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DOES ISSUING EQUITIES HELP R&D ACTIVITY? EVIDENCE FROM UNLISTED ITALIAN HIGH-TECH MANUFACTURING FIRMS

by Silvia Magri*

Abstract

This paper evaluates the causal effect of issuing equities on the probability that a firm will engage in R&D activity. Equity is a preferable source of external finance for innovation than debt. It does not require collateral, does not exacerbate moral hazard problems connected with the substitution of high-risk for low-risk projects, quite common when using debt, and, unlike debt, does not increase the probability of bankruptcy; equity also allows investors to reap the entire benefit of returns on successful innovative projects. The paper focuses on high-tech firms for which asymmetric information problems are more pervasive. Implementing an instrumental variable estimation, we find that issuing equity increases the probability of the firm making R&D expenditure by 30-40 per cent. We detect considerable heterogeneity across firms: the impact of issuing equity is significant only for small, young, and more highly leveraged firms. We also find interesting evidence that issuing equity increases R&D expenditure in relation to sales.

JEL Classification: G21, G32, O31, 032.
Keywords: R&D, innovation, equity issues, high-tech firms.

Contents

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1 Introduction[1]

In the financing of innovation asymmetric information plays a very important role. Innovative firms often prefer to cloak new ideas in protective secrecy to prevent other competitors to use them. The quality of the signal sent outside the firm is therefore weak. In this context of pronounced information asymmetries and wide variability of the returns of innovative projects, external financiers find it very difficult to assess new ideas and adverse selection problems are widespread. Monitoring firms' activity and their effort to tackle moral hazard is also problematic: financial resources can easily be reallocated from low-risk to high-risk projects and innovative firms have little or no collateral to pledge to external financiers in order to align incentives.

External finance can therefore be very costly for innovative firms, which is why they finance R&D mainly out of internally generated resources such as cash flow (Hall, 2009).[2] However, cash flow may not be sufficient to finance major innovative projects because it is cyclical. Furthermore, in their first few years of activity firms do not normally generate any internal financial resources. As a consequence, innovative firms may have to rely on external finance, either debt or equity.

The theoretical literature states that innovative firms should prefer equity to debt. Debt, especially bank debt, often requires collateral that innovative firms may lack of. Debt can exacerbate moral hazard problems, as innovative firms can easily replace low-risk investments with innovative high-risk projects which have a higher probability of failure and, should they succeed, offer lenders no share in extra-returns (Jensen and Meckling, 1976; Carpenter and Petersen, 2002). Finally, the marginal cost of new debt for innovative firms can soar inasmuch as the probability and the severity of failure increase rapidly when debts rise and collateral is nil. Financing innovation with equity is a better option: equity does not require collateral, does not exacerbate moral hazard problems connected with debt, does not increase the firm's bankruptcy probability, and allows investors to share fully in the returns of the project in case of success.

The empirical literature has consistently found that equity is more commonly used than debt in financing innovation (Blass and Yosha, 2003; Aghion, Bond, Klemm and Marinescu, 2004; Brown, Fazzari and Petersen, 2009). However, the evidence is still scarce, specifically for European coun-

[1]The views expressed in this article are those of the author and do not necessarily reflect those of the Bank of Italy. I would like to thank for their useful comments and suggestions three anonymous referees, Antonio Accetturo, Fabio Bertoni, Laura Bottazzi, Matteo Bugamelli, Giorgio Gobbi, William Greene, Jacques Mairesse and other participants at the Bank of Italy's seminars, and at the 63 Annual Meeting of the Midwest Finance Association. Matteo Accornero, Cinzia Chini and Stefania De Mitri provided excellent research assistance.

[2]According to the Efige dataset, which collects harmonized statistical information on European firms (14,000 firms surveyed across 7 countries), in the main European countries more than 80 per cent of R&D expenditures is financed using cash-flow or intra-group financing.

tries, owing to the difficulties of gathering data that include information on firms' innovative activity and financial flows. Understanding the relation between innovation and firms' financing is a crucial, but still under-explored research question (Acharya and Xu, 2013).

This paper specifically studies the effect of an increase in outside equity on the Italian firms' propensity to engage in R&D activity. The focus is on high-tech firms, which are more subject to adverse selection and moral hazard problems inasmuch as they belong to sectors where products are relatively complex and contracts are complicated (Noon, 2007). In particular, we focus on R&D activity as we want to analyze firms that have incurred some R&D expenditures and need to finance them in order to produce innovative ideas. We want to avoid considering firms that merely describe themselves as innovative, without making any significant investments and facing up-front costs for which finance matters. In general, we refer to R&D activity, and when we use the word innovation the readers should consider this specific input of the innovation activity.

Italy is a very interesting case study. Figure 1 shows that the proportion of equity to firms' total liabilities in Italy is around 50 per cent, against almost 60 per cent in Germany and the UK and more than 60 per cent in France and the US. Symmetrically, indicators regarding the ratio of business R&D to GDP and patents show that Italy lags behind (Figure 2). Data from surveys confirm that both the share of firms that invest in R&D and the proportion of R&D on sales are low in Italy (Figure 3). The various reasons for the Italian gap in R&D activity have been extensively analyzed (Bank of Italy, 2013; Bugamelli, Cannari, Lotti and Magri, 2012). In this paper we concentrate on the link with financial aspects.

The effect of equity on innovation is not easy to determine because firms that increase outside equity may be intrinsically different from the other firms, owing to some unobservable characteristics. In other words, financial choice might be endogenous, i.e. linked to some unobservable variables that could explain both the financial choice and the propensity to innovate. We need therefore to find an exogenous source of variation of equity in order to consider the effect of issuing equity on R&D activity as a causal effect. In this paper our identification strategy is to instrument the endogenous dummy "issuing equities" with some variables which are correlated with this financial decision, but are not linked with unobservable variables, i.e. the error term, in the main equation explaining the firms' propensity to innovate. The instruments used in this paper are variables measured at *local* level (municipality, province and region) that should capture the habit of issuing equity or the incentive to do so and are not correlated with the *firm* unobserved factors that can influence its propensity to innovate either because no explicit link can be found or because this link has been controlled for. As a robustness test, we also present the results obtained with a panel fixed effect estimation in which the identification strategy is to compare the same firm across different years using a longitudinal dataset.

To preview the results, the evidence shows that issuing equity has an important positive effect on the probability that firms engage in R&D activity. With an instrumental variable (IV) bivariate probit model we find that issuing equity increases the probability of R&D for high-tech manufacturing firms by 30-40 per cent. The effect is much greater than in simple probit models: the IV estimations indicate that not controlling for endogeneity problems creates an important attenuation bias in measuring the effect of equity. There is significant heterogeneity in the effect of issuing equity on the probability of R&D: this effect arises only for small, young, and more highly leveraged high-tech firms. We also find some interesting evidence on the R&D intensity: for high-tech firms issuing equities, the R&D in relation to sales increases by around 2-3 percentage points, more than doubling the average R&D intensity for the whole sample of firms with R&D.

The empirical literature more related with this study focuses on the United States and generally finds that the effect of equity on innovation is important (Atanassov, Nanda and Seru, 2007), specifically for young high-tech firms (Brown et al., 2009) and for firms in external finance dependent industries (Acharya and Xu, 2013). However, all these papers focus only on listed companies; this is true also for a study analyzing the same topic for European firms (Martinsson, 2010) that finds that external equity has an effect only for the UK companies, arguing that the lack of an effect for the continental European countries is explained by their less developed equity markets compared with the US and the UK. As for Italy, the evidence concerning the link between equity and innovation is scant. Micucci and Rossi (2011) find that Italian manufacturing companies issuing publicly traded debt and/or listed on a stock market are more likely to innovate.

Another strand of literature related to this paper concerns venture capitalists. Some studies have found important effects of venture capital on firms' performance indicators (Puri and Zarutskie, 2011; Chemmanur, Krishnan and Nandy, 2011), though not, except in a few cases, on innovation activity (Link, Ruhm and Siegel, 2012). Berger and Schaeck (2011) analyze a sample of small and medium size companies (SMEs) in Germany, Italy and the UK and draw the conclusion that banks and venture capitalists are substitutes; they also find that firms turn to venture capitalists if they deem bank financing unsuitable, indicating that firms are aware of which type of financing best suits their business.

This paper contributes to this literature in several ways. First of all, unlike most of the previous studies, we consider also unlisted firms since we want to understand the general importance of issuing equities independently of stock-exchange listing; as a matter of fact, very few Italian firms are listed (in our sample less than 2 per cent). Secondly, our dataset includes small firms, which are generally subject to more severe asymmetric information problems and data on which are far harder to collect. We also focus on equity issues rather than on equity in the balance-sheet structure: the latter could also increase as a result of retained earnings, i.e. an internal financial source, whereas we concentrate on external finance and specifically on outside equity for the reasons mentioned at the onset of the Introduction. Finally, we try different strategies to make sure that the results can be interpreted as a causal effect of issuing equity on innovation.

The paper is organized as follows. Section 2 briefly sets out the reasons why equity should be preferred to debt in financing R&D. Section 3 describes our dataset, the main variables used and descriptive statistics. Section 4 explains the estimation strategies, while Section 5 comments the results. In Section 6 some robustness exercises are carried out and in Section 7 the analysis is extended to a number of specific issues. Section 8 discusses the results and concludes.

2 Why equity should be preferred to debt in financing R&D activity?

Most of the theoretical models on capital markets imperfections and financial constraints rely on the pecking order theory, drawn by Myers (1984) and Myers and Majluf (1984), as the traditional financing hierarchy. Internal financial source is the cheapest source of finance and when firms need to rely on external finance they use debt rather than equity; it is often argued that the new equity finance is prohibitively expensive due to issuing costs and adverse selection problems arising from asymmetric information forcing firms to sell equities at a sharp discount. However, there are several reasons why an extensive use of debt finance may not be suitable for high-tech firms and why the marginal cost of new debt finance can rise rapidly with an increasing leverage (Carpenter and Petersen, 2002; Brown et al., 2009).

Specifically when uncertainty is high, like for R&D projects, lenders may insist to secure loans with guarantees, while inside collateral is limited for high-tech firms as most R&D investments is intangible or firm-specific. The lack of assets that can be offered as a collateral is an important constraint for high-tech firms that would like to use debt to finance R&D.

R&D projects are quite risky, but if successful their returns can be very high. However, the nature of debt contract is such that creditors do not benefit of the high returns from the R&D

projects in the good state of nature as they gain only the fixed amount of interests. Creditors therefore are only concerned with the bottom part of the project returns' distributions (Stiglitz, 1985).

Adverse selection problems underlined in Stiglitz and Weiss (1981) can be more severe for R&D investments which are characterized by higher uncertainty and asymmetric information compared with physical investments. Firms know more about the riskiness of the projects than outside investors, but they are not willing to reveal it; as knowledge is non-rival, when revealed it can be used by other firms (Arrow, 1962). In order to reduce adverse selection problems lenders prefer to ration credit rather than increasing interest rates. This means that the schedule of supply of debt finance could become easily vertical for high-tech firms.

Moral hazard problems connected with debt can also play a more important role for high-tech firms. Managers of high-tech firms have more opportunities to substitute high-risk for low-risk projects. As creditors know ex-ante this attitude they can ration credit or ask that some covenants can be attached to debt to control more strictly the firm behavior. As moral hazard problems increase with leverage, equity can become more useful to finance R&D when firm leverage is higher. When leverage increases, the marginal cost of bankruptcy also rises very quickly. Brealey and Myers (2000) specifically single out high-tech firms as an example where financial distress costs can rapidly increase with debt because their projects are very risky and their collateral is low.

In summary, unlike in the traditional pecking order theory, the marginal cost of debt can increase steeply for high-tech firms when leverage rises. When debt is the only source of external finance there could hence be an important funding gap for high-tech firms. This gap could be more pronounced for small and young firms, for which asymmetric information problems are more pervasive (Hall, 2009).

In general, equity finance does not require collateral and its cost does not rise steadily while firms rely more on equity as there is no increase in financial distress like in the case of debt. The marginal cost of new equity is therefore almost flat like that of cash flow; the supply of new equity could therefore be highly elastic. Equity is well suited to finance R&D investments as shareholders can entirely benefit of upside returns when projects are successful. Finally, equity finance does not create the moral hazard problem above mentioned: this is risk capital meant to finance risky investments.

However, equity can be affected by issuing costs and adverse selection problems that arise from information asymmetries. This creates a wedge between the marginal cost of issuing equity and that of internal finance, which for a long time has been evaluated - as mentioned - so high that equity has almost not been considered as a source of finance. Nonetheless, two aspects are worth mentioning. First asymmetric information problems are certainly high in a public company, where most of shareholders are not involved in the firm's management. They are less pervasive in a firm with few shareholders that know the firm production function and its markets and customers; this is specifically true for venture capitalists that are active investors in the firm (Garmaise, 2007). This consideration is also important for the issuing costs. As argued, a firm can issue equities not necessarily through listing on a stock exchange, which implies substantial costs, but also increasing the number of shareholders, asking more funding to the current shareholders or relying on venture capitalists. Furthermore, the costs of listing in a stock market have been decreasing over time: many initiatives have been taken to reduce these costs specifically for small and medium size firms that decide to list on a stock market.

Some theoretical models have started to underline the role of new equity financing in solving some imperfections in capital markets. In Bolton and Freixas (2000) model, the riskiest firms are too risky to obtain bank loans or issue bonds; the only option available is equity financing, even if the costs are high. More recently Rajan (2012) argues that the high degree of uncertainty associated with start-ups and the low initial cash flows militate against fixed payments and therefore against debt. Equity is the favored instrument for raising finance in many start-ups. Equity markets are very important in providing the capital and the incentives that a firm needs to develop new ideas. He concludes that this helps explaining why the nature of firms and the extent of innovation differ so much in different financing environments.

In conclusion, the hypothesis tested in this paper is that high-tech firms that issue equities are more likely to engage in R&D activity and that this effect should be stronger for young, small and highly leveraged firms. We also verify if issuing equities has an effect on R&D intensity as well, i.e. on the intensive R&D margin.

3 Data description

3.1 Dataset used in the analysis

The first dataset used in this paper is the Survey of Manufacturing Firms (SMF) which is carried out every three years and covers a wide range of topics. We use three waves of the Survey (1998-2000; 2001-2003, 2004-2006); the sample of each wave consists of about 4,500-5,000 manufacturing firms and is stratified by geographical area, industry and firm size. All firms with more than 500 employees are included; the sample is representative of small and medium firms either; micro-firms with less than 10 employees are not recorded.[3] [4]

This dataset is useful for our purposes because it allows us to single out firms that are engaged in R&D activity.[5] Specifically, the SMF contains information on R&D expenditures, whereas in many other dataset, collecting firms' balance sheets, R&D expenditures are often included in other items and could not be directly elicited. Some firms are interviewed in more than one wave: from the three waves we get 10,720 manufacturing firms.

In order to have in the same dataset information on firms' innovative attitude and financial structure, above all the sources of funds which are one of the variables of interest in this paper, we merge, by using their fiscal code, these 10,720 manufacturing firms with those in Cerved, a dataset that collects balance sheets of all Italian corporations; only few firms (around 80) in the SMF survey cannot be found in the Cerved database. Data in Cerved are gathered since 1993. However, for the joint analysis of R&D indicators in SMF and financial data in Cerved only a sub-sample of these observations are considered; we focus on the period 1998-2006 for which we have data from the SMF survey.

In the end, after excluding firms with missing values on some variables used in the estimations, the sample of firms is made of 5,971 firms and 19,776 firm-year observations. However, as mentioned, we focus on high-tech firms, based on the OECD classification, whose sample is made of 1,776 firms and 6,138 firm-year observations. A larger or smaller number of firms and observations is considered in the estimations that include fewer or more regressors; specific indications are reported in the tables containing the estimations' results.

3.2 Definition of the variables used in the analysis

In this paper firms are considered innovative if in the SMF survey they declare some positive R&D expenditures. If a firm is present in more than one wave of the SMF is allowed to entry and exit the innovative status along the period 1998-2006 according to the amount of R&D expenditures in

[3] Until the 2001-2003 wave, the SMF Survey was conducted by the Centre of Study on Small and Medium Firms (Osservatorio sulle Piccole e Medie Imprese), an institution associated with Capitalia, an Italian bank. The following survey 2004-2006 was carried out by Unicredit another Italian bank who incorporated Capitalia. More detailed information can be found on the website www.unicredit.it.

[4] We decide not to include the most recent wave of the SMF survey (2007-2009) because this survey has been changed compared to the previous ones for reasons connected with harmonization of the questions as it has been conducted in seven European countries under the Efige project. As a consequence of these changes important discontinuities arise.

[5] This dataset has been extensively used by several other studies on Italian SMEs (Baggella, Becchetti and Caggese, 2001; Detragiache, Garella and Guiso, 2000; Angelini and Generale, 2008; Benfratello, Schiantarelli and Sembenelli, 2008; Ughetto, 2008; Herrera and Minetti, 2007).

each wave of SMF.[6]

Specific attention has been devoted to the analysis of flows of funds data. Net finance is the sum of cash flow, i.e. internally generated funds, and the net change in external sources of finance, i.e. debts or equity. Net finance could be positive or negative, where the latter case regards firms that for example reduce debt or buy back shares or had negative cash flow. We define a dummy (equity) that is equal to 1 for firms that in a specific year have a positive amount of net issues of equity. Similar dummies are also created for net positive issues of financial debt and for positive cash flow in order to verify their impact on the firm propensity of R&D as well. As for robustness, we also try to evaluate the impact of net equity over net finance so that we can use a continuous variable, though in this case we need to limit the analysis to firms with positive net finance.[7]

The industry is measured by the Ateco 2007 code (2/3 digits) recorded in Cerved; by using this code we also classify firms in high-tech sectors using the OECD classification.[8] Firm size is measured by the number of employees from Cerved; when this number is missing we alternatively use data from the SMF survey. Age is the difference between the year to which the data refer and the inception year recorded in the SMF survey; some negative outliers are excluded from the analysis. The area (5 areas) is based on the location of the company's registered office. The other variables used as controls firm's characteristics in the baseline estimation are a dummy equal 1 if the firm is exporting, and for firms belonging to a group or a consortium, and the ratio of graduate employees to total employees. As additional controls we also include inventory on total assets as a measure of collateral, an indicator of profitability measured by cash-flow on total assets and an indicator of productivity given by valued added divided by the number of employees. More details about the variables used in the estimations are reported in the Appendix where we also include the sources of the data.

[6]In the SMF survey research and development expenditures are defined as creating activities aimed at increasing knowledge and using this knowledge in new applications, such as the development of new or improved products and processes.

[7]These items from the uses and sources of funds are mandatory in the Cerved dataset only for firms that need to have an ordinary balance sheet; however, there are many non-financial companies with a simplified balance sheet that include these figures even though not mandatory.

[8]We include in the high-tech sectors firms that are in high-technology sectors (pharmaceutical, aircraft, medical, precision and optical instruments, radio, television and communication equipment, office, accounting and computer machinery) and in medium-high-technology sectors (electrical machinery and apparatus, motor vehicles, trailers and semi trailers, railroad and transport equipment, chemical and chemical products, machinery and equipment).

3.3 Descriptive statistics: a glance at the data

Descriptive statistics regarding the sample of firms used in the baseline estimation give us some interesting clues for the following analysis. In Table 1 means and standard deviations of the variables used in the estimations are reported for the sample of high-tech manufacturing firms; means of the explanatory variables are also calculated for the two sub-samples of innovative and non-innovative firms to verify their differences.

The share of firms engaged in R&D activity in the sample of high-tech firms is equal to 58 per cent, while the intensity of R&D on sales is around 2 per cent for the sample of R&D firms. As for the main explanatory variables, 16 per cent of the firms issue net positive amount of equities; this share is a bit higher for innovative firms, though the difference is not statistically significant. In order to evaluate the difference with other sources of finance, we also include some statistics for debt and and cash-flow. The percentage of firms issuing a net positive amount of debt is by far higher (54 per cent) and even in this case there is no significant difference according to the firm innovative status. Around 90 per cent of high-tech firms have a positive cash-flow in the period analyzed and this share is higher for innovative firms.

As pointed out in many other papers, innovative firms tend to be larger, a bit older, and more frequently they export, belong to a group or to a consortium. As expected they also use a much higher share of graduated employees (11.1 versus 9.8 per cent; 10.5 per cent for the whole sample); they are less likely to be located in the Southern regions. As for the additional controls used in robustness exercises, innovative firms have a slightly higher share of inventory on total assets and are more profitable; there is however no difference in firm productivity based on the innovative status. The table contains further evidence for other variables measured at local level that we use either as controls or instruments in the instrumental variable estimation; there are some differences between the average values of these variable for innovative and non-innovative firms, though they are not striking, also for the instruments. Descriptive statistics are pretty similar when we consider the whole sample of manufacturing firms; the only remarkable difference is that for this sample the share of firms with R&D decreases to 41 per cent.[9]

Firms engaged in R&D activity are therefore quite different from those that are not and these differences regard many relevant characteristics. It is therefore important to control for these features in the estimations. However, we decide to include in the baseline estimation only those

[9] We do not report these statistics for the sake of saving space; they are available upon request. In Figure 3 in order to compare data across different countries only firms with internal R&D are considered and the share is therefore lower.

firms' characteristics that could be considered reasonably exogenous; some robustness tests are carried out in Section 6 including more regressors in the estimation. The variables used in the baseline estimation also show a low level of pairwise correlation.

4 Estimation strategy

To deal with the research question which is central in this paper, i.e. how much issuing new equity can help innovation, the following baseline equation is estimated:

$$ProbR\&D_{it} = \alpha + \beta * equity_{it} + \gamma * X_{it} + \tau_t + \epsilon_{it} \tag{1}$$

where $ProbR\&D_{it}$ is the innovative output of the firm i in the year t that we measure using a dummy equal 1 for firms engaged in R&D activity; in section 7 we extend the analysis to R&D intensity. The $equity_{it}$ is a dummy equal to 1 when the firm issues a net positive amount of equity. In the baseline equation X_{it} are controls that we assume to be exogenous firm's characteristics such as industry (2-3 digits), area where the firm is located (5 areas), size, age, propensity to export, being part of a group or of a general type of consortium, and human capital measured by the share of graduated employees in the firm. We also report the results of estimations with fewer, more exogenous regressors (only size and age) and with more controls such as inventory on total assets, firm profitability and productivity. In the robustness section we run a specification with even more controls; the baseline estimation is the result of the trade-off of increasing the controls for firm characteristics, to reduce the unobserved features, while trying to contain endogeneity problems. Time dummies (τ_t) are always included.

When testing the equity effect with this estimation we face a problem as a firm issuing equity can be intrinsically different from one that decides not to rely on this financial source. In other words, equity could be linked to innovation through other unobservable variables. We can argue that there is association or correlation between equity and innovation, though it is by far more difficult to say something about causality (Angrist and Pischke, 2009). In a more formal way, the treatment of equity is not randomly or exogenously assigned, but is chosen by firms and it could be chosen by firms that already have decided to engage in R&D activity. Ideally, we would like to have a random equity issuance assignment to the firm. If the assignment to the treatment is random, there is no problem in evaluating the causal effect: in this case the strategy is based on comparing the different outcomes across treated and non-treated firms, controlling for the observable firm characteristics.

In order to gauge a *causal* effect of positive net equity issues on R&D activity we rely on a main identification strategies to control for firm unobservable characteristics based on an instrumental variable estimation (IV). As usual, we need to find an instrument that is correlated with issuing equity, but that should not be linked to the unobservable error term in the main equation concerning firm R&D activity. In this paper we use three instruments. The first is the share of loans granted by Special Credit Institutes on total loans measured at provincial level. Special Credit Institutes (SCI) worked until 1993 and were specialized in long-term credit: the idea is that in the provinces where they were more widespread, firms got used (habit) in getting long-term financing, including issuing equity. We use the SCI weights in 1984, the farthest year we were able to find with provincial breakdown, in order to have a variable that is not linked to other current local aspects of the economy that could affect innovation, though we also control for them. The second instrument we rely on is the ratio of households' liquid assets to total financial assets, measured at a regional level in the period under analysis; the idea is that firms find it easier to issue equities in areas where households have more liquid assets to buy them. Being located in a region where *households* (not firms) have more liquid financial assets should not be linked to any specific factor explaining *firm's* decision.

Finally, the third instrument is an indicator of credit rationing measured at municipality level; firms answer a question in the Survey of Manufacturing Firms where they are asked whether they demanded for a greater amount of credit without getting it (see the Appendix for more details). We calculate an average in the period under analysis of the firms that could not get the desired credit at municipality level. The idea is that living in a municipality where it is more difficult to get credit induces firms to gather more frequently money from other sources, including shareholders. This indicator is measured at municipality level and it could be correlated with unobserved heterogeneity at the level of municipality that can explain firm's innovative attitude. However, in the IV estimation we also control for some variables measured at municipality level capturing both the entrepreneurial development (the ratio of self-employed to total employees in the municipality from Census in 1991) and the financial development (the number of bank branches for 100,000 inhabitants for the period covered in the analysis); we also control for the credit quality of borrowers through an indicator measuring the percentage of new bad loans on total loans at the end of previous period, calculated in this case at provincial level and measured for all the years of the period under analysis. More controls are also tried in the robustness section.

Overall, we have many indicators at local level, municipality or province, that can assure that we have controlled for the most important local financial and economic factors influencing firms' decision to innovate. The three instruments have the expected signs in the first stage estimations for issuing equities, they are powerful and valid; more details are reported in the section commenting the results.

With this estimation strategy the equation to estimate is the following:

$$ProbR\&D_{it} = \alpha + \beta * equity_{it} + \gamma * X_{it} + \tau_t + \epsilon_{1it} \tag{2}$$

where the dummy $equity_{it}$ is instrumented trough this first-stage equation:

$$Probequity_{it} = \alpha + \theta * instruments + \xi * X_{it} + \tau_t + \epsilon_{2it} \tag{3}$$

The estimation of binary choice models with endogenous regressors is not straightforward (Baum, Dong, Lewbel and Yang, 2012). We first follow the suggestions of some empirical analysts (Angrist and Pischke, 2009) and estimate equations 2 and 3 with a two-stage least square (2SLS) model which assumes that the probability of R&D and of issuing equities are both linear function of their explanatory variables.[10]Usually with binary dependent variables the 2SLS model works well for values of the explanatory variables near the sample average (Wooldridge, 2009). Nonetheless, it has some very well-known problems. First, the predicted values can fall outside of the 0-1 interval of probabilities; secondly, this model constrains the partial effects of any explanatory variables to be constant.

Several alternative approaches to this estimation exist and each has advantages and disadvantages widely discussed (Baum et al., 2012; Angrist and Pischke, 2009). In the end, in this paper we prefer to estimate a bivariate probit model that can be written in this way (for the sake of simplicity, we suppress the subscript for the time and the firm):

$$ProbR\&D = \alpha + \beta * equity + \gamma * X_1 + \tau_t + \epsilon_1 \tag{4}$$

$$Probequity = \alpha + \theta * instruments + \xi * X_2 + \tau_t + \epsilon_2 \tag{5}$$

$$(\epsilon_1, \epsilon_2, X_1, X_2) \sim N(0, 0, 1, 1, \rho) \tag{6}$$

[10]They argue that while a nonlinear model may fit the conditional expectation function for limited dependent variable models more closely than a linear model, when it comes to marginal effects this probably matters little. This optimistic conclusion is not a theorem, but it seems to be fairly robustly true (Angrist and Pischke, 2009).

where the two probit models 4 and 5 are estimated simultaneously through maximum likelihood estimation; in the estimation of the second probability model for issuing equity we keep our instruments that are important explanatory variables in this model.[11] This model permits to estimate the causal effect β of issuing equity on the probability of R&D allowing for the correlation of the errors terms in the two probit models (ρ).

As a robustness test we also estimate a panel fixed effect model where, unlike in the previous estimation based on pooled data of different cross-section waves of the firm surveys, the longitudinal nature of the dataset is exploited. Essentially most of the firms (more than three quarters) are in the dataset for 3 years (one SMF survey) and in this estimation the firm is considered the same (fixed effect) in the period under analysis; some firms are present for 6 years (21 per cent of the firms in the high-tech sample) and even for 9 years (3 per cent of the firms in the high-tech sample); in the latter case they have been interviewed in all the three SMF surveys. The identification strategy in this case is based on controlling for firm unobservable characteristics through firm fixed effect. In other words, we use the same firm before the treatment (issuing equity) as a control for itself after the treatment. The assumption this identification strategy relies on is that firm's intrinsic unobservable features are fixed over time; if there are unobservable variables correlated with the treatment that change over time and that can therefore influence the choice of the treatment and the results, the identification strategy is not working. Finally, unlike the previous IV estimation, measurement error of the endogenous variable is not controlled for.

Under this strategy, the estimated equation is:

$$ProbR\&D_{it} = \alpha + \beta * equity_{it} + \gamma * X_{it} + \theta_i + \tau_t + \epsilon_{it} \tag{7}$$

where θ_i is the firm specific fixed effect and τ_t is the common time fixed effect. This model is estimated as a *linear* probability model with a firm fixed effect.

5 Results

In this section we present the results of the estimations testing the impact of issuing equity on the firm propensity to engage in R&D activity. We first start from an estimation that ignores the problems connected with firm unobserved heterogeneity. Then we comment the results obtained

[11] Greene (2003) argues that this is a recursive, simultaneous-equation model where the endogenous nature of one of the variables on the right-hand side of the first equation can be ignored in formulating the log-likelihood. Essentially, in this estimation we are maximizing the log-likelihood, whereas in linear regression case we manipulate certain sample moments that do not converge to the necessary population parameters in the presence of simultaneity.

with the instrumental variable estimations aimed at measuring the causal effect of issuing equity on R&D along the lines explained in Section 4.

5.1 Pooled probit estimations

The results of the probit model estimated on the pooled sample of the three different waves of the SMF survey for high-tech firms are reported in Table 2 (6,138 firm-year observations for the baseline estimation). The correlation between issuing equity and doing R&D is positive and significant. The economic impact is not remarkable: for firms issuing positive amount of net equity the probability of doing R&D is roughly 3 percentage points higher, almost 6 per cent of the estimated probability (59 per cent).

The other variables have the expected signs: larger, older, export-oriented firms are more likely to innovate; similarly firms belonging to a consortium or with a higher share of graduate employees.[12] The results for the correlation between equity and innovation hold in model 2 of Table 2, where fewer, more exogenous regressors are considered (only firm size and age) and the number of firm-year observations increase to 10,529.[13] The evidence is similar in model 3 where controls for some other firms' characteristics are included. Firms with more pledgable assets, such as inventories, that could be offered as a collateral to the lender, and those with a higher profitability are more likely to innovate. Further controls are considered in the robustness section. We also estimate an OLS linear probability model as in further estimations, aimed at finding a causal effect of issuing equity on innovation, we sometimes rely on linear probability models. Reassuringly, the coefficients for issuing equity are very similar to the marginal effects estimated in the probit pooled estimation.

5.2 Instrumental variable estimations

In this sub-section we present the results obtained with the instrumental variable estimation using the three instruments discussed in Section 4. Table 3 contains the results of the two-stage least square estimator (2SLS, columns 1 and 2), of the bivariate probit model (columns 3 and 4) and of a probit model using a continuous variable for issuing equities (column 5). The number of observations is slightly lower compared to Table 2 as in these estimations we include instruments and more controls for economic and financial factors at local level that are missing for some firms.

[12]Belonging to a group has a negative effect on the probability of R&D, which is confirmed in the IV bivariate probit estimation, though not in all specifications. It could be that for high-tech firms belonging to a group R&D expenditures are recorded by the holding company, creating an attenuation bias for this explanatory variable.

[13]The results are not due to the different sample; running a similar estimation with fewer regressors on the same sample as the specification in column 1 gives the same results.

In the 2SLS estimation the instruments appear to be well correlated with the endogenous dummy for issuing equities. The F test of excluded instruments is almost equal to 7 and therefore not far from the threshold level of 10 for not having weak instruments (Stock and Yogo, 2005; Angrist and Pischke, 2009). In general, the relative weakness of the instruments makes the finding somewhat biased towards the OLS results (Stock, Wright and Yogo, 2002; Minetti, Murro and Paiella, 2011) and therefore in our case towards results that could be affected by an attenuation bias; nonetheless, based on Stock and Yogo tabulations (2002) of the critical values for the weak instrument tests, we reject the null hypothesis of a relative bias greater than 20 per cent. The signs are those expected. In the first-stage equations the probability of issuing equities is higher for those firms located in municipalities where the frequency of credit rationing is higher, in the provinces where Special Credit Institutes were more widespread in the past, and in regions where households have a larger share of liquid assets available to invest in shares. The other condition for valid instruments is that they are not correlated with the error term in the main equation; this condition for the three instruments used in this paper has already been discussed in Section 4. Furthermore, the Hansen J statistic does not rejects, with a wide margin, the joint null hypothesis that the instruments are uncorrelated with the error term, and that they are correctly excluded from the main estimated equation (over-identification test reported at the bottom of the table).

Looking at the second stage 2SLS estimation, we find that the effect of issuing equities on the probability that the firm engages in R&D activity is positive and significant. The magnitude of this effect is more than 10 times higher than the correlations observed in the simple probit estimations. Specifically, the marginal effect of issuing equity is equal to 49 percentage points, 80 per cent of the estimated probability of doing R&D for the high-tech firms. The other variables have similar effects than in previous estimations; one of the largest impact is the one connected with being an exporting firm that increases the probability of R&D by one third.

The huge increase in the impact is informative about the causal importance of equity for innovation, though the magnitude of the effect should be taken with great caution. In general, it is not unusual to find much higher IV marginal effects compared to the effects of estimations that do not consider the omitted variable problem, specifically when the endogenous variable to instrument is a binary indicator (Arendt and Holm, 2006). Overall, this is a typical sign of attenuation bias in the estimations that do not consider the problems of endogeneity and selection. In the specification considered in this paper there are indeed two possible causes of attenuation bias, i.e. an omitted variable and a reverse causation bias. An omitted variable bias could be connected with the fact that there are some unobservable firm's characteristics, such as for instance firm ability, that increase the probability of innovation; however, more able firms tend to avoid relying on an expensive financial source such as equity trying to exploit all the ways to generate the cheapest internal financial sources. This creates an attenuation bias for the coefficient of equity in the R&D equation. As for the reverse causation, it is likely that innovative firms are more profitable (Table 1); therefore they have a higher cash-flow and rely less on external financial sources such as equity; this also creates an attenuation bias for the coefficient of equity in the R&D equation where the endogenous variable is not instrumented.

Nonetheless, it is also true that 2SLS IV estimator used with binary indicators has some very well-known problems examined in Section 4. As mentioned, empirical analysts (Baum et al., 2012; Angrist and Pischke, 2009) suggest that a valid alternative is to estimate a bivariate probit model, carefully described in Section 4. This approach is more elaborate as it entails a maximum likelihood estimation with a fully parameterized joint distribution of the error terms in the two probability models, one for issuing equities and the other for doing R&D; the model is identified by assuming that the error terms are normally distributed and that the instruments are independent of these random components. One interesting feature of the bivariate probit estimation is that we can recover the correlation between the error terms in the two probability models which could be informative about the source of possible bias in the simple probit estimations that do not take into account this correlation.

In Table 3 (columns 3 and 4) the evidence is that, in a bivariate probit model, issuing equities has a positive and significant impact on the probability of R&D for high-tech firms and the magnitude of the effect is almost halved compared to 2SLS results. In detail, issuing equities increases the probability that a firm engages in R&D by 26 percentage points, roughly 40 per cent the estimated probability.[14] It is interesting to note that the correlation between the error terms in the two probit models, the first for the probability of R&D and the second for the probability of issuing equities, is quite large and negative. This means that unobservable variables that increase the probability of R&D generally reduce the probability of issuing equities creating that sort of attenuation bias previously described. In the last column of the table we also report the result of an instrumental variable probit estimation where, instead of using the dummy equity, we rely on a continuous variable such as the ratio of net equity issues on net finance; in this case, however, we need to limit the analysis to firms with positive net finance (4,545 observations). In the second-stage estimation

[14]As a term of comparison, being an exporting firm increases the probability of R&D by 19 percentage points.

the evidence is that even increasing the amount of net equity has a positive effect on innovation: when the ratio rises by one standard deviation (0.2), the effect is such that to increase the probability of R&D by 20 percentage points, one third of the estimated probability in the sample.

Finally, in table 4 we report the results of different specifications of the bivariate probit model. In the first two specifications fewer variables are included: only size and age in the first model, and the baseline excluding human capital in the second model; the number of firm-year observations increases to more than 9,000 and the instruments seem more powerful as detected by the F test in the 2SLS reported by memo at the bottom of the table (F test higher than 8). With only size and age, the marginal effect of issuing equities on the probability of R&D slightly decreases to a value around 16 percentage points, i.e. roughly one third of the estimated probability; in the second specification excluding human capital the effect is similar to that estimated in the baseline, around 40 per cent of the estimated R&D probability.[15] In the final specifications more controls are added without any significant change compared to the baseline estimation reported in Table 3.

On the whole, the results obtained with the IV bivariate probit models can be reckoned as very reasonable and helpful to understand the causal impact of issuing equities on R&D activity.

6 Robustness

6.1 Panel estimation with firm fixed effect

As a first robustness test, in this sub-section we present the results obtained with a panel fixed effect model, i.e. by estimating the effect of issuing equity controlling for unobservable firm's characteristics through a firm fixed effect (FE). To estimate a panel model with firm fixed effect we need to rely on a linear probability model that when estimated on the pooled sample gives very similar results to those reported for the non-linear probability model (Table 2). In the panel FE estimation the standard errors are clustered at the firm level, i.e. allowing the errors to be correlated within the firm. We rely on an unbalanced sample of firms by considering all firms that are in the sample at least 3 years; the average period of presence in the sample is almost 4 years.

The results are reported in Table 5 for the sample of high-tech firms. In the first two columns the firm is allowed to change the R&D status only in different SMF waves, i.e. in the three years of each wave the R&D status is fixed as often firms declare a positive or zero amount of R&D for all three years of the wave; in the last two columns the firm is allowed to change the R&D status even

[15]The results are not due to the different sample; running a similar estimation with fewer regressors on the same sample as the specification in Table 3 gives the same results.

within the SMF wave when for some of the three years in the wave the firm R&D expenditures become positive from zero or viceversa. This estimation is quite demanding as only the variables that change during the period under analysis can contribute. In the specifications in the first two columns, excluding equity, very few variables, only firm's size and its propensity to export, appear to have a causal effect on innovation. More importantly, there is still an effect of issuing equities on the probability of R&D which is equal to 2 percentage points. This marginal effect needs to be evaluated against the relevant joint estimated probability that the firm is engaged in R&D and that is switching the equity issuance status, i.e. the firm starts issuing equities in the period under analysis, as these are the only firms for which the effect of issuing equity can be estimated. This probability is roughly 23 per cent; therefore the marginal effect is such as to increase it by almost 10 per cent. When we allow the firm to change the R&D status even within the SMF wave almost all variables lose their significance, though the effect of issuing equities on the probability of R&D still arises and is even larger, equal to 3 percentage points (almost 15 per cent of the relevant estimated probability; column 3). The results hold in estimations where more controls are considered (columns 2 and 4).

Overall, the evidence is that even with this very demanding specification, where only the switchers to the status of issuing equities contribute to the results and very few variables are still significant, we are able to find a causal effect of issuing equities on the probability that a high-tech firm engages in R&D activity. The fact that the relative magnitude of this effect is lower than that observed with the instrumental variable estimations (10-15 versus 30-40 per cent of the estimated probability of R&D) could be explained by considering that, unlike IV models, the panel fixed effect specification does not tackle the measurement error of the endogenous variable; measurement error causes attenuation bias and therefore in our case tends to decrease the estimation of the effect towards the OLS model. It is true that the dummy for issuing equities is built using balance-sheet items that should be measured without any error; however firms can rely on some balance-sheet policies that create measurement problems even with these data. Furthermore, this identification strategy relies on the assumption that firm unobservable variables are fixed over time; if this assumption is not true, the identification strategy fails.

6.2 Instruments

We then try to evaluate the robustness of the instruments used in our IV estimations. We run 2SLS and bivariate probit models using one instrument at the time. The results hold when we use as a single instrument either the share of loans granted by Special Credit Institutions, measured at the provincial level, or the ratio of households' liquid assets to total financial assets, calculated at a regional level; they do not hold when the instrument based on credit rationing, measured at municipality level, is included alone, mainly because the power of this instrument when included alone is not too high. We also run 2SLS and bivariate probit model with just the two first instruments and the results are very similar to those reported in Table 3. In the end, we decide that our preferred specification is that reported in Table 3, which also includes the credit rationing as an instrument, because it increases the power of the set of instruments.

We also discretize the instruments as suggested by Angrist and Pischke (2009). For the share of loans granted by Special Credit Institutions we consider a dummy equal 1 if the share was higher than the 90 percentile of the distribution; for the ratio of households' liquid assets to total financial assets we rely on a dummy equal to 1 when the ratio was higher than the median value of the distribution; as for credit rationing we calculate a dummy equal to 1 when the share of firms that are credit rationed at the municipality level is higher than 90 percentile. The results obtained with the three discretized instruments included together are similar to those previously commented. Furthermore, the results obtained when using the first two instruments discretized and included alone are similar to those obtained with the previous continuous instruments included alone and with the results in the baseline estimation of Table 3. The results with credit rationing discretized and included alone are better than those obtained with the continuous credit rationing alone, but still when included alone in the 2SLS and bivariate probit model this instrument is not powerful enough and the evidence is weaker.

In Section 4 we discuss the fact that we include different variables at local level (province or municipality) in order to control for some unobservable local features that can be correlated with the instruments used in the paper and that can also influence the firms' decision to engage in R&D activity. As a robustness exercise we also run instrumental variable 2SLS and bivariate probit model using as additional controls a measure of productivity calculated at a regional level (value added divided by the number of employees) and the regional value added growth. All the previous results hold; specifically when controlling for productivity and value added growth at regional level, the marginal effect of issuing equities on the probability of R&D in the baseline estimation is a bit lower (23 percentage points), one third of the estimated probability of R&D.

6.3 Further controls

We also estimate the 2SLS and bivariate probit models for the whole sample of firms. In this case, the number of firm-year observations increases more than three times (to around 18,000 observations) and the instruments appear to be more powerful as the F test for excluded instruments is above 10. The unreported results are very similar to those commented for the sample of high-tech firms (Table 3). The marginal effect of issuing equities on the probability of R&D is around 20 percentage points, almost half of the estimated probability that a firm is engaged in R&D activity in the whole sample.

We then verify the results when further controls are included in the estimations. The trade-off is between controlling for more firm's characteristics, therefore reducing the unobserved heterogeneity, while including some variables that more certainly suffer from endogeneity problems. The variables included separately and then jointly in the estimations are a dummy equal 1 if the firm has received financial or fiscal incentives, that could be an important factor in explaining the decision to become an innovative firm, some controls for the main firm's competitors, i.e. a dummy equal 1 if the main competitors are foreign, a variable controlling whether the firm has hired new employees or not, the score calculated in the Cerved dataset which is an indicator of the risk of the firm, and some indicators connected with the firm's financial structure such as leverage and the ratio of bank to total financial debt.[16] In general the results of the bivariate probit models hold.[17] In an estimation where we include all the controls reported in column 4 of Table 3 and those mentioned in this paragraph, issuing equities has still an important marginal effect on the probability of R&D, equal to more than 30 percentage points (more than 60 per cent of the estimated probability).

Another robustness exercise consists in introducing one lag of the variables different from the one instrumented, i.e. dummy for issuing equities, in order to reduce their endogeneity. In the instrumental variable bivariate probit estimation all the results hold and the marginal effect is unchanged; with the panel fixed effect estimation the effect is even higher, around 20 per cent of the relevant estimated probability.

We finally test whether the results of the pooled probit estimations in Tables 2 and those of the panel FE estimations for high-tech firms in Table 5 hold when we include additional controls at local level used for the IV estimations, such as the the entrepreneurship ratio measured at municipality level in 1991, the number of bank branches for 100,000 inhabitants measured at municipality level

[16]The firm rating in Cerved goes from 1 (highly safe firm) to 9 (highly risky firm)

[17]Specifically, the results about issuing equities do not hold for some specifications when including alone either the dummy equal 1 when the firm has got fiscal or financial incentives or the leverage.

and the ratio of new bad loans on total loans measured at provincial level, both of them for the different years of the period under analysis. All the results hold.

7 Extension of the analysis

7.1 Heterogeneity in the effect of issuing equity on the probability of R&D

On the basis of what we have argued in Section 2, issuing equities to finance R&D activity could be more useful for small and young firms for which asymmetric information problems are more widespread. As for size this was also the evidence of previous papers concerning Italian firms. Magri (2009) found that small innovative Italian firms have noticeably different financial structures compared with small non-innovative firms: they rely more on internal resources and less on bank loans. For large firms this is not true: their financial structures do not differ very much according to the firm's innovative attitude; information problems connected with the innovation activity do not appear to affect their financing decisions.

In Figure 4 we report the marginal effects of issuing equities on the probability of R&D estimated with IV bivariate probit models separately for small and medium-large firms and for young and old firms; we always refer to the group of high-tech manufacturing firms that has been the focus of our analysis. Small firms are those with fewer than 50 employees according to the EU definition, while young firms have been in activity for less than 21 years, the median value of the age distribution for the sample of high-tech firms.[18]

Focusing on heterogenous effects by size, we observe that the marginal effect of issuing equities on the probability of R&D is significant only for small firms: the effect is quite large, 42 percentage points, approximately equal to the relevant estimated probability of R&D for the sample of small high-tech firms. The correspondent marginal effect for medium-large high-tech firms is very small and not significant. As for firm age, the heterogeneity of the equity effect is less strong, but still evident. The marginal effect of issuing equity on R&D probability is significant only for young firms: it is equal to 34 percentage points, more than half of the estimated probability for the sample of young high-tech firms; the marginal effect for old firms is not significant.

We also focus our attention on firms with high and low leverage. As explained in Section 2, the idea is that for firms with high leverage the marginal cost of new debt could increase very quickly due to the fact that the probability and the severity of failure increase fast for high-tech

[18] The thresholds are fixed over time; we allow firms to enter or exit the different classes according to their size and age during the period under analysis. This is also true for leverage and amount of equity issued, the other variables used in this subsection.

firms. For them the benefit of issuing equity to finance innovation should be stronger. In Figure 4 we report the results of estimation of IV bivariate probit models for high tech firms with high and low leverage (higher or lower than 30 per cent, the first quartile of the leverage distribution). The marginal effect of issuing equities on the probability of R&D is significant only for high-tech firms with higher leverage: it is equal to 23 percentage points, almost 40 per cent of the relevant estimated probability of R&D.

In the previous sections we focus our attention on high-tech firms because they belong to sectors where products are more complex to understand and contracts are more difficult to write. In general for these firms asymmetric information problems are hence more widespread and debt is less suitable as a source of finance. In Figure 4 we also report the results of an estimation of the IV bivariate probit model for the sample of firms that do not belong to high-tech sectors: the marginal effect of issuing equities is no longer significant, albeit with a p-value that is not very high (0.15). Overall, it appears that for non high-tech firms the impact of issuing equity on the probability of R&D is less widespread and likely affects fewer firms than in the sample of high-tech firms.

Finally, we look at the effect of issuing equities according to the amount of equity issued. We first define a dummy (low amount) that is equal to 1 if the firm issues equity, has a positive net finance and the ratio of equity issues to net finance is lower than the median value of the distribution of this ratio (9 per cent of net finance for firms issuing equities); symmetrically we can define another variable (high amount) for firms issuing equity, with positive net finance and whose ratio of equity issues to net finance is higher than 9 per cent. We estimate an IV bivariate probit model using these two dummies. From Figure 4, essentially the marginal effect of issuing equities on the probability of R&D arises only for firms issuing a low amount of equity; the effect is 45 percentage points, more than three fourth of the relevant estimated probability of R&D. On the contrary, the marginal effect of issuing equities is even negative, though not significant, for those firms issuing a very large amount of equities; indeed these firms could have specific problems such as going through difficult times and therefore in need for important recapitalization to cover losses.

Overall, we can conclude that there are important heterogeneities in the effect of issuing equities on the probability of R&D along the lines envisaged by the theory, where the largest differences can be detected according to firms' size and leverage.

7.2 The effect of debt and cash flow on the probability of R&D

In Section 2 we have argued that for high-tech firms the traditional pecking order theory, according to which after cash flow firms should first prefer debt and then equity, is likely not well suited. When internal financial sources are exhausted these firms could have more benefits in relying on issuing equities rather than debt

In this section we also look at the effect of issuing a positive amount of net debt or having a positive cash flow on the probability of R&D specifically to evaluate the impact of debt on financing innovation. In Table 6 we report the results of the estimations of probit model on the sample of the pooled three SMF waves when debt and cash flow are first included separately (first two columns) and then together with the dummy issuing equity (third column). The evidence is that debt and cash flow are positively correlated with the propensity that a firm engages in R&D activity. Specifically, the marginal effect of cash flow is higher, equal to 8 percentage points almost 15 per cent of the estimated probability of R&D for the sample used in this estimation. When all the dummies capturing the three financial sources are included together, the tests show that the marginal effect of debt is similar to that of equity in these estimations measuring correlations, while that of cash flow is higher.

The last two columns of Table 6 show the results of the panel fixed effect estimations that measure a causal effect of issuing debt or having positive cash flow on the probability of R&D along the lines explained in Section 4. Unfortunately, we are not able to rely on the preferred instrumental variable estimations to detect a causal effect as the instruments used for issuing equities are not valid for the other two sources of finance, i.e. they are not very well correlated with the dummies issuing debt or having positive cash flow. Interestingly, the dummy referring to positive issues of debt is no longer significant in the panel fixed effect estimation (fourth column): the positive correlation found in the probit pooled estimation arises only in cross-section estimations and does not survive in the within-firm framework; firms issuing debt are more likely to engage in R&D activity, though this source of external finance does not seem to cause an increase in the probability of R&D, at least for the switchers.[19] As expected, given the importance of internal financial sources in financing innovation, in the last column of the table we detect a causal effect of having positive cash flow on the probability of R&D, which is similar in magnitude to that of issuing equity (2 percentage points; see Table 5 for comparison); this marginal effect is a bit higher than 10 per cent of the

[19]This is also confirmed by a panel between effect estimation that captures the effect of debt on the cross-section dimension of the longitudinal dataset: in this case the marginal effect of issuing positive amount of debt on the probability of R&D is still significant.

relevant estimated probability that firms have R&D and change the status from a zero or negative to positive cash flow.[20]

7.3 The effect of equity on the intensity of R&D on sales

We finally focus the attention on the intensity of R&D on sales, i.e. the intensive margin. In this last paragraph we first comment the evidence of the effect of issuing equity on the intensity of R&D on sales elicited from tobit and Heckman estimations. Both estimations, run on the pooled sample of firms, have advantages and disadvantages.

It has been argued that the tobit specification is quite restrictive because it imposes that both the decision to engage in R&D activity and the decision concerning the amount of R&D expenditures depend on the same factors, which are also restricted to have the same sign (Cragg, 1971; Fin and Schmidt, 1984). These hypotheses are not necessarily always satisfied, though compared with a Heckman estimation we are able to run the regression on all firms without any sample selection. We have also to keep in mind that the instrumental variable tobit estimation works specifically for endogenous continous variable. This is the reason why we also present a specification for the IV tobit estimation where the dummy issuing equities is substituted for a variable measuring the ratio of net equities on net finance, only for firms that have positive net finance.

In measuring the effect of issuing equities on the R&D intensity we can also estimate a sample-selection model, i.e. a Heckman estimation that evaluates the impact of issuing equities on R&D intensity only for firms with positive R&D expenditures, by correcting the bias for the sample selection, i.e. taking into account that the estimation is run only on a sub-sample of firms. In order to run this estimation it is important to find a variable that can work as an exclusion restriction in this sample-selection model, i.e. a variable that can influence the firm decision to engage in R&D activity, but has no affect on the level of R&D on sales, i.e. the intensive margin. Following other papers (Arnaudo, Scalise and Tanzi, 2014; Lotti and Marin, 2014), we use as an exclusion restriction the firm's export propensity which has a very strong and significant effect on the decision to engage in R&D activity, while is not so important in influencing the firms' R&D intensive margin.[21] In this Heckman estimation we also use the instruments to tackle the endogeneity problems: essentially

[20] These probabilities are reported at the bottom of the Table 6; many firms do always have positive cash flow, so only a minority of those with positive R&D expenditures change the status from zero or negative to positive cash flow.

[21] The difference in the frequency of R&D activity between exporting and non exporting firms is more then 20 percentage points and is highly statistical significant; the R&D intensity on sales for firms having R&D is around 2 per cent for both samples of exporting and non-exporting firms and the difference is not statistically significant at 1 per cent.

we run an instrumental variable linear model including the Mill's ratio to control for the selection in the sample (Greene, 2003).

The results in Table 7 show that with a simple tobit estimation (first column), ignoring the endogeneity problem, issuing equities increases the ratio of R&D on sales by 0.1 percentage points, a bit less than 10 per cent of the average value of this ratio (1.9 per cent) for the sample of R&D firms. When tackling the endogenous nature of equity with an instrumental variable tobit model (second column), where the instruments are the same as the ones used before, the effect of equity is much larger: for firms issuing equities the R&D intensity measured on sales is twice as large than the average intensity for the sample of firms with R&D. The third column of the table shows that the effect of equity is confirmed when we include a continuous variable. The table shows the marginal effect of increasing the ratio of equity issues on net finance by 1, i.e. from 0 equity issues to 1 (net equity issues equal to total net finance); when we consider a more reasonable change, the marginal effect corresponding to one standard deviation change (0.1) in the ratio of equity issues on net finance is such that the average R&D intensity on sales increases by 35 per cent.[22] In the last column, we present the results of the second-stage instrumental variable Heckman model on R&D on sales that are even more powerful than those of the IV tobit model: issuing equity increases the R&D intensity by around 3 percentage points, more than twice as much as the average intensity for the sample of firms with R&D. All the results hold when fewer or more controls are included in the regressions. As for the heterogeneity, the strongest evidence is that equity issues are very important for R&D intensity only for highly leveraged firms.

8 Discussion of results and conclusions

In a country like Italy, whose indicators of both R&D and equity show a gap compared with the other main countries, it is crucial to find out if the effect of issuing equity on the R&D activity is a causal effect because this would be a strong and clear indication for both policy makers and firms' financial decisions.

This paper has found a causal effect of issuing equities on R&D activity. For high-tech firms and with our preferred instrumental variable estimations, issuing equity increases the probability of R&D by 30-40 per cent. We also find considerable heterogeneity in the effect of issuing equity, which is significant only for small and young firms, for which asymmetric information problems

[22]In order to reach the convergence of the maximum likelihood estimation we need to exclude human capital from this estimation.

are more pervasive, and for more highly leveraged firms, for which the risk of bankruptcy is higher and equity should be preferred to debt financing. In the paper we run many robustness tests including a panel fixed effect estimation, which is based on the assumption that the unobservable firm characteristics are fixed over time and that does not tackle the measurement errors problems: the positive effect of issuing equity is still evident though less powerful, around 10-15 per cent of the relevant estimated probability of R&D. Finally, we also detect evidence that issuing equity has an important effect on R&D expenditures to sales, i.e. on the intensive margin.

How does the evidence found in this paper compare with previous studies? For US listed firms, Atanassov et al. (2007), whose estimation most closely resembles those carried out in our paper, albeit without controls for unobserved heterogeneity, find for that equity issues (seasoned equity offerings) have an important economic effect on innovation: the firms issuing equities experience a 54 per cent increase in citations per patent two years after the issue, compared with a 43 per cent increase for firms making their first bond issue; no effects are found for firms taking out bank loans. Micucci and Rossi (2011) find that for Italian manufacturing firms listed on a stock market market or issuing bonds the probability of R&D increases by 11 percentage points (one fourth of the estimated probability); for smaller firms (those with up to 200 employees) the effect is much greater, 20 percentage points (almost two thirds of the estimated probability). Brown et al. (2009) estimate dynamic R&D models for US listed high-tech firms and find significant effects of cash flow and external equity for young firms, but not for mature companies. The coefficients for young firms indicate that finance supply shifts can explain most of the 1990's R&D boom, which implies a significant connection between finance and innovation. In summary, previous studies that found significant effects of equities issuance on innovation also found that the effects are large from an economic point of view.

Overall, there is plainly room for manoeuvre in a country like Italy, where only 17 per cent of firms make net equity issues (16 per cent in the sample of high-tech firms) and net equity issues are equal to only 2 per cent of total net finance, even for high-tech firms (Table 8). This percentage rises to 5 per cent for listed high-tech firms, which is still far below the 29 per cent found for US listed high-tech firms (Brown et al., 2009). Focusing on the difference between Italy and the US listed high-tech firms, it is striking to notice that the latter also rely heavily on cash flow, but when they need external finance they prefer equity to debt.

Recent policy measures in Italy have diminished the large tax advantage of using debt instead of equity, permitting a portion of the increase in equity to be deducted from taxable income (under a law enacted at the end of 2011) and introducing some tax benefits for the investors in venture capital funds (law enacted in 2011) and for individuals and companies buying shares in innovative start-ups (law enacted in in 2012). These steps are likely to have an impact on firms' financial structures, creating a more favorable environment for financing R&D activity.

Appendix

Detailed description of the variables used in the estimation

R&D: dummy equal 1 for firms having positive R&D expenditures. Source: Survey of Manufacturing Firms (SMF).

Equity: dummy equal 1 for firms issuing net positive amount of equity. Source: Cerved.

Size: the number of employees. Source: Cerved and if missing SMF.

Age: difference between the year of the analysis and the inception year. Source: SMF.

Export: dummy equal 1 for firms that export part of their sales. Source: SMF.

Group: dummy equal 1 for firms that belong to a group. Source: SMF.

Consortium: dummy equal 1 for firms that belong to a consortium or cooperative; there could be different types of consortium such as those to get loans, those that help firms exporting, those that help firms in their research and development activities, and other types of consortium. Source: SMF.

Human capital: the share of graduate employees on total employees. Source: Cerved and SMF.

Inventory: the share of inventory on total assets. Source: Cerved.

Profitability: the share of cash flow on total assets. Source: Cerved.

Productivity: firm productivity measured as the ratio of value added on the number of employees. Source: Cerved and SMF.

South: dummy equal 1 for firms located in Southern regions and Islands (used in descriptive statistics; in estimations dummies for different 5 macro-area (North-West, North-East, Center, South and Islands) are included. Source: Cerved.

Debt: dummy equal 1 for firms issuing net positive amount of debt. Source: Cerved.

Cflow: dummy equal 1 for firms with positive cash flow. Cash flow is a measure of internal financial sources and is to equal to profits net of taxes plus depreciations and other non financial costs. Source: Cerved.

Razcred-mun: the ratio of firms that have demanded a higher quantity of bank loans without getting it; the ratio is measured at the municipality level and it is an average of the period under analysis. Source: SMF.

Sciloan-prov: the share of Special Credit Institute (SCI) loans on total loans measured at provincial level in 1984. Source: Bank of Italy.

Hsliq-reg: the share of households' liquid assets (banknotes and deposits) on total financial assets measured at regional level for the different years of the period under analysis. Source: Financial Accounts.

Entre91-mun: the share of self-employed on total employees measured at municipality level in 1991. Source: Census 1991.

Branchesab-mun: the number of bank branches for 100,000 inhabitants measured at municipality for the different years of the period under analysis. Source: Istat for the population; Bank of Italy for the bank branches.

Newbadloan-pv: new quarterly bad loans on total non-financial firms' loans at the end of previous quarter, seasonally adjusted and reported on a year-basis; measured at provincial level for the different years of the period under analysis. Source: Bank of Italy.

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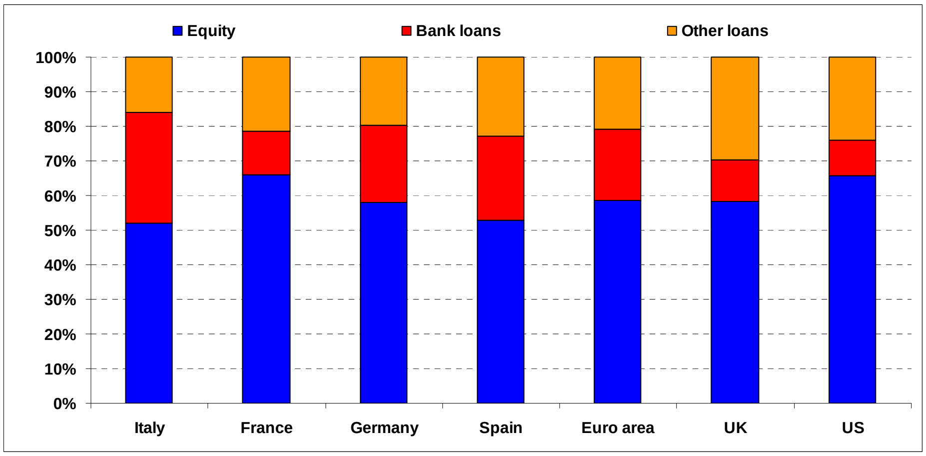
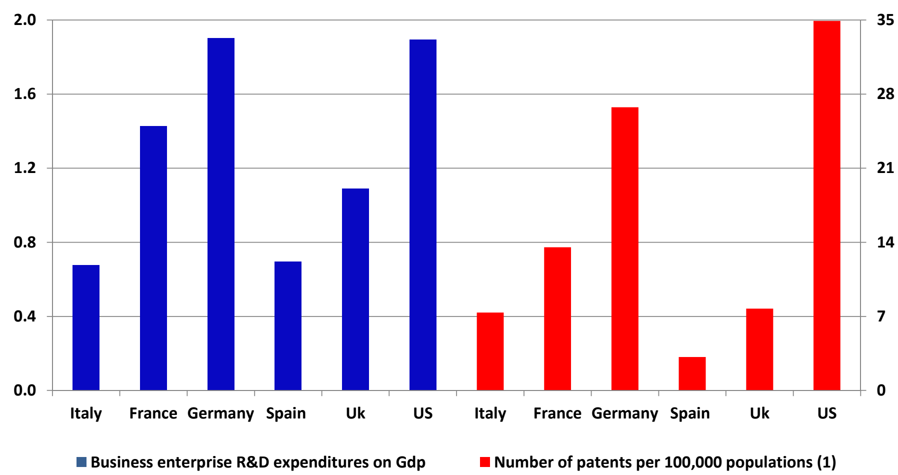
Tables and figures

Figure 1: Firms' financial structure: an international comparison



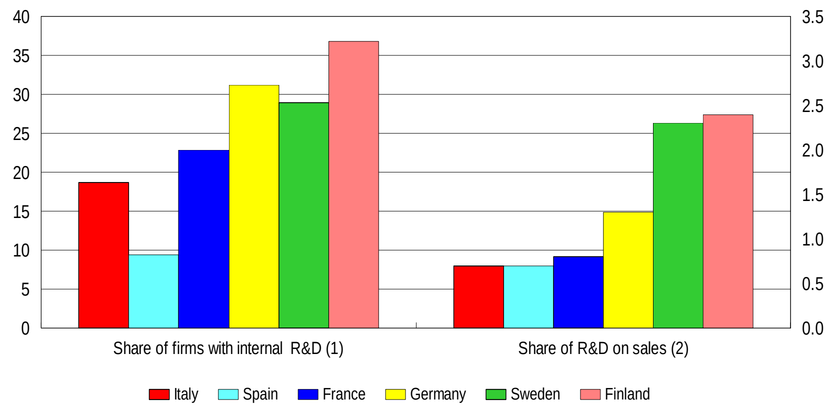
Source: Financial Accounts, Eurostat; data refer to 2012; percentage values.

Figure 2: R&D and patents indicators: an international comparison



Sources: R&D *Main science and technology indicators, 2011,* OECD, percentage values; patents: for European countries number of patents applications to the European Patent Office, 2010 Eurostat, for the US number of patents granted by the US Patent and Trademark Offfice, 2010. (1) Right-hand scale. Left panel percentage values; right panel numbers.

Figure 3: R&D indicators from survey data: an international comparison



Sources: Eurostat, Community Innovation Survey, 2008-2010; for Germany data are for 2006-2008. Data refer to all firms.(1) Left-hand scale (2) Right-hand scale; percentage values.

Table 1: Descriptive statistics of the sample of high-tech firms

Variables	Mean	Std Dev	Non innovative	Innovative	T-Test
R&D	.584	.493	0	1	
R&D on sales	.010	.017	0	.019	
Equity	.157	.364	.151	.162	0.219
Net equity on net finance	.021	.208	.016	.025	0.098
Firm's characteristics					
Size (log)	3.95	1.16	3.62	4.18	0.000
Age (log)	2.99	.792	2.91	3.04	0.000
Export	.853	.354	.761	.918	0.000
Group	.332	.471	.285	.366	0.000
Consortium	.083	.276	.051	.107	0.000
Human capital	.105	.128	.098	.111	0.000
South	.087	.283	.125	.061	0.000
Inventory	.215	.125	.208	.220	0.000
Profitability	.061	.085	.055	.065	0.000
Productivity	55.5	35.2	55.3	55.6	0.779
Local variables					
Entremun91	.242	.049	.240	.243	0.003
Spabmun	62.4	24.5	59.6	64.4	0.000
Newbadloanpv	1.41	2.12	1.44	1.39	0.408
Razcred-mun	.088	.164	.092	.084	0.075
Sciloan-prov	.323	.086	.325	.322	0.091
Hsliq-reg	.218	.067	.226	.213	0.000
Other financial sources - dummies					
Debt	.544	.498	.532	.553	0.111
Cashflow	.891	.312	.868	.907	0.000

Variables are described in detail in the Appendix. Descriptive statistics are calculated over the sample of high-tech firms used in the baseline estimation made of 1,776 firms and 6,138 firm-year observations. The number of observations for non innovative firms (R&D=0) is 2,553, that for innovative firms (R&D=1) is 3,585. The t-test on the difference of the means between the sub-samples is the p-value of a two-sample t-test with unequal variances. Descriptive statistics are similar for the whole sample of manufacturing firms (5,971 firms and 19,776 fir-year observations), excluding the lower percentage of firm doing R&D (0.415).

Table 2: The probability of R&D and equity: sample of high-tech firms
(pooled probit estimation - marginal effects)

Variables	1	2	3
Equity	.0327*	.0230*	.0344*
	(.0181)	(.0140)	(.0183)
Size (log)	.1007***	.0788***	.0992***
	(.0072)	(.0046)	(.0073)
Age (log)	.0167*	.0297***	.0155*
	(.0088)	(.0065)	(.0089)
Export	.2290***		.2280***
	(.0193)		(.0195)
Group	-.0339**		-.0254
	(.0160)		(.0162)
Consortium	.1486***		.1452***
	(.0223)		(.0224)
Human capital	.2757***		.2974***
	(.0583)		(.0591)
Inventory			.2277***
			(.0564)
Profitability			.2827***
			(.0854)
Productivity			-.0002
			(.0002)
Observations	6,138	10,529	6,111
Pseudo R^2	0.1006	0.0611	0.1038
Obs. probability	0.5841	0.4924	0.5855
Est. probability	0.5919	0.4918	0.5936

In column 1 the baseline estimation is reported, in column 2 an estimation with fewer regressors (only size and age) and in column 3 an estimation with more controls. Estimations on the sample of pooled three waves surveys. The construction of the sample is illustrated in the text; the period of the analysis is 1998-2006. Variables are described in detail in the Appendix. In all the estimations time, industry and area dummies are included with controls for Pavitt classification as well. Robust heteroskedastic standard errors are in brackets; * significant at 10%, ** at 5% and *** at 1%.

Table 3: The probability of R&D and equity: sample of high-tech firms
(instrumental variable estimation - 2SLS, bivariate probit model and probit model)

Variables	1 stage 2SLS Equity	2 stage 2SLS R&D	1 bivariate probit Equity	2 bivariate probit R&D	2 probit R&D
Equity		.4886*		.2594**	
		(.2785)		(.1173)	
Net equity					1.1420***
on net finance					(.4111)
Size (log)	.0111**	.0850***	.0088*	.0841***	.0603***
	(.0050)	(.0072)	(.0048)	(.0085)	(.0183)
Age (log)	-.0541***	.0381**	-.0479***	.0263***	.0404***
	(.0073)	(.0172)	(.0062)	(.0101)	(.0141)
Export	.0194	.2055***	.0174	.1899***	.1379***
	(.0141)	(.0198)	(.0143)	(.0205)	(.0426)
Group	.0294***	-.0531***	.0285**	-.0424***	-.0474***
	(.0117)	(.0182)	(.0113)	(.0146)	(.0165)
Consortium	-.0131	.1389***	-.0136	.1306***	.1178***
	(.0166)	(.0224)	(.0179)	(.0229)	(.0267)
Human capital	.0284	.2837***	.0340	.2673***	.2128***
	(.0402)	(.0554)	(.0366)	(.0534)	(.0753)
Entre91-mun	-.0150	.3151**	.0055	.2767**	.0696
	(.1078)	(.1493)	(.1070)	(.1379)	(.1493)
Branchesab-mun	.0001	.0012***	.0001	.0012***	.0010***
	(.0002)	(.0003)	(.0002)	(.0003)	(.0004)
Newbadloan-pv	.0033	.0038	.0034	.0046	.0046
	(.0026)	(.0029)	(.0023)	(.0029)	(.0033)
Razcred-mun	.0778**		.0719***		
	(.0321)		(.0269)		
Sciloan-prov	.1365**		.1306**		
	(.0660)		(.0600)		
Hsliq-reg	.6087***		.6194***		
	(.1997)		(.1899)		
Observations	5,668	5,668	5,668	5,668	4,545
F test (excluded instruments)	6.83				
Overid test(p-value)		0.2322			
Exogeneity test(p-value)		0.0765			0.0472
Corr. between errors ρ				-.3834*	
Robust std errors for ρ				(.2024)	
Test ρ=0 p-value				0.0886	
Est. probability		0.5918		0.5918	0.5918

For the 2SLS model, robust heteroskedastic standard errors are in brackets; overid is a Hansen J test for overidentification where the joint null hypothesis is that the instruments are uncorrelated with the error term, and they are correctly excluded from the main estimated equation; in the exogeneity test the null hypothesis is that the instrumented variable is exogenous. In the last column, equity is included as a continuous variable; the estimation is run only on firms with positive net finance. In the bivariate probit model and in the probit model standard errors for marginal effects calculated with Delta method are in brackets; ρ is the correlation between the error terms in the two probit models. * significant at 10%, ** at 5% and *** at 1%.

Table 4: The probability of R&D and equity: sample of high-tech firms
(instrumental variable estimation - different specifications of bivariate probit model)

Variables	1 probit Equity	2 probit R&D	1 probit Equity	2 probit R&D	1 probit Equity	2 probit R&D
Equity		.1618*		.2188*		.2773***
		(.0972)		(.1141)		(.1052)
Size (log)	.0199***	.0702***	.0148***	.0724***	.0121**	.0813***
	(.0031)	(.0059)	(.0035)	(.0071)	(.0047)	(.0084)
Age (log)	-.0468***	.0335***	-.0452***	.0236***	-.0439***	.0253***
	(.0046)	(.0076)	(.0047)	(.0081)	(.0061)	(.0095)
Export			.0126	.1511***	.0202	.1879***
			(.0103)	(.0150)	(.0142)	(.0203)
Group			.0266***	-.0189	.0340***	-.0360**
			(.0089)	(.0123)	(.0113)	(.0149)
Consortium			-.0060	.1348***	-.0106	.1254***
			(.0148)	(.0196)	(.0178)	(.0227)
Human capital					.0544	.2830***
					(.0366)	(.0564)
Inventory					.0486	.1871***
					(.0385)	(.0524)
Profitability					-.1371**	.3168***
					(.0580)	(.0772)
Productivity					-.0014***	.0000
					(.0002)	(.0002)
Entre91-mun	.0024	.3322***	-.0047	.2911***	-.0287	.2711**
	(.0824)	(.1107)	(.0840)	(.1095)	(.1076)	(.1373)
Branchesab-mun	.0002	.0004*	.0001	.0007***	.0002	.0011***
	(.0002)	(.0002)	(.0002)	(.0002)	(.0002)	(.0003)
Newbadloan-pv	.0015	.0035	.0014	.0044	.0032	.0047
	(.0020)	(.0029)	(.0021)	(.0029)	(.0023)	(.0029)
Razcred-mun	.0733***		.0720***		.0570**	
	(.0207)		(.0208)		(.0262)	
Sciloan-prov	.1584***		.1606***		.1264**	
	(.0473)		(.0474)		(.0590)	
Hsliq-reg	.2994*		.2977*		.5953***	
	(.1589)		(.1609)		(.1876)	
Observations	9,531	9,531	9,336	9,336	5,644	5,644
Corr. between errors ρ		-.2113		-.3107		-.4166*
Robust std errors for ρ		(.1479)		(.1834)		(.1839)
Test ρ=0 p-value		0.1659		0.1134		0.0462
Memo items from 2SLS						
F test (exc. instruments)	8.58		8.24		5.59	
Overid test(p-value)		0.5363		0.4365		0.2424
Est. probability		0.4940		0.4999		0.5934

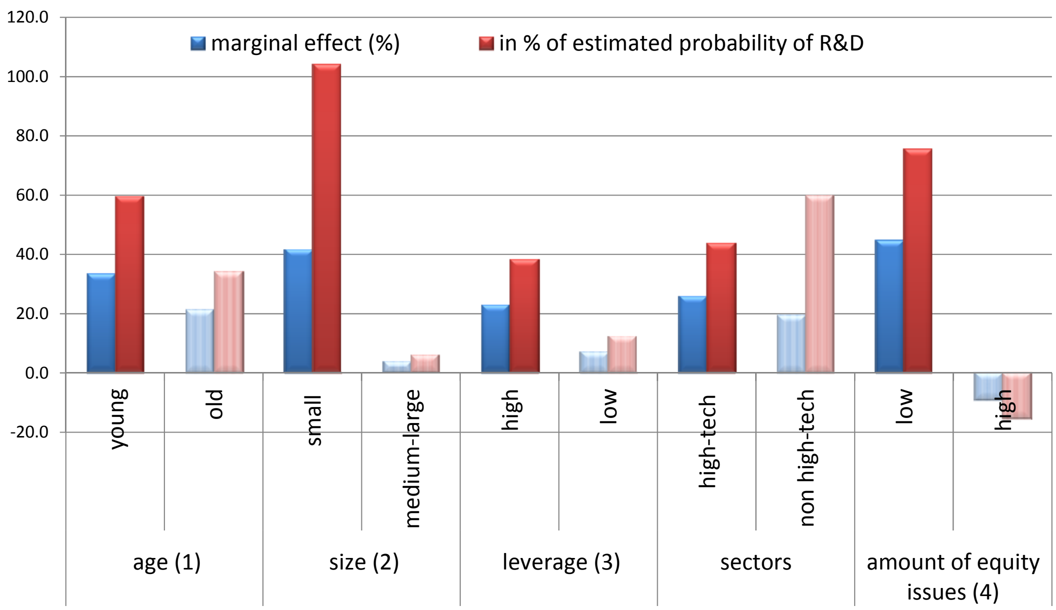
In the first specification only size and age; the second specification is similar to the baseline without human capital, the third specification includes more regressors. Estimations on the sample of pooled three waves surveys. In all the estimations tine, industry and area dummies are included with controls for Pavitt classification as well. Standard errors for marginal effects calculated with Delta method are in brackets; ρ is the correlation between the error terms in the two probit models. * significant at 10%, ** at 5% and *** at 1%.

Table 5: The probability of R&D and equity: sample of high-tech firms
(panel fixed effect estimation - linear probability model)

Variables	1	2	3	4
Equity	.0186*	.0185*	.0300**	.0305**
	(.0099)	(.0100)	(.0127)	(.0128)
Size (log)	.0853***	.0900***	.0450	.0463
	(.0276)	(.0281)	(.0300)	(.0309)
Age (log)	.0057	.0054	-.0781	-.0861
	(.0718)	(.0751)	(.0708)	(.0742)
Export	.1855*	.1830*	.1309	.1302
	(.1107)	(.1106)	(.0987)	(.0988)
Group	-.0694	-.0693	-.0400	-.0395
	(.0654)	(.0664)	(.0605)	(.0615)
Consortium	.0329	.0339	.0719	.0720
	(.0645)	(.0644)	(.0621)	(.0620)
Human capital	-.1297	-.1304	-.0658	-.0649
	(.2274)	(.2284)	(.2033)	(.2031)
Inventory		-.0182		.0361
		(.0848)		(.0974)
Profitability		.0859*		.0515
		(.0473)		(.0578)
Productivity		.0002		.0000
		(.0002)		(.0002)
Observations	5,547	5,508	5,547	5,508
No.firms	1,434	1,422	1,434	1,422
Min.period (years)	3	3	3	3
Avg.period (years)	3.9	3.9	3.9	3.9
Max.period (years)	9	9	9	9
R^2 overall	0.0514	0.0574	0.0150	0.0138
R^2 within	0.0317	0.0334	0.0538	0.0538
Est. probability	0.23	0.23	0.23	0.23

In the first two column the firm is allowed to change the R&D status only in different SMF waves, i.e. in the three years of each wave the status is fixed as often firms declare a positive or zero amount of R&D for all three years of the wave; in the last two columns the firm is allowed to change the R&D status even within the SMF wave when for some of the three years in the wave the R&D becomes positive from zero or viceversa. The estimated probability of R&D is the joint probability that firms are doing R&D and have a switching status for issuing equities in the period under analysis, i.e. the firms for which in this fixed effect estimation the coefficient of equity can be estimated. The construction of the sample is illustrated in the text; the period of the analysis is 1998-2006. Variables are described in detail in the Appendix. In all the estimations time, industry and area dummies are included. Robust heteroscedastic standard errors clustered at firm level are in brackets; * significant at 10%, ** at 5% and *** at 1%.

Figure 4: Heterogenous effects of issuing equities on the probability of R&D



Only the effects reported in dark colors are statistically significant. (1) Young: firms in activity by less than 21 years (median value of the age distribution); old: firms in activity by more than 21 years. (2) Small: firms with less than 50 employees; medium-large: firms with more than 50 employees according to the EU definition of small firms. (3) High: firms with leverage higher than 30 per cent (1 quartile of the leverage distribution); low : firms with leverage lower than 30 per cent. (4) Low: the dummy in this estimation is equal to 1 if firms issue equities, if net finance is positive and the ratio of equity issues on net finance is lower than the median value of its distribution (9 per cent); High: the dummy in this estimation is equal to 1 if firms issues equities, if net finance is positive and the ratio of equity issues on net finance is greater than the median value of the distribution (9 per cent).

Table 6: The probability of R&D, debt and cash flow: sample of high-tech firms
(pooled probit and panel estimations - marginal effects)

Variables	pooled debt	pooled cash flow	pooled all	panel debt	panel cash flow
Debt	.0340***		.0336**	.0050	
	(.0132)		(.0132)	(.0061)	
Cash flow		.0786***	.0830***		.0192*
		(.0219)	(.0219)		(.0111)
Equity			.0354*		
			(.0182)		
Size (log)	.1011***	.1002***	.1001***	.0847***	0839***
	(.0072)	(.0072)	(.0072)	(.0277)	(.0275)
Age (log)	.0164*	.0156*	.0186**	.0041	.0021
	(.0088)	(.0088)	(.0088)	(.0718)	(.0718)
Export	.2305***	.2284***	.2292***	.1846*	.1840*
	(.0193)	(.0193)	(.0193)	(.1107)	(.1105)
Group	-.0316**	-.0280*	-.0285*	-.0694	-.0691
	(.0160)	(.0160)	(.0160)	(.0655)	(.0654)
Consortium	.1473***	.1472***	.1469***	.0328	.0322
	(.0224)	(.0224)	(.0224)	(.0647)	(.0646)
Human capital	.2740***	.2790***	.2778***	-.1267	-.1252
	(.0584)	(.0579)	(.0580)	(.2277)	(.2275)
Test debt=equity			.9292		
Test cash flow=equity			.0905		
Test debt=cash flow			.0549		
Observations	6,138	6,138	6,138	5,547	5,547
Pseudo R^2	0.1010	0.1018	0.1031		
No.firms				1,434	1,434
Min.period (years)				3	3
Avg.period (years)				3.9	3.9
Max.period (years)				9	9
R^2 overall				0.0498	0.0498
R^2 within				0.0311	0.0315
Est. probability	0.5919	0.5919	0.5919	0.4801	0.1657

In the first three specifications pooled probit models; in the last two specifications panel fixed effects models. In the panel fixed effect estimation the estimated probability of R&D is the joint probability that firms are doing R&D and have a switching status for issuing debt or having positive cash flow in the period under analysis, i.e. the firms for which in this fixed effect estimation the coefficient of debt or cash flow can be estimated. For tests testing the equality of the marginal effect of different financial sources the p-value is reported. Estimations on the sample of pooled three waves surveys. The construction of the sample is illustrated in the text; the period of the analysis is 1998-2006. Variables are described in detail in the Appendix. In all the estimations time, industry and area dummies are included with controls for Pavitt classification as well. Robust heteroskedastic standard errors are in brackets; for panels clustered at firm level; * significant at 10%, ** at 5% and *** at at 1%.

Table 7: R&D on sales and equity: sample of high-tech firms
(tobit, instrumental variable tobit and Heckman estimations - marginal effects)

Variables	tobit	IV tobit dummy	IV tobit continous variable	IV Heckman if R&D>0
Equity	.0011**	.0241**		.0314***
	(.0004)	(.0110)		(.0124)
Net equity on			.0724**	
net finance			(.0290)	
Size (log)	.0016***	.0015***	.0009***	.0027**
	(.0002)	(.0002)		(.0013)
Age (log)	-.0001	.0011	.0018**	.0003
	(.0002)	(.0006)	(.0007)	(.0010)
Export	.0048***	.0044***	.0034***	
	(.0005)	(.0007)	(.0007)	
Group	-.0004	-.0014	-.0013	-.0019
	(.0004)	(.0006)	(.0008)	(.0016)
Consortium	.0032***	.0035***	.0037***	.0074***
	(.0006)	(.0008)	(.0009)	(.0024)
Human capital	.0124***	.0133***		.0404***
	(.0014)	(.0017)		(.0055)
Mill's ratio				.0252***
				(.0084)
Observations	5,885	5,436	7,096	2,867
Left-censored obs (R&D≤0)	2,787	2,569	3,928	
Righ-censored obs (R&D>0)	3,098	2,867	3,168	
Average value of R&D on sales	0.0194	0.0194	0.0194	0.0194

In column 1 tobit estimation for the baseline specification; in column 2 instrumental variable tobit estimation with endogenous dummy variable; in column 3 instrumental variable tobit estimation with endogenous continuous variable, i.e. equity issues on net finance only for firm-year observations with positive net finance (human capital is excluded to reach the convergence of maximum likelihood estimations; this explains the increase in the number of observations). For the Tobit estimations, the marginal effect reported is the one relevant for the uncensored observations, i.e. only for firm-year observations for which R&D expenditures are greater than zero. In column 4 instrumental variable Heckman model estimated only on firms with positive R&D; the Mill's ratio controls for sample selection: the exclusion restriction for the second stage model is to be an exporting firm. Estimations on the sample of pooled three waves surveys. The construction of the sample is illustrated in the text; the period of the analysis is 1998-2006. Variables are described in detail in the Appendix. In all the estimations time, industry and area dummies are included with controls for Pavitt classification as well. Standard errors are in brackets; *significant at 10%, ** at 5% and *** at at 1%.

Table 8: Composition of net finance
(share on total net finance)

Sources of finance	Italy all sample	Italy high-tech	Italy high-tech listed	US high-tech listed
New net equities/net finance	.02	.02	.05	.29
New net debt/net finance	.43	.41	.23	.02
Cash flow/net finance	.55	.56	.72	.69
Sum	1	1	1	1

These statistics are calculated on the sample used for the estimation including all firms both with positive and negative net finance. When calculated only on firms with positive net finance the relative importance of cash flow compared with debt increases, while the relative weight of net equities issues is still small, around 3 percentage points. The same statistics are very similar for the whole sample of firms in the SMF survey. Data for the US are taken from Brown et al (2009).

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