estimated average treatment effect of public subsidies on the treated group (ATT) was negative but not statistically significant. This suggests that there was no resource effect. The results also showed that public subsidies encouraged subsidized firms to use banks as a source of funding. The variable *Change in total bank debt* was positively and significantly related to the receipt of subsidies in the short and medium term and in both rounds (with the exclusion of the 2007 round in the medium term). To the extent that banks pay special attention to the positive signals linked to the passing of a bank-type screening and obtaining public subsidies, the significant increase in bank debt for subsidized firms reflects the relevance of 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 the *Change in long-term debt* were positive, larger and more statistically significant, especially in the medium term.

These changes in the time 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 particular in a higher long-term exposure with banks (*Long-term bank debt over total bank debt*).

Lastly, looking at the average cost of debt (*Cost of debt*), the DID estimates were negative and statistically significant, except for the 2007 round in the short-term. R&D subsidies therefore allowed firms to reduce their average cost of debt compared to matched firms, in both the short and medium term. In line with the presence of a certification effect, the impact was stronger in the medium term, from two to four years after the award of the public subsidy.

Summing up, the R&D subsidy program had a mixed and statistically insignificant impact on overall indebtedness, but allowed SMEs to reduce their short-term borrowing and increase their long-term financing. The program also reduced the average costs of debt in SMEs. Focusing on bank financing, subsidized firms increased their use of loans from banks in the short- and medium-term, and especially the long-term. The estimates were consistent across the two rounds of the subsidy program, 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 goes beyond the implementation of the research project and the presence of a resource effect. This is especially true for the time 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 firms' debt was unclear and would be expected to arise 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 did not have information on the amount of the grants, so we were unable to quantify the precise effects. However, the comparison between subsidized and control firms provided useful information on the average effects. Table 5 shows that short-term debt of subsidized firms decreased by approximately 4%. For long-term debt, the impact was stronger, ranging from +18% to +38%. The estimates of *Change in total bank debt* also suggested an important effect on bank debt, with growth between 23% and 58%.

In terms of amount of resources, short-term debt decreases by about €190,000, while the increase in long-term debt varies between €168,000 and €350,000. As for the average cost of debt, the smallest coefficient of *Cost of debt* was −0.098, and the greatest was −0.169. Comparing these changes to the average cost of debt in subsidized firms (5.1), we can conclude that the decline in the cost of debt ranged from 1.9 to 3.3 percentage points.

[Insert Table 5 about here]

5.3. Robustness analysis

To confirm the validity of our main results, we tested the validity of the parallel-trend assumption. By combining matching with DID, we could take care of observable heterogeneity between subsidized and control firms, and time-invariant unobserved characteristics that differed between the two groups. The reliability of this empirical strategy, however, depends crucially on the assumption that there were no time-varying differences between subsidized and control firms. This parallel-trend assumption could not be proved 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 before the implementation of the subsidy program (Gertler et al. 2011). If the outcomes had the same trends before the program started, it is reasonable to conclude that they would have continued to move in tandem during the study period.

We therefore compared changes in the outcome variables 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 rate of the outcome variables, so we used their level. The results are summarized in Table 6 and show that the various outcomes were not significantly different for subsidized and control firms before the two rounds of the subsidy program. This supports the plausibility of the parallel-trend assumption. The only exception was short-term borrowing from banks, which decreased slightly in subsidized firms before the 2005 round. This result suggests that recipient firms might have anticipated the receipt of public subsidies, and reduced their short-term borrowing just before the start of the R&D program, increasing it again immediately after their application had been accepted, when they could benefit from the certification effect of a subsidy. However, the statistical significance was low ($p < 0.1$) and the same result was not found in the 2007 round, so we excluded the possibility that our DID overestimated the effect of the program. This robustness test also suggests that we can exclude the presence of an anticipation effect, which is often known as Ashenfelter's Dip, for the other outcomes as well.

[Insert Table 6 about here]

As a further sensitivity check, we replicated the main analysis using the Nearest Neighbor (NN) instead of Kernel matching.[6] Table 7 shows the results for total indebtedness and bank financing. The signs of the coefficients and the statistical significance were in line with the main results, although point estimates had larger absolute magnitudes, and were more imprecise with less significance. In general, however, the findings of the main analysis were robust to the use of NN matching.

[Insert Table 7 about here]

[6] We matched each subsidized firm with the five closest unsubsidized firms using the propensity scores.

Lastly, the main results were verified by estimating a fixed effects model in a regression-based approach. The estimates are shown in Table A3 and were consistent with the main analysis.

5.4. The effects of R&D subsidies by firms' age

To obtain more information about the empirical relevance of the certification and resource hypotheses, we replicated the analysis distinguishing between two different sub-samples of young and older firms. Assuming that young firms are more informationally opaque than mature firms, they were expected to benefit more from the positive signal of subsidy awarding. 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 value of 18.6 years, and a median value of 18 years. We therefore used 18 years as the threshold to identify the two groups of firms: firms under 18 years old were "young", those of 18 years and over were "mature".[7] Our sub-sample 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 8). First, young firms significantly increased their overall indebtedness. The *Change in total debt* was positive in both the short and medium term for the 2005 round and *Total debt over total assets* increased in round 2007. By contrast, consistent with the resource effect, the receipt of subsidies reduced the overall debt of older firms during the implementation of the research project.

R&D subsidies also reduced short-term borrowing and increased long-term financing of young firms, while had no effects on the long-term debt of mature firms. The coefficients on *Change in short-term debt* were negative for both young and mature firms, while only for the former the coefficient of *Change in long-term debt* was positive and statistically 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, however, the positive sign of *Long-term debt over total debt* was explained by the reduction in short-term debt.

The results for total bank debt were mixed. Young firms only showed positive coefficients for *Change in total bank debt* in the 2005 round. The coefficients, however, were smaller than for mature firms and this partly contradicts the certification hypothesis. However, further support for the certification role of R&D subsidies was provided by long-term bank financing. Both types of firms increased their use of long-term bank debt in the medium term (*Long-term bank debt over total bank debt*), but the coefficients were significantly higher for young firms. It therefore seems likely that the subsidized firms re-balanced their bank

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

debt, increasing the weight of long-term debts to total bank debt, and this effect was more pronounced for young firms. Similarly, the average cost of debt (*Cost of debt*) decreased for all firms, but the magnitude of the coefficients suggested that the impact was greater for young firms.

[Insert Table 8 about here]

6. Conclusions

R&D and innovation are crucial for firms' 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. Previous studies have stressed 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 and Pugh 2016; Marino et al. 2016). Little attention, however, has been paid to the effect of R&D subsidies on other organizational and economic choices of subsidized firms. This study extends our knowledge about the behavioral effects of public funding for private R&D, which go beyond the traditional goals of supporting private R&D investments or improving innovation performance of subsidized firms. Specifically, we focus on the effects of R&D subsidies on the amount, structure and costs 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 study program was an ideal setting for analysis because a commercial bank evaluated the financial aspects of the research projects. Our empirical findings show that receiving R&D subsidies had three major effects on the debt of firms. First, after receiving subsidies, firms modified the time 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 results suggest that passing the screening process embedded in the R&D subsidy program provided a positive certification effect for SMEs, which helped them to overcome or mitigate financing constraints. This 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 financiers knew that the firms awarded by R&D grants had been positively evaluated by a commercial bank. This provided an informative signal about the quality of the firm's research project and, more generally, about its health. This reduced the risk of financing in the eyes of external debt providers. Our analysis by firm age confirmed that the certification effects of R&D subsidies were stronger for young firms, which are generally expected to be more informationally opaque and financially constrained. For mature firms, the receipt of subsidies had significant resource effects, reducing their total debt.

A limitation of our research was the variable used to measure R&D subsidies. The lack of data meant that we did not have precise information about the amount of the subsidy in each case, and we approximated the receipt of public resources using a binary indicator. The certification effect of R&D subsidies is likely to

be chiefly dependent on being awarded with a grant rather than the amount of the grant (Lerner 1999), but the precise amount of the subsidy would be useful to assess the relevance of the resource effect. Another limitation of this study was that it considered a very specific program implemented on a regional scale, with a relatively small sample of firms receiving R&D grants. The external validity of our analysis is therefore inevitably limited, and future studies will need to analyze different contexts using larger datasets.

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

	Resource effect	Certification effect
Change in total debt	+/=/−	+/=
Total debt over total assets	−	+/=
Change in short-term debt	+/=/−	−
Change in long-term debt	=	+
Long-term debt over total debt	+/=/−	+
Change in total bank debt	+/=/−	+/=
Long-term bank debt over total bank debt	+/=/−	+/=
Cost of debt	−/=	−

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*

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	5,684	3,924	5,997	2,754	1,146	6,601	5.6***
Short-term debt	4,747	1,130	4,824	2,167	978	4,081	7.9***
Long-term debt	937	245	1,800	587	47.6	4,018	1.1
Total bank debt	3,468	1,949	3,921	2,785	1,395	6,262	1.0
Short-term bank debt	2,281	1,375	2,524	1,840	849	2,694	1.5
Long-term bank debt	1,187	209	2,005	945	102	4,715	0.5
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
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†	8,946	5,606	8,420	3,900	1,935	6.069	10.3***
Value added†	2,460	1,609	2,355	837	410.3	1,468	13.5***
Employees	55.3	45	48.3	31.1	15	59.3	4.4***
Total assets†	7,601	4,780	7,436	3,636	1,578	7,662	6.5***
EBITDA/sales	12.8	7.6	45.1	9.3	7.3	34.1	1.2
Return on equity (ROE)	3.3	3.8	26.1	8.2	5.6	26.7	−2.3**
Tangible assets†	1,266	758	1,331	1,012	199.3	4,898	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†	1,087	814.7	1,006	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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 4. Balancing test for Kernel matching in the two rounds of the subsidy program

	Round 2005		Round 2007	
	Subsidized firms	Difference from unsubsidized firms after matching	Subsidized firms	Difference from unsubsidized firms after matching
Indebtedness	5.4	1.0	11.1	0.1
Cash flow	666.8	−22.2	333.1	28.9
Age	19.6	-0.6	17.2	0.4
Total assets†	9,824	−75.9	7,323	123.2
EBITDA/sales	9.3	1.1	15.6	−0.1
Return on equity (ROE)	3.8	−0.1	4.5	−0.1
Tangible assets†	1,369	0.05*	1,156	−0.01
Intangible assets†	167.5	0.01	179.2	−0.01
Wages†	1,369	−70.7	1,006	10.2
Patents	0.06	0.01	0.06	0.01

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.

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

	Round 2005	Round 2007
	Change in total debt (%)	
Short-term average effect	−0.014	0.006
	(0.018)	(0.016)
Medium-term average effect	−0.002	−0.008
	(0.017)	(0.017)
Number of treated/untreated firms	73/1,558	89/2,986
	Total debt over total assets	
Short-term average effect	−0.014	0.003
	(0.012)	(0.009)
Medium-term average effect	−0.006	−0.008
	(0.011)	(0.009)
Number of treated/untreated firms	73/1,135	89/2,701
	Change in short-term debt (%)	
Short-term average effect	−0.041*	−0.030*
	(0.022)	(0.018)
Medium-term average effect	−0.014	−0.038**
	(0.023)	(0.016)
Number of treated/untreated firms	73/1,571	89/3,005
	Change in long-term debt (%)	
Short-term average effect	0.131	0.329***
	(0.087)	(0.100)
Medium-term average effect	0.187**	0.379***
	(0.083)	(0.086)
Number of treated/untreated firms	62/1,148	75/2,076
	Long-term debt over total debt	
Short-term average effect	0.020**	0.010
	(0.009)	(0.007)
Medium-term average effect	0.036***	0.015**
	(0.008)	(0.007)
Number of treated/untreated firms	73/1,836	89/2,978
	Change in total bank debt (%)	
Short-term average effect	0.581***	0.238*
	(0.205)	(0.134)
Medium-term average effect	0.443**	0.087
	(0.180)	(0.107)
Number of treated/untreated firms	51/502	65/748
	Long-term bank debt over total bank debt	
Short-term average effect	0.056*	0.007
	(0.032)	(0.021)
Medium-term average effect	0.107***	0.058**
	(0.029)	(0.028)
Number of treated/untreated firms	51/736	65/878
	Cost of debt	
Short-term average effect	−0.145*	0.056
	(0.079)	(0.037)
Medium-term average effect	−0.169**	−0.098***
	(0.073)	(0.034)
Number of treated/untreated firms	51/696	77/2,369

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

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

	Round 2005	Round 2007
Total debt	32.4 (127.1)	105.4 (168.7)
Short-term debt	−80.1 (160.9)	159.1 (165.8)
Long-term debt	−85.3 (124.4)	−53.7 (174.2)
Total bank debt	−179.3 (133.7)	189.8 (176.7)
Short-term bank debt	−246.7* (144.5)	137.2 (106.2)
Long-term bank debt	26.52 (116.1)	32.6 (219.3)
Cost of debt	−0.068 (0.100)	−0.228 (0.175)

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

Table 7. DID estimates on the effects of R&D subsidies with NN matching

	Round 2005	Round 2007
	Change in total debt (%)	
Short-term average effect	−0.014	0.019
	(0.053)	(0.062)
Medium-term average effect	0.009	0.028
	(0.055)	(0.054)
	Total debt over total assets	
Short-term average effect	−0.001	−0.001
	(0.026)	(0.024)
Medium-term average effect	−0.002	−0.021
	(0.028)	(0.025)
	Change in short-term debt (%)	
Short-term average effect	−0.18**	−0.006
	(0.022)	(0.077)
Medium-term average effect	−0.032	−0.185*
	(0.074)	(0.107)
	Change in long-term debt (%)	
Short-term average effect	0.102	0.964
	(0.697)	(0.131)
Medium-term average effect	0.908**	0.691***
	(0.450)	(0.230)
	Long-term debt over total debt	
Short-term average effect	0.026*	0.019
	(0.015)	(0.015)
Medium-term average effect	0.046**	0.027*
	(0.021)	(0.015)
	Change in total bank debt (%)	
Short-term average effect	0.407*	1.627*
	(0.229)	(0.957)
Medium-term average effect	0.189	0.909
	(0.468)	(0.670)
	Long-term bank debt over total bank debt	
Short-term average effect	0.037**	0.013
	(0.017)	(0.045)
Medium-term average effect	0.107*	0.044
	(0.057)	(0.062)
	Cost of debt	
Short-term average effect	−0.116	−0.064
	(0.134)	(0.079)
Medium-term average effect	−0.041	−0.111**
	(0.178)	(0.051)

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

Table 8. DID estimates on the effects of R&D subsidies for young and mature firms

	Round 2005		Round 2007	
	Age < 18 years	Age ≥ 18 years	Age < 18 years	Age ≥ 18 years
		Change in total debt (%)		
Short-term average effect	0.074***	−0.081***	0.023	−0.050**
	(0.028)	(0.027)	(0.025)	(0.022)
Medium-term average effect	0.106***	−0.031	0.041	−0.040
	(0.031)	(0.024)	(0.035)	(0.029)
		Total debt over total assets		
Short-term average effect	0.010	−0.037**	0.025**	0.017
	(0.16)	(0.019)	(0.011)	(0.014)
Medium-term average effect	0.006	−0.053	0.066***	0.018
	(0.015)	(0.038)	(0.011)	(0.014)
		Change in short-term debt (%)		
Short-term average effect	−0.361*	−0.060*	−0.206	−0.015
	(0.021)	(0.031)	(0.489)	(0.023)
Medium-term average effect	−0.090	−0.063**	−0.098	−0.024
	(0.525)	(0.026)	(0.380)	(0.021)
		Change in long-term debt (%)		
Short-term average effect	1.901*	0.048	0.593	0.345**
	(1.046)	(0.516)	(0.448)	(0.161)
Medium-term average effect	1.004*	0.096	0.582*	0.035
	(0.561)	(0.157)	(0.308)	(0.146)
		Long-term debt over total debt		
Short-term average effect	0.033**	0.003	0.038	0.011
	(0.014)	(0.011)	(0.059)	(0.011)
Medium-term average effect	0.067***	0.028**	0.020**	0.019*
	(0.015)	(0.014)	(0.009)	(0.011)
		Change in total bank debt (%)		
Short-term average effect	0.453***	0.509*	0.206	−0.275
	(0.213)	(0.305)	(0.489)	(0.255)
Medium-term average effect	0.351*	0.500**	0.098	−0.173
	(0.188)	(0.206)	(0.380)	(0.132)
		Long-term bank debt over total bank debt		
Short-term average effect	0.037	0.012**	0.086	0.005
	(0.076)	(0.061)	(0.059)	(0.038)
Medium-term average effect	0.203***	0.078*	0.008	0.058*
	(0.071)	0.040	(0.069)	(0.032)
		Cost of debt		
Short-term average effect	0.049	−0.100	−0.001	−0.066
	(0.200)	(0.128)	(0.058)	(0.056)
Medium-term average effect	−0.449***	−0.281**	−0.199***	−0.140*
	(0.169)	(0.122)	(0.054)	(0.082)

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

Appendix

Table A1. Definition of variables used in the empirical analysis

Variable	Definition
Total debt over total assets	Total debt / Total assets
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	Finance costs / Total 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
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	Intangible 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. Average treatment effect on the treated (ATT) of the program and outcome variables for funded and matched firms

	Round 2005				Round 2007			
	Funded firms	Matched firms	ATT	Standard error *t*-test	Funded firms	Matched firms	ATT	Standard error *t*-test
				Change in total debt (%)				
Short term	0.015	0.029	−0.014	0.018	−0.070	−0.076	0.006	0.016
Medium term	−0.052	−0.050	−0.002	0.017	−0.090	−0.082	−0.008	0.017
				Change in short-term debt (%)				
Short term	0.008	0.049	−0.041*	0.022	−0.116	−0.086	−0.030*	0.018
Medium term	−0.066	−0.052	−0.014	0.023	−0.123	−0.085	−0.038**	0.016
				Change in long-term debt (%)				
Short term	0.059	−0.072	0.131	0.087	0.319	−0.011	0.329***	0.100
Medium term	0.213	0.026	0.187**	0.083	0.315	−0.064	0.379***	0.086
				Long-term debt over total debt				
Short term	0.022	0.002	0.020**	0.009	0.013	0.003	0.010	0.007
Medium term	0.047	0.011	0.036***	0.008	0.021	0.006	0.015**	0.007
				Change in total bank debt (%)				
Short term	0.179	−0.402	0.581***	0.205	0.112	−0.126	0.238*	0.134
Medium term	0.102	−0.341	0.443**	0.180	−0.103	0.190	0.087	0.107
				Long-term bank debt over total bank debt				
Short term	0.078	0.022	0.056*	0.032	−0.010	−0.017	0.007	0.021
Medium term	0.096	−0.011	0.107***	0.029	0.099	0.041	0.058**	0.028
				Cost of debt				
Short term	0.075	0.220	−0.145*	0.079	0.237	0.181	0.056	0.037
Medium term	0.067	0.236	−0.169**	0.073	0.028	0.126	−0.098***	0.034

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table A3. Fixed effects estimates on the effects of R&D subsidies

	Round 2005	Round 2007
	Change in total debt (%)	
Short-term average effect	−0.012	−0.011
	(0.042)	(0.153)
Medium-term average effect	−0.032	−0.022
	(0.064)	(0.046)
	Total debt over total assets	
Short-term average effect	−0.012	0.006
	(0.009)	(0.010)
Medium-term average effect	−0.008	−0.003
	(0.015)	(0.014)
	Change in short-term debt (%)	
Short-term average effect	−0.024**	−0.080**
	(0.012)	(0.023)
Medium-term average effect	−0.038**	−0.012
	(0.018)	(0.017)
	Change in long-term debt (%)	
Short-term average effect	0.024*	0.090
	(0.014)	(0.013)
Medium-term average effect	0.038**	0.123**
	(0.018)	(0.062)
	Long-term debt over total debt	
Short-term average effect	0.012	0.006
	(0.015)	(0.019)
Medium-term average effect	0.024**	0.018**
	(0.011)	(0.008)
	Change in total bank debt (%)	
Short-term average effect	0.504*	0.491
	(0.301)	(0.622)
Medium-term average effect	0.467*	0.098*
	(0.155)	(0.055)
	Long-term bank debt over total bank debt	
Short-term average effect	0.065*	0.013
	(0.019)	(0.019)
Medium-term average effect	0.95**	0.036**
	(0.047)	(0.013)
	Cost of debt	
Short-term average effect	−0.144*	0.049
	(0.229)	(0.058)
Medium-term average effect	−0.188*	−0.196***
	(0.102)	(0.065)

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