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Financing R&D investments: relationship lending or financial markets?

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FINANCING R&D INVESTMENTS:
RELATIONSHIP LENDING OR FINANCIAL MARKETS?

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Abstract

The financial system performs a key role in spurring economic growth, providing firms with the necessary funds to carry out research and to develop new products and new technologies. We analyse the financing of R&D activity in Italy, using data at firm-level that cover a wide range of sources of financing, such as internal funds, bank loans, and the access to financial markets.

From one hand, our analysis confirms the importance of relationship lending in favouring innovative activities. The relation between innovative firms and their main bank tends to be longer, in order to abate information asymmetry, even if a low credit concentration is a common feature among these firms, presumably with the aim to attenuate hold-up problems.

On the other hand, firms that rely on bonds and outside equity financing tend to invest more in R&D, suggesting that relationship lending is only a partial substitute for the direct access to financial markets. As a whole, our analysis suggests that financial markets are crucial in order to finance innovation.

JEL Classification: G21, O30.

Key words: Research and Development (R&D); Relationship lending; Financial markets; Italian economy.

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1. Introduction*

New products or new technologies require funds to carry out feasibility studies, to implement the production of new goods and to adapt the internal organization of the firm. Financial constraints represent one of the main obstacles inhibiting these changes, due to an exacerbation of asymmetric information problems. In Italy innovation financing is a particularly relevant issue, since the scarce innovative capabilities by firms has been charged to be one of the main reasons explaining the low growth of the Italian economy in the last decade. As Italy is a bank-oriented economy, the role of banks is predominant also in innovation financing; yet it is controversial whether bank financing, even when characterized by tight relations between lending banks and borrowing firms, may be a substitute for the direct access to financial markets.

Innovative firms face greater difficulties in obtaining external finance, because their activity is risky and hard to collateralize. Banks could mitigate these information asymmetries by establishing long-lasting relationships with innovative firms. However, when the firm is “informationally captured”, the lending bank can extract an additional rent or threat not to provide additional funds because of its low substitutability (*hold-up*; Sharpe, 1990; Rajan, 1992). Furthermore, banks may not have the necessary skills to evaluate new technologies and tend to discourage these investments (Rajan and Zingales 2003; Atanassov, Nanda and Seru, 2007). Thus, the theoretical literature reaches conflicting predictions on whether relationship-based financing fosters or inhibits technological progress.

In this paper we analyse the role of financial factors in explaining innovative activity of Italian manufacturing firms, using micro data at firm level. While there is a lively debate at the macro-level on the role of financial factors in fostering innovation (O’Sullivan, 2004; Levine, 2005), the micro-economic evidence is still controversial,

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even if the literature on this topic is rapidly growing (Herrera and Minetti, 2007; Benfratello, Schiantarelli and Sembenelli, 2008; Alessandrini, Presbitero and Zazzaro, 2010).

We use a unique dataset that combines various sources of data on R&D expenditure at firm level and on many aspects of its financing. Using the Bank of Italy's survey on manufacturing firms (INVIND), we draw information on Research and Development (R&D) expenditure and relate it to firm characteristics such as size, exports, workforce, age and governance. From balance sheet data (Centrale dei Bilanci), we obtain information on internal funds (cash flow) and leverage ratios. Using data from the Italian Credit Bureau (Centrale dei rischi), we build specific indices on the type of relationship with the lending banks, such as the length of the bank-firm relation and the degree of concentration of outstanding bank debt. Our data also contains information about the access to financial markets by the firms: this allows us to compare the role of relationship-based financing relative to arm-length finance (outside equity and bond financing), that is the main research question of our paper.

From the econometric standpoint, the relation between financial constraints and R&D is affected by unobservable firm's characteristics that cannot be easily eliminated in cross-sectional data. By using panel data, we disentangle the role of different variables in R&D activity, while controlling for unobserved firm's characteristics. Further, both quantitative and qualitative dependent variables are considered, to control for the *propensity to* perform and the *intensity of* the investment in R&D.

Our analysis confirms the importance of financial factors in conditioning innovative activities. The dependence of R&D investment with respect to cash flow corroborates the relevance of financial frictions for small and medium enterprises. Long-lasting relations with the main bank are relevant in easing these financial constraints and favouring the decision to carry out R&D activity. However, innovative firms tend to have longer relationships with the main bank but also a low concentration of outstanding debt among lending banks. We argue that this configuration could be adopted in order to strengthen bank's information on the firm, while the firm attenuates the information capture by spreading its debt among many banks. Anyway, the direct access to financial markets appears to be much more important in order to finance innovation.

Overall, our results document that a long-lasting relationship with the main bank mitigates the entry costs in a risky activity such as R&D (R&D propensity), but it is not enough to enhance R&D investments (R&D intensity). To this aim, direct access to financial markets is crucial: relationship-based financing, even important, may be just a *partial* substitute for arm-length finance. From a policy view, our results indicate that for a bank-oriented economy like Italy there are growth opportunities by deepening its financial system towards more developed financial markets.

Among the other results, the export propensity, size and localization of firms proved to be very important in shaping R&D activity. R&D investments are more intense for firms located in the main urban areas, while no significant difference is detected between industrial districts and other non-agglomerated areas.

This paper is organized as follows. Section 2 discusses the theoretical and empirical literature. Section 3 presents the data. The econometric analyses are reported on Sections 4 (the adopted models) and 5 (the estimated results). Section 6 concludes.

2. Literature review

From the seminal paper of King and Levine (1993) onwards, a large body of empirical literature has studied the contribution of finance to growth, drawing on Schumpeter's writings on the microeconomics of innovation. This literature claims that a well-functioning financial system (both markets and financial institutions) spurs innovation and economic growth (see the reviews of O'Sullivan, 2004, and Levine, 2005).

There is a wide consensus in the literature that financial constraints represent one of the main obstacles inhibiting R&D activities, due to asymmetric information between the entrepreneur and the financier.[1] Firms have better information than

[1] Gorodnichenko and Schnitzer (2010), using a broad sample of firms located in Eastern Europe and Commonwealth of Independent States, find that financial constraints restrain the ability of

potential financiers about the likelihood of success of the innovative projects. The cost of financing R&D investments (the lemons' premium required because of asymmetric information) is higher than in the case of equipment expenses, because the former are usually riskier and long-term oriented. Besides, innovation is an activity which cannot be easily collateralized. Thus, it may be costly to carry out such investments using external finance and entrepreneurs may resort to internal sources, such as cash flow.

Consistently with theoretical predictions, the empirical literature finds a positive correlation between R&D and cash flow. Hall (1992) found a positive elasticity between R&D and cash flow in a large sample of U.S. manufacturing firms. Himmelberg and Petersen (1994) extended this result to small firms in high-tech industries. Similar evidence were documented also for French firms by Mulkay et al. (2001), for British and German firms by Bond et al. (2006), and for Italian firms by Ughetto (2008). Brown, Fazzari and Petersen (2009) show that US firms relied heavily on cash reserves to smooth R&D spending during a period characterized by boom and bust in stock market returns.

In order to finance innovations (at least radical ones), the direct access to financial markets should be preferable to other sources of external finance. According to Allen and Gale (1999), when there are different opinions among investors, projects are more likely to be financed if firms have direct access to financial markets, where the financiers participate to the upside potential of the company. These differences are more likely for innovative activities.

This is also consistent with the model put forward by Atanassov, Nanda and Seru (2007). They assume that firms with more innovative projects tend to rely on arm's length financing, which allows greater independence to managers. On the contrary, less innovative firms, whose projects are easier to evaluate, give less discretion to managers and bank borrowing is prevalent.[2] In their empirical analysis on a large panel of US

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domestically owned firms to innovate and export and hence to catch up to the technological frontiers. For Europe, other analyses (Mohnen and Roller, 2005; Mohnen *et al.*, 2008; Savignac, 2006) confirm that insufficient finance inhibits firm innovativeness. Magri (2007) emphasizes the difficulties encountered by small innovative firms. For a general review, see also Hall and Lerner (2009).

[2] See also the discussion in Lerner, Sorensen and Stromberg (2011).

companies from 1974-2000, Atanassov, Nanda and Seru (2007) find that companies relying more on outside equity or bond financing receive a larger number of patents compared to other firms. They interpret this evidence as a signal that banks are less able to evaluate new technologies and therefore discourage investment in innovation. Also Rajan and Zingales (2003) highlight that in relationship-based financing, the lender may have not the necessary skills to properly evaluate innovative technologies; thus, their close monitoring might discourage such investments. Similar findings are reported by Blass and Yosha (2003) and Aghion *et al.* (2004); these studies, using data for Israel and UK respectively, show that large listed innovative firms tend to finance their activity by issuing shares.

Banks seem ill-suited to provide the necessary funding to sustain R&D projects also according to Hoewer, Schmidt and Sofka (2011): firms overcome risk considerations by their lending banks only if they can signal the value of their R&D activities through previous successful patent activities.

Provided that the financing of R&D expenditures by means of bank loans are at disadvantage compared to arm's length financing, firms could nevertheless offset this disadvantage by strengthening their relations with the banks. Banks may play a role by reducing informational asymmetries thanks to a better knowledge of firm's prospects, gathered through repeated interactions over time. In relationship-based lending, the bank invests to gather information on the quality of the borrower. This investment is especially valuable for small and opaque firms without direct access to financial markets (Boot, 2000; Berger and Udell, 2006).

However, a tight credit relationship can expose the firm to the risk of being "informationally captured" by the bank: the lending bank may cross-subsidize initial lower interest rates with future higher profits (hold-up, Sharpe, 1990) or can threaten not to provide additional funds to the borrowing firm (Rajan, 1992). Innovative firms face more severe hold-up problems, because the prospects of R&D investments are generally more informationally opaque and new financiers are difficult to find (Rajan and Zingales, 2001). Hence, firms may spread their outstanding debt on a larger number of lending banks to cope with this hold-up problem (Ongena and Smith, 2000). They might want to decrease the credit concentration to assure themselves against liquidity shocks by the main bank, since a fund withdrawal by the main bank is difficult to offset for opaque and risky firms (Detragiache, Garella and Guiso, 2000). According to Atanassov, Nanda and Seru (2007), not only banks will tend to discourage innovative investments, but they will be more prone to shut down on-going ones. This explanation is consistent with the evidence reported in Ongena *et al*. (2007), where it is shown that riskier and less liquid firms are expected to have a larger number of banks and a significant lower degree of credit concentration.

Second, due to the ease of imitation of inventive ideas, firms are reluctant to reveal their innovative ideas to the marketplace. Thus, they could have a strategic preference not to disclose information (Bhattacharya and Chiesa, 1995; von Rheinbaben and Ruckes, 2004). In the model put forth by von Rheinbaben and Ruckes (2004), for example, if a firm discloses confidential information to lenders, these can more precisely evaluate its risk, thus reducing interest rate, but at cost of hampering firm profitability since the information may be revealed to rival firms: the model predicts a U-shaped relation between innovativeness and the number of bank lending relationships. As there is substantial cost to revealing information, the quality of the signal the bank can extract about a potential project is lower (Anton and Yao, 1998). As a whole, the effects of banks information on innovativeness are a priori ambiguous.

While the idea that innovative ideas are more difficult to be financed than traditional investment projects dates backs to Schumpeter's writings, only a recent strand of literature has studied the impact of relationship lending on firms' propensity to innovate. To our knowledge, the majority of the extant empirical literature use data on Italian manufacturing firms (Alessandrini, Presbitero and Zazzaro, 2010; Benfratello, Schiantarelli and Sembenelli, 2008; Ferri and Rotondi, 2006; Giannetti, 2009; Herrera and Minetti, 2007). This focus on Italy may be explained – besides the availability of data at a micro level (all of the above quoted works use the Capitalia's Survey on Small and Medium Enterprises) – by its strong characterisation as a bank-based economy. In a nutshell, these works find that firm innovativeness is triggered by a more competitive local banking system and by closer ties, in terms of length of the relationship, between banks and their borrowers. More in detail, Herrera and Minetti (2007) find that banks' information (proxied by the length of credit relationships) fosters firm's innovation, measured by process and (with a stronger effect) product innovation. Benfratello, Schiantarelli and Sembenelli (2008) show that banking development (captured by the evolution in bank branch density) affects the probability of process innovation, particularly for firms that are small and operating in high-tech industries or in sectors more reliant on external finance. Giannetti (2009) analyses the impact of financing obstacles across different innovation phases (invention and introduction of new technologies), finding that relationship-based financing plays an important role in both phases, especially for high-tech firms. Ferri and Rotondi (2006), controlling for the diffusion of industrial districts, find that the duration of the bank relationship positively affects the likelihood of process innovation. The analysis of Alessandrini, Presbitero and Zazzaro (2010) documents that SMEs located in provinces where the local banking system is functionally distant introduce less innovations, while the market share of large banks exerts only a slightly positive effect on firms' propensity to innovate. This set of researches constitutes a valuable benchmark for evaluating our analysis; at the same time, we differentiate from them for a number of aspects, concerning data and research purpose. In particular, our main goal consists in comparing different sources of finance and, more in detail, the role of relationship lending with respect to the direct access to financial markets.

3. Data and descriptive statistics

The data set considers firm-level data, obtained from the Bank of Italy's Survey on Investment by Manufacturing Firms (INVIND). This is an open panel of nearly 2,000 Italian manufacturing firms with at least 50 employees (Banca d'Italia, 2009). The questionnaire collects a wide range of information: year of foundation, location, sector of activity, employment, sales (domestic and foreign), investments, etc. It reports also quantitative information on firm's yearly R&D expenditure.

Balance sheet data are drawn from official records filed to the Italian Chambers of Commerce and reported by Cerved Group. These firm-level data have been matched with the statistics from the Italian Credit Register (Centrale dei Rischi), which reports data on credit lines granted by every bank lending to the selected firms.

After merging these sources, the sample consists of around 1,800 firms and nearly 5,400 observations between 2004 and 2009. It is an unbalanced panel (INVIND is an open panel, albeit it tends to be stable over time), with an average of 3 observations for each firm.

Table 1 reports the composition of the dataset by size (number of employees), sector of activity (based on the Pavitt technological classification), export propensity, localization and age. Table A shows the definition of the variables.

The sample appears to be representative of the Italian economy, with most firms being small (less than 200 employees) and operating in low-tech industries (40 per cent of the observations). Almost 20 per cent of the sample refers to highly export oriented firms (more than two third of their production are exported), while another 28 per cent exports more than one third of the production. Firms are fairly aged: only 5 per cent of the observations refers to firms less than 8 years old.

As Italy is characterised by strong territorial differences both in the productive and in the financial structure, it is important to control for the location of firms. To this end we use a set of dummy about geographical areas (North-West, North-East, Centre, South) and the type of local labour system (large metropolitan areas, defined as local labour systems with more than one million inhabitants; industrial districts, defined according to the Sforzi-Istat methodology (Istat, 2005); other non-agglomerated areas).

We use two alternative (even if related) variables in order to measure R&D activity. The first is a dummy equals to 1 if a firm invests in R&D expenditures (R&D *propensity*), catching the occurrence of the phenomenon irrespective to its amount. The second catches the *intensity* of these investments and it is computed by the ratio between the amount of R&D investments and total sales.

Table 1 reports the frequency of R&D expenditure and its share on total sales. Half of the sample performs R&D, with an investment equal to, on average, 1 per cent of total sales.

There is positive correlation between R&D and size: 69 per cent of large firms (more than 500 employees) performs R&D, against 44 per cent of small firms (less than 200) and 57 per cent for medium ones (200-500 workers). The same is true for the level of investment: in large firms, nearly 2.3 per cent of the sales is invested in R&D, against 0.8 per cent for smaller firms.

Both R&D propensity and intensity substantially increase with export levels. The sector of activity is important, too. 72 per cent of science based firms carry out research, and they invest more than 4 per cent of their sales. These figures are respectively 46 per cent and 0.5 per cent for low-tech firms. Older and younger firms show less clear-cut differences, albeit younger firms (less than 8 years old) invest more than the average.

Among the main controls, firm's location is especially interesting. Spill-over effects are among the main sources of innovation that the theory has enlightened. R&D is frequently carried out by firms located in agglomerated areas, either metropolitan areas or industrial districts. However, in the latter case, the investment is in line with the average. Both the occurrence and the level of R&D activity are lower in the South.

Table 2 reports also the composition of the sample according to variables that describe the type of financing and relationship with the banking system.

Firms may finance the innovative activity using internal funds. In the empirical analysis, we use the ratio of cash-flow on total sales (*cash flow*) to control for this feature. To finance its R&D activity, a firm may resort to financial markets by issuing bonds or equity, or it may engage in relationship-based financing. Therefore, we introduce a dummy for the access to financial markets, which is equal to one if the firm is listed or has issued bonds (*financial markets*).

Relationship-based lending is a somewhat complicate concept to measure, due to its multidimensional nature; to describe the type of relationship established between borrowing firms and lending banks, we adopt two main variables, regarding the duration of the relationship with the main bank and the credit concentration. The main bank is assumed to be the bank which has the higher share over total outstanding bank debt of the firm. The length of the relationship with this bank is computed starting from

2000. As a robustness check, we consider also a dummy for relationships longer than 5 years (the median value in the sample) instead of the continuous variable, which mitigates the possible truncation problem.

The second variable is the Herfindahl concentration index of bank debt among all the lending banks (*Herfindahl*). This index, commonly used in the empirical research, should catch whether there is a main bank – when total loans are highly concentrated towards just one intermediary – or the firm has diversified its credit, to avoid hold-up problems or to assure against liquidity shocks by the main bank. The size of the main bank is also considered (*bank size*).

Finally, we control for the role of bank loans over total financing debt and for the composition of the credit lines the bank has extended to the firm according to their maturity (*short term debt*).

The frequency of R&D is increasing with the length of the relationship with the main bank. However, the investment levels are lower, even if the differences are very small. Credit concentration index is inversely related to the occurrence of R&D and positively to level of R&D investments. Higher cash flows seem to improve the R&D propensity, but there are not differences in the intensity of investments. Last, the access to financial markets (listed firms or with public debt outstanding) is accompanied with higher R&D activity, both in terms of propensity and intensity. Nonetheless, this evidence could be explained also by the size of the firms, generally larger for listed companies, and therefore these aspects should be controlled by a proper multivariate analysis.

Table 3 shows the main statistics for the variables used in the empirical analysis, which are always considered with one-year lag with respect to R&D, in order to limit potential endogeneity problems. Table 4 reports the correlation coefficients.

4. The econometric models

4.1. R&D propensity

To analyse the firm's propensity to carry out research, the dependent variable is defined as a dummy, equals to one if the firm has invested in R&D in the year of observation or in the previous year; 0 otherwise. Since the dependent variable is discrete, the standard linear probability model (LPM) estimated by OLS is inefficient. Heteroscedasticity determines biased standard errors and erroneous hypothesis testing.[3] Furthermore, LPM can bring to predicted probabilities outside the 0-1 range. For these reasons, a probit model is considered; the probability to observe an event being equal to the normal cumulative distribution function evaluated at β'x, where x is a set of explanatory variables and β the estimated coefficients.

This discrete outcome can be viewed as the observed counterpart of a latent continuous variable y* crossing a threshold τ. One can think that the research activity is recorded only when it passes a certain threshold, or when it is organized in proper departments. As an alternative explanation, there might be some kind of indivisibilities in the investment, which can be undertaken only over a certain threshold. Assume that this latent variable y* is a function of the explanatory variables x, in the form of y*=β'x $+\varepsilon$. Then, the observed dependent to study will be:

$$y = \begin{cases} 1 & if \ y^* > \tau \\ 0 & if \ y^* \le \tau \end{cases}$$

Further, the existence of individual differences across firms should be addressed. A simple cross-section probit model would assume that the error term in the latent response function is identically distributed and independent from the x. Thus,

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[3] The usual homoscedasticity hypothesis is violated, since the variance of the dependent y, conditional on the covariates x, is equal to:

$$\text{var}\ (y\,|\,x) = prob(y=1\,|\,x)(1-prob(y=1\,|\,x)) \ = \beta' x(1-\beta' x).$$

Thus, the variance of errors depends on the x and is not constant.

conditional on the x, every firm has the same probability to invest in R&D and $prob(y_i=1|x_i)=prob(y_j=1|x_j)$, which is an unrealistic assumption (Baltagi, 2005).

The existence of panel information allows disentangling the individual behaviour from the average, by decomposing the error term in a time-invariant individual component and a residual. The lack to control for unobserved characteristics may bring to misspecification. Therefore, the propensity to carry out research is estimated by means of a probit model with random effects to catch firm heterogeneity u_i, according to the following specification:

$$[1] \quad prob(R\&D=1)_{it} = \Phi(a + b\,X_{i\,t-1} + \varphi F_{it-1} + \gamma C_i + u_i + e_{it})$$
$$with: \ \mathrm{E}(e\,|\,x)=0; \mathrm{var}(e\,|\,x)=1$$

where Φ is the normal cumulative distribution function, u_i is the random disturbance characterising the i_{th} firm and constant through time, independent from the error term e_{it} and from the regressors.[4]

The regressors X_{it-1} are the set of variables which describe the type of external financing the firm has undertaken. These are: the cash flow; the relationship-lending variables (the length of the relation with the main bank and the concentration of outstanding bank-debt among the lending banks); the access to financial markets. We also add controls for the share of bank loans over total financing, the maturity of the outstanding bank loans (share of short term bank loans over total banks loans) and the size of the main bank. F_{it-1} are a set of controls for the firms' characteristics. These are: size (log of the number of employees); age; leverage; the composition of the labour force, i.e. the share of white collars over total workers as a proxy of human capital; export propensity, as the share of exported production over total sales. C_i are time-invariant dummies to control for the localization of the firm (metropolitan areas; industrial districts; macro-regions); its sector of activity, according to Pavitt taxonomy; group membership.

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4 In linear panel data regression models, the coefficients are estimated consistently by first removing the individual specific effect u_i trough the Within transformation (difference form the average). Here, stronger assumptions are needed to introduce the error component model, specifically that there is strict exogeneity of explanatory variables from individual effects.

Equation [1] is estimated by means of maximum likelihood estimation. A test for the pooling of the observations is carried out by means of a likelihood ratio test; it rejects the null that the simple probit model is consistent. A Hausman-type test is also considered; it is based on the idea that the usual probit MLE, ignoring the individual effects, is consistent and efficient only under the null of no individual effects and inconsistent under the alternative. The probit with random effects is consistent whether H_0 is true or not, but it is inefficient under H_0.

4.2 *Intensity of the investments in R&D*

To improve the understanding of the phenomena, we also consider a specification where the dependent variable measures the intensity of the R&D activity, and it is equal to the (log) of expenses in R&D over total sales of the firm.

As stated before, half of the sample has reported zero R&D investment. Again, we assume that the level of investment is censored to zero every time it is lower than a certain threshold. This can happen because some type of indivisibilities or because the expenses are too low to justify a separate accounting, or R&D is performed informally, i.e. not in a proper department; hence, data are difficult to gather or even to estimate for survey purpose. In this framework, OLS would be inconsistent either considering only strictly positive information or allowing censored observations to be set to zero (Wooldridge, 2002). Therefore, the model used to estimate the previous function is a Tobit model on the whole sample. Once more, the estimates are complicated by the fact that the data used are a panel of nearly 2,000 firms over the 2004-09 time-span. Therefore, the estimates consider a Tobit model with random effects, according to the following specification:

[2] $$\log\left(1+\frac{R\,\&\,D}{sales}\right)_{it} = a + b\,X_{i\,t-1} + \varphi\,F_{it-1} + \gamma\,C_i + u_i + e_{it}$$

The error-term has two components, $\varepsilon_{it} = e_{it} + u_i$, both normally distributed with zero mean and independent; u_i refers to the random effect by firm. The formulation in terms of (log) likelihood function is:

[3] $$\ln L = \sum_{y_{it}>0} \ln \frac{1}{\sigma} \phi\left(\frac{y_{it} - x_{i,t-1}\beta}{\sigma}\right) + \sum_{y_i=0} \ln\left[1 - \Phi\left(\frac{\beta' x_{i,t-1}}{\sigma}\right)\right]$$

where ϕ and Φ respectively denote the normal density and standardized cumulated function, and $x_{i,t-1}$ are all the regressors, for the sake of simplicity reported as if there are all lagged one period.

Conceptually, this is a blend of two distinct models, corresponding to the classical regression for the positive observations (the intensity of the investment) and to the probability cumulated up to the censoring point (zero) for the limiting observations. Since the model is the sum of two parts, in the tables we report the marginal effects on the intensity of the investment – the latent variable y* – conditional on being observed.

This model is again compared with a pooled model (Tobit) by means of a likelihood ratio test. The regressors are the same as before.

5. The econometric results

Table 5 shows the results for the probability to perform the Research and Development activity inside the firms; it reports the marginal effects computed at the average for each variables. Table 6 covers the estimates for the intensity of R&D investments, defined as (log) R&D expenses over total sales, reporting the marginal effects on the expected value of the latent variable, y*, conditional on being observed.

Both the likelihood ratio test and the Hausman test for the pooling of the observations reject the null that the simple Probit model is consistent. The same is true for the Tobit estimates, compared by means of a LR test. The panel variance component is very important: it explains more than 70 per cent of total variance in the propensity estimates (table 5) and around 60 per cent in the intensity equations (table 6).

5.1 Financial factors

In our results, financial factors proved very important in affecting innovative activity. Cash flow has a positive impact on the level of investments for small and medium enterprises. However, the variable is not significant in affecting R&D propensity, suggesting that internal sources are not enough to undertake this type of investment and external finance is needed. Considering R&D expenditure, medium enterprises (up to 500 employees) have an estimated investment of around 0.91 per cent of total sales; one standard deviation increase in cash flow improves the expenses by 0.04 points (to 0.95 percent); the impact is 0.06 point for smaller firms (up to 200 employees), improving the average investments from 0.85 to 0.91 per cent of total sales.[5] Whilst limited in magnitude, the pro-cyclical effect of this variable confirms the importance of financial frictions in conditioning R&D activity.

Direct access to financial markets relaxes financial constraints and favours R&D activity. The effect is economically very strong: starting from an estimated average propensity to perform R&D around 44 per cent in the whole sample, the expected probability is 12 percentage points higher for firms that have issued bonds or are listed. This effect is further reinforced for firms with less than 500 workers, where the enhancement is still 12 points but the average propensity is lower, around 40 per cent; the impact rises to 22 percentage points for firm with less than 200 workers, for which the average estimated propensity to perform R&D is around 34 per cent of the cases.

The results on the intensity of R&D investments point to the same direction: the access to financial markets has a positive and significant impact on total R&D expenditure, increasing it by 0.21 percentage points on the whole sample (from 1.07 to 1.28 per cent of total sales), and by 0.41 percentage points for small firms (from 0.85 to 1.26 per cent of total sales).

As far as relationship lending is concerned, the proxies used in the estimates are significant; the picture they design, however, is somewhat complex.

An increase in the length of the relationship has a statistically detectable positive effect both on the propensity and on the intensity of R&D. This is in line with previous findings (Herrera and Minetti, 2007). The economic effect, however, is much stronger

5 Such improvements are a good approximation also in terms of the original R&D/sales ratio, whose increase have the same magnitude when calculated as:

$$\frac{R\&D}{sales} = \left(e^{\ln\left(1+\frac{R\&D}{sales}\right)} - 1 \right)$$

on the propensity to perform rather than on the amount of the investments undertaken by the firms, for which the magnitude of the marginal effect is very limited. This result is consistent with the hypothesis that a tight credit relationship with the main bank helps assuring external funds to cover the seed and development phase of the innovative process.

On the other hand, less concentrated debt seems common among firms with a higher research propensity, but the credit concentration index is not significant in the intensity estimates. If borrowing from a large number of banks is the reaction to credit rationing, this variable should have affected also the intensity of expenses in R&D. Since it has no effect on total expenses, this result seems to suggest mainly an insurance motivation (Detragiache, Garella and Guiso, 2000). The reasoning goes as follow. A reduction of credit supply by the main bank could have a strong negative impact on a firm deeply engaged in innovative activities and related investments. For these firms, switching costs are prohibitive and a decrease in credit granted may end up in the firm exiting from the market. As a consequence, they will tend to diversify the lending banks, spreading their credit lines among many intermediaries. Since the innovative activity is highly uncertain and risky, the firm may want to be insured against the effect on credit supply of possible delays or negative outcomes of its research projects. Besides, this result is consistent also with the idea that firms have a strategic preference not to disclose information by increasing the number of lending banks (Bhattacharya and Chiesa, 1995; von Rheinbaben and Ruckes, 2004).

The contrasting results obtained for the duration of the relation and for the credit concentration in the estimates of R&D propensity make it difficult to give a comprehensive evaluation of the role of relationship lending. The latter is a multifaceted concept that is hard to catch just by means of one variable; in the literature the strength of relationship is believed to be positively related both to the length of the relation (consistently with our results) and to credit concentration (while we estimate a negative coefficient for this variable). To give a comprehensive answer about the role of relationship lending, we look at the magnitude of the different effects. One standard deviation increase in the length of the relationship improves the probability to perform R&D activity by 3.5 percentage points. At the same time, increasing the Herfindahl index by one standard deviation reduces this probability by 2.8 points; therefore the first effect appears to prevail. In case of smaller firms, however, the two effects tend to offset each other: the two impacts from one standard deviation increase in the two variables are, respectively, -4.6 points for the concentration index, against +4.9 points for the length of the relationship.

On the other hand, when analysing the intensity of R&D investments, the impact of relationship lending clearly turns out even more limited. Herfindahl is positive for the whole sample and negative for SMEs, but it is never significant. The length of the relation has a positive and statistically significant effect. However, its influence is economically very small: one standard deviation increase in this variable raises the expenses by just than 0.04 points (form 1.07 to 1.11 as percentage of total sales); the effect for small firms is 0.06 points (from 0.85 to 0.91).

We try to compare the two types of external finance (access to financial market vs relationship lending). On the whole sample, the probability to carry out R&D investments is 44 per cent and the expenses amount to 1.07 of total sales. For firms that issued public bonds or equity this probability rises to 55.7 per cent and the investment to 1.27 of total sales. Even relationship-based lending stimulates R&D, but its contribution appears to be milder, especially in stimulating the level of investments. Consider that if the length of the bank-firm relation moves from the 1st to the 3rd quartile of the distribution, the probability of R&D rises from 41.6 to 47.3 per cent but the expenses only from 1.04 to 1.12. The difference is even sharper for SMEs (up to 200 employees): for SMEs showing a long-lasting relation with their main bank, the propensity and the intensity of R&D are, respectively, 38.7 per cent and 0.90 of total sales, against 55.3 and 1.24 per cent for SMEs with a direct access to financial markets.

Overall, financial factors appear to be more important for SMEs than for larger firms. These results seem to point to a crucial role of relationship lending in the initial phase, when the firm has to decide whether to invest or not in a risky activity such as R&D, but it is not enough to enhance substantially R&D investments. To this aim, the direct access to financial markets proves to be much more effective.

Finally, as for as other financial variables, the share of bank lending on external finance and that of short-term over total loans have a negative impact, but they are never statistically significant. The differences in the size of the main bank are weak, but they show that a relationship with a large bank (the benchmark) tends to favour R&D activity.

5.2 Firms characteristics and location factors

The estimates confirm the usual correlation between R&D and firm size. Employment (in logs) is always significant and economically relevant in raising both the likelihood to perform and the investment in R&D: increasing the variable by one standard deviation raises the expected probability by 12 percentage points. Similar results are found for export performance. The variable is always significant; considering the marginal effects, an increase in one standard deviation in exports over total sales improves the expected probability to perform R&D by 7.5 percentage points. Firms that undertake R&D tend to be more indebted, but the coefficient is significant only at ten per cent and in the whole sample. The coefficients of *Age* and *Group* are never significant.

As far as the level of the investment is concerned, they show that one standard deviation increase in size (log of employees) improves the expenditure by 0.17 percentage points, i.e. it rises from the estimated average of 1.07 to 1.24 per cent. For the exports, one standard deviation increase raises the R&D expenditure by 0.16 percentage points for the whole sample (form 1.07 to 1.23 per cent), by 0.15 points for SMEs (from 0.85 to 1.00). Estimated results are weaker for the proxy of human capital, with just 0.05 points improvement in R&D intensity following one standard deviation increase in the share of white collars over total employment; the variable is not significant for small and medium-sized firms.

Again, *Age* and *Group* are not significant.

R&D is more frequent and the investment larger in high and medium-tech industries. The estimated propensity is higher by 11 points among *Specialized suppliers* and by 21 points among *Science-based* firms with respect to the benchmark (*Suppliers* *dominated firms*). The expenses increase by 0.50 points for *Specialized suppliers* and by 1.8 points for the *Science-based* firms. The latter is the highest increase in the estimates, which means that total expenses are more than tripled with respect the average, to 2.9 per cent of sales. The effect is smaller for firms up to 200 employees, but still important: the increases are equal to 0.42 and 0.95, respectively for the two sectors. Again, a 0.95 increase means that the expenses are more than doubled in *Science-based* firms against the benchmark.

Location factors seem relatively important to enhance innovative activity run by small firms. When the regressions consider the whole sample, no significant effect on both the propensity to perform and the investment in R&D is detected. However, when the sample is limited to firms with less than 500 employees, the location in large metropolitan areas becomes statistically significant (at 5 per cent) and economically relevant for the research activity. This effect is further reinforced when firms with less than 200 workers are considered: staying in a big city increases the likelihood of R&D by 25 percentage points for firms up to 500 workers and by 39 percentage points for smaller firms (up to 200). The investment is enhanced by 0.5 and 0.9 percentage points. The latter effect is very important, rising the estimated expenses from an average of 0.85 to 1.75 per cent. This finding is in line with previous theory and evidence. Duranton and Puga (2001) have highlighted the role that metropolitan areas play in fostering innovation: diversified urban environments facilitate research and experimentation of new ideas. Fantino, Mori and Scalise (2011) show, for the Italian case, that the distance from top research centres, usually located in the largest cities, is one of the most important factors in fostering the innovativeness of firms, especially of SMEs (in the form of knowledge transfer agreements with universities).

The location inside industrial districts, on the other hand, seems to have a positive effect, but the variable is never statistically significant. This result is confirmed when the variable is split to control for firms specialized in the district sector of activity or in a different sector. [6]

[6] The different propensity to invest in R&D between firms located in the main urban areas and those located in industrial districts could be at the root of the divergence of productivity detected by Di Giacinto *et al.* (2011). The authors, using a very large sample of about 29,000 Italian manufacturing firms

Research is rare in the South (-7.4 points) and investment lower (-0.37 points); in the North-East, its frequency is higher (21 p.p.) than in the North-West (the benchmark), but the difference in the intensity is significant only at 10 per cent significance level.

6. Concluding remarks

Due to severe asymmetric information problems, innovative firms find it difficult to obtain external finance. In this paper we analyse the contribution of external finance to innovation, in particular comparing the role of direct access to financial markets by firms with that of relationship lending.

In a bank-centred economy, like Italian one, the role of banks is pervasive while the financial markets are underdeveloped in comparison to other advanced countries. Using an extremely detailed dataset of about 1,800 Italian manufacturing firms, enriched with data on credit lines granted by every lending bank, we document that R&D-intensive firms tend to have a complex relationship with the banking system: they maintain close relations with their main bank, strengthened by repeated interaction over time, but they also spread their debt among many banks. This peculiar credit relationship might be adopted in order to reduce information asymmetries (thanks to longer duration), while attenuating hold-up problems (via a lower credit concentration).

However, our analysis, while documenting the relevance of relationship-based lending for the financing of R&D activities, shows that the relationship lending is only a *partial* substitute for the direct access to financial markets. In fact, firms issuing public debt and equity tend to invest much more in R&D than firms maintaining strict relations with their lending banks. From a policy perspective, our results suggest that innovation activity in Italy could be stimulated by deepening financial system towards more developed financial markets.

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observed in the last 15 years, find that the local productivity advantages, measured by Total Factor Productivity, have declined over time for industrial districts, while those of urban areas remained stable.

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Tab. A – Definition of variables

Variables	Source: Centrale dei Bilanci / Cerved and Invind
R&D propensity:	dummy equal to one if the firm has invested in R&D in the year of observation or in the previous year
R&D intensity:	log of 1 plus expenditures in R&D on total sales.
Size:	(Log of) total employees.
White collars:	share of non-production workers (white collars) over the total number of workers.
Export:	Share of export over total sales.
Age:	number of years since the firm began operations.
Leverage:	Ratio of financial debts to the sum of financial debts and net equity.
Cash flow	Cash flow as a percentage of Total sales.
Area dummies:	set of dummies related to the geographical location of the firm (in a Metropolitan areas or in an industrial districts).
Sector dummies:	set of dummies related to the activity sector of the firm, according to the Pavitt classification.
Group:	dummy equals to 1 if a firm is part of a business group.
Financial markets:	dummy equals to 1 if a firm is listed in a stock market exchange or has issued bonds.
	Source: Central Credit Register
Herfindahl:	index of credit concentration computed according to the Herfindahl method.
Length:	duration of the relation with the main bank.
Banks loans	Total credit used by the firm towards the banking system as percentage of financial debts
Short term bank loans	Share of short term loans over total loans from the banking system
Bank size:	Set of dummy variables related to the size of the main bank.

Tab. 1 - Composition of the sample and R&D activity

	Composition of the sample	n. obs.	Freq. of R&D > 0	R&D investment over total sales Mean	S. E.	p95
Size (employment)						
< 200	0.69	3,616	0.4378	0.0082	0.0004	0.0416
200 - 500	0.20	1,033	0.5702	0.0095	0.0009	0.0424
> 500	0.12	608	0.6908	0.0227	0.0025	0.0975
Sector (Pavitt)						
Supplier dominated	0.41	2,220	0.4577	0.0054	0.0003	0.0259
Scale intensive	0.30	1,627	0.4106	0.0063	0.0005	0.0311
Specialized suppliers	0.23	1233	0.5929	0.0153	0.0011	0.0726
Science based	0.06	313	0.7157	0.0429	0.0049	0.2303
Export over total sales						
<= 0.33	0.53	2,777	0.4112	0.007	0.0005	0.0333
0.33 - 0.66	0.28	1,475	0.5736	0.0126	0.001	0.0476
> 0.66	0.19	1,005	0.601	0.0151	0.0012	0.0734
Age						
<= 8 years	0.05	274	0.4781	0.0209	0.0037	0.1374
9 - 19 years	0.21	1,106	0.4331	0.0087	0.0007	0.0532
20 - 33 years	0.25	1,347	0.4699	0.0094	0.001	0.0398
34 - 47 years	0.26	1,407	0.4918	0.0096	0.0008	0.0434
48 - 93 years	0.18	995	0.5688	0.0102	0.0008	0.0449
> 93 years	0.05	264	0.5227	0.0111	0.0027	0.0338
Group						
0	0.51	2,767	0.4474	0.0071	0.0004	0.0356
1	0.49	2,626	0.5335	0.0132	0.0008	0.0577
Metropolitan areas						
Outside 0	0.96	5,151	0.4873	0.0099	0.0005	0.0429
Inside 1	0.04	242	0.5331	0.0156	0.0027	0.0786
Industrial districts						
Outside 0	0.66	3,549	0.4618	0.0105	0.0006	0.0482
Inside 1	0.34	1,844	0.5423	0.0095	0.0006	0.0429
Area						
North West 1	0.24	1,274	0.5345	0.0136	0.0013	0.0493
North East 2	0.22	1,161	0.6279	0.012	0.0008	0.0506
Centre 3	0.23	1,225	0.5298	0.0108	0.001	0.0461
South 4	0.32	1,733	0.3347	0.0059	0.0005	0.0308
Total		5,393	0.4893	0.0101	0.0004	0.0454

Tab. 2 – Types of financing and R&D activity

		Composition of the sample	n. obs.	Freq. of R&D > 0	R&D investment over total sales Mean	S. E.	p95
Length							
< 4 years	1	0.19	1,034	0.4458	0.0127	0.0014	0.057
4 – 5 years	2	0.36	1,942	0.4804	0.0096	0.0008	0.0432
6 -7 years	3	0.32	1,738	0.5052	0.0093	0.0006	0.0435
> 7 years	4	0.13	679	0.5405	0.01	0.0009	0.0438
Herfindahl							
< 0.137	1	0.27	1,456	0.5639	0.0085	0.0006	0.0362
0.137- 0.204	2	0.26	1,394	0.5158	0.0087	0.0005	0.042
0.205 -0.330	3	0.24	1,302	0.457	0.0092	0.0008	0.049
>= 0.331	4	0.23	1,241	0.4061	0.0151	0.0016	0.0786
Financial markets (Bonds or Equity)							
	0	0.93	5,021	0.4746	0.0095	0.0004	0.0417
	1	0.07	372	0.6882	0.0191	0.0023	0.0887
Cash flow							
Low	0	0.46	2,475	0.4687	0.0102	0.0008	0.044
High	1	0.54	2,918	0.5069	0.0101	0.0005	0.0465
Bank size							
Very large	1	0.57	3,097	0.4882	0.0104	0.0006	0.0475
Large	2	0.03	167	0.4251	0.0157	0.0036	0.0689
Medium	3	0.21	1,125	0.5324	0.0105	0.0009	0.0476
Small	4	0.14	747	0.4659	0.0084	0.001	0.0366
Very small	5	0.05	257	0.4241	0.007	0.0011	0.038
Total			**5,393**	**0.4893**	**0.0101**	**0.0004**	**0.0454**

Tab. 3 – Sample statistics

variables	mean	Se (mean)	p50	sd	iqr	min	max	p5	p95	Q1	Q3
total sample											
drd	.4946146	.0072666	0	.5000238	1	0	1	0	1	0	1
Rdsales	.0095527	.0004173	0	.0277764	.0081081	0	.6153846	0	.0447856	0	.0081081
Lnrdsales	.0091747	.0003759	0	.025024	.0080754	0	.4795731	0	.0438117	0	.0080754
Log Empl. (t-1)	5.026719	.0135484	4.795791	.9322862	1.153363	3.044523	10.07065	3.951244	6.889591	4.343805	5.497168
White collars (t-1)	.3244691	.0025963	.33	.1786541	.1701275	0	1	.0833333	.6970803	.2076503	.3777778
Share exports (t-1)	.3348665	.00427	.276699	.2938274	.5316766	0	1.10386	0	.858569	.04329	.5749666
Group	.4836325	.0072631	0	.4997848	1	0	1	0	1	0	1
Age	37.54403	.3910335	33	26.90754	27	1	270	9	93	19	46
Metrop. areas	.0443506	.0029922	0	.2058945	0	0	1	0	0	0	0
Districts	.3463569	.0069154	0	.4758588	1	0	1	0	1	0	1
Leverage (t-1)	.3287757	.0023452	.3372028	.1613774	.2415546	.0000238	.8545882	.054921	.5832419	.2055282	.4470828
Cash flow (t-1)	.0641342	.0017446	.0656137	.1200469	.0725076	-3.61824	1.194742	-.0639735	.19123	.0320118	.1045194
Finan. markets.	.067793	.0036537	0	.251417	0	0	1	0	1	0	0
Herfindahl (t-1)	.2417974	.0027695	.1800265	.190576	.1533235	0	1	.0790528	.6433409	.1254638	.2787873
Length (t-1)	4.281098	.0269884	4	1.857108	3	0	7	1	7	3	6
Bank debt (t-1)	.2900737	.0038408	.2154605	.2642908	.2745869	1.31e-08	2.500748	.0116898	.8347483	.1127419	.3873288
Short-term debt (t-1)	.8008051	.0023739	.825369	.1633484	.2301764	.1577883	1	.484537	1	.704423	.9345994
up to 500 employees											
drd	.4745223	.0078167	0	.4994116	1	0	1	0	1	0	1
Rdsales	.008575	.0004029	0	.0252299	.0068864	0	.6153846	0	.0424242	0	.0068864
Lnrdsales	.0082632	.0003637	0	.0227717	.0068628	0	.4795731	0	.041549	0	.0068628
Log Empl. (t-1)	4.781764	.0095802	4.672829	.6120822	.940649	3.044523	7.044905	3.931826	5.948035	4.29046	5.231109
White collars (t-1)	.3176388	.0027229	.33	.1739706	.1623956	0	1	.0810811	.6798246	.2040816	.3664773
Share exports (t-1)	.3181293	.0045505	.2517867	.2907313	.5166667	0	1	0	.8500131	.0333333	.55
Group	.4429201	.0077757	0	.4967921	1	0	1	0	1	0	1
Age	36.21828	.4168687	30	26.63396	27	1	270	8	87	18	45
Metrop. areas	.0406663	.0030919	0	.1975402	0	0	1	0	0	0	0
Districts	.3576678	.007503	0	.4793723	1	0	1	0	1	0	1
Leverage (t-1)	.3359281	.0025012	.3447342	.1598008	.2347838	.0000238	.8439906	.063831	.5872487	.2183043	.453088
Cash flow (t-1)	.0632888	.0019326	.0646774	.1234743	.0722353	-3.61824	1.194742	-.0579839	.1891939	.0311484	.1033838
Finan. markets.	.0526703	.0034966	0	.2234017	0	0	1	0	1	0	0
Herfindahl (t-1)	.2402277	.0028889	.1820967	.1845709	.1475264	0	1	.0839979	.6088891	.1278797	.2754061
Length (t-1)	4.265556	.0290499	4	1.856011	3	0	7	1	7	3	6
Bank debt (t-1)	.2996409	.0040428	.2295122	.2582974	.2765782	8.13e-08	2.301956	.0225762	.8433052	.1217097	.3982878
Short-term debt (t-1)	.7991969	.0025485	.8238345	.1628244	.2285516	.1577883	1	.4861913	1	.7033659	.9319175
up to 200											
drd	.4434347	.0087958	0	.4968679	1	0	1	0	1	0	1
Rdsales	.0083201	.0004282	0	.0236949	.0060541	0	.4079383	0	.0424634	0	.0060541
Lnrdsales	.008035	.0003954	0	.0218814	.0060358	0	.3421264	0	.0415866	0	.0060358
Log Empl. (t-1)	4.529552	.0071922	4.510859	.4062772	.6315889	3.044523	5.771441	3.931826	5.225747	4.204693	4.836282
White collars (t-1)	.3116758	.0030671	.3278688	.1732593	.1679198	0	1	.0769231	.6595744	.1929825	.3609022
Share exports (t-1)	.2920394	.0051123	.2027088	.288786	.4857355	0	1	0	.85	.0182015	.503937
Group	.3594484	.0084957	0	.479914	1	0	1	0	1	0	1
Age	35.10874	.4609495	29	26.03855	26	1	187	8	83	18	44
Metrop. areas	.0376058	.0033683	0	.1902706	0	0	1	0	0	0	0
Districts	.339392	.0083835	0	.4735772	1	0	1	0	1	0	1
Leverage (t-1)	.338844	.0028398	.3446953	.1604194	.2381618	.00006	.8439906	.0673024	.5910965	.2199279	.4580897
Cash flow (t-1)	.060561	.0023373	.0636545	.132032	.0702713	-3.61824	1.194742	-.0630688	.1885874	.0304638	.1007351
Finan. markets.	.0448135	.0036631	0	.2069268	0	0	1	0	0	0	0
Herfindahl (t-1)	.2486404	.0032096	.1917121	.181308	.1540121	0	1	.089697	.6074983	.1354591	.2894711
Length (t-1)	4.24193	.0327909	4	1.852325	3	0	7	1	7	3	6
Bank debt (t-1)	.3170162	.0046843	.2466004	.26461	.2899028	1.65e-06	2.301956	.0298554	.8649571	.1319981	.4219009
Short-term debt (t-1)	.8002239	.0029022	.8263198	.1639395	.2319855	.1577883	1	.4820717	1	.7026704	.9346559

Tab. 4 – Correlations

	drd	Rd sales	Ln rdsales	Log Empl. (t-1)	White collars (t-1)	Share exports (t-1)	Group	Age	Metrop. areas	Districts	Leverage (t-1)	Cash flow (t-1)	Finan. markets.	Herfindahl (t-1)	Length (t-1)	Bank debt (t-1)
drd	1.000															
Rdsales	0.322	1.000														
Lnrdsales	0.344	0.998	1.000													
Log Empl. (t-1)	0.211	0.155	0.159	1.000												
White collars (t-1)	0.075	0.191	0.196	0.121	1.000											
Share of exports (t-1)	0.203	0.128	0.136	0.181	-0.040	1.000										
Group	0.097	0.099	0.101	0.435	0.154	0.149	1.000									
Age	0.071	-0.006	-0.006	0.189	0.071	0.071	0.052	1.000								
Metrop. Areas	0.022	0.039	0.041	0.221	0.106	-0.016	0.086	0.058	1.000							
Districts	0.081	-0.013	-0.010	0.006	-0.034	0.165	-0.006	0.041	-0.152	1.000						
Leverage (t-1)	0.043	-0.004	-0.004	-0.068	-0.020	0.008	-0.017	0.011	-0.010	0.044	1.000					
Cash flow (t-1)	-0.007	0.013	0.015	0.002	0.001	-0.001	0.020	-0.002	0.013	0.006	-0.026	1.000				
Finan. Markets.	0.110	0.069	0.074	0.219	0.059	0.068	0.166	0.078	0.034	0.010	-0.004	0.015	1.000			
Herfindahl (t-1)	-0.106	0.088	0.085	-0.100	-0.009	-0.117	-0.069	-0.079	0.026	-0.139	-0.231	-0.044	-0.052	1.000		
Length (t-1)	0.049	-0.024	-0.021	-0.028	0.065	0.005	0.120	0.027	-0.008	0.025	0.043	-0.008	0.090	-0.067	1.000	
Bank debt (t-1)	-0.092	-0.031	-0.031	-0.221	-0.047	-0.063	-0.141	-0.046	-0.061	-0.021	-0.357	-0.012	-0.063	0.392	-0.026	1.000
Short-term debt (t-1)	-0.0407	-0.0179	-0.0173	-0.097	-0.0087	0.0025	-0.0333	-0.064	0.008	0.009	-0.034	-0.027	-0.045	-0.025	-0.019	-0.151

Tab. 5 - Propensity to perform R&D activity (dependent variable: R&D (1/0))

(Marginal effects at the average of the variables and standard errors in parenthesis)

R&D (1/0)	simple probit	Probit random effects		
	whole sample	whole sample	up to 500 emp.	up to 200 emp.
	[1]	[2]	[3]	[4] .
Employment (log) (t-1)	0.0677***	0.1293***	0.1176***	0.1058**
	(0.009)	(0.026)	(0.037)	(0.053)
White collars (t-1)	-0.0098	-0.1148	-0.1183	-0.0301
	(0.043)	(0.089)	(0.094)	(0.099)
Export (share of total sales) (t-1)	0.1802***	0.2568***	0.2400***	0.2088***
	(0.026)	(0.070)	(0.072)	(0.078)
Age	0.0001	0.0007	0.0008	0.0013
	(0.000)	(0.001)	(0.001)	(0.001)
Group (1/0) (d)	-0.0306*	-0.0341	-0.0510	-0.0539
	(0.016)	(0.038)	(0.039)	(0.042)
Metropolitan areas (1/0) (d)	0.0866**	0.1500	0.2481**	0.3869***
	(0.035)	(0.096)	(0.102)	(0.114)
Industrial districts (1/0) (d)	0.0267*	0.0462	0.0727	0.0626
	(0.016)	(0.048)	(0.050)	(0.055)
Leverage (t-1)	0.0821*	0.1953*	0.1562	0.0509
	(0.049)	(0.113)	(0.117)	(0.128)
Cash flow (t-1)	0.0649	0.1174	0.1277	0.1462
	(0.047)	(0.096)	(0.100)	(0.106)
Financial markets (1/0) (d)	0.1247***	0.1247*	0.1211*	0.2198**
	(0.028)	(0.064)	(0.073)	(0.102)
Herfindahl (t-1)	-0.1296***	-0.1515*	-0.2081**	-0.2560**
	(0.039)	(0.091)	(0.097)	(0.112)
Length (t-1)	0.0089**	0.0189***	0.0236***	0.0266***
	(0.004)	(0.007)	(0.007)	(0.007)
Bank debt (share of total financing) (t-1)	-0.0290	-0.0212	-0.0362	0.0116
	(0.029)	(0.058)	(0.062)	(0.065)
Short term bank debt (share of total bank debt) (t-1)	-0.0533***	-0.0197	-0.0410	-0.0139
	(0.020)	(0.038)	(0.040)	(0.044)
Pavitt - Scale intensive (d)	-0.0284	-0.0789	-0.0862*	-0.0884*
	(0.017)	(0.050)	(0.050)	(0.053)
Pavitt -Specialised suppliers (d)	0.1147***	0.2384***	0.2031***	0.1542**
	(0.019)	(0.054)	(0.057)	(0.064)
Pavitt -Science based (d)	0.2093***	0.3674***	0.2998***	0.3263***
	(0.031)	(0.072)	(0.096)	(0.116)
North-East	0.1194***	0.2109***	0.1905***	0.2084***
	(0.021)	(0.061)	(0.067)	(0.080)
Centre	0.0487**	0.0313	0.0342	0.0906
	(0.021)	(0.063)	(0.065)	(0.075)
South	-0.0739***	-0.2435***	-0.2083***	-0.1638**
	(0.022)	(0.059)	(0.061)	(0.068)
Bank size - large	-0.1205***	-0.2185***	-0.2629***	-0.2726***
	(0.040)	(0.061)	(0.051)	(0.042)
Bank size - medium	0.0054	-0.0447	-0.0570	-0.0340
	(0.018)	(0.035)	(0.036)	(0.039)
Bank size - small	-0.0255	-0.0556	-0.0604	-0.0647
	(0.021)	(0.040)	(0.040)	(0.041)
Bank size - very small	-0.0562*	-0.1148*	-0.1046*	-0.1276**
	(0.033)	(0.061)	(0.062)	(0.060)
N obs. (N. of groups)	5399	5399 (1814)	4649 (1597)	3616 (1270)
Rho (ρ = variance due to panel over total variance)	---	0.7611	0.7513	0.75234
Chi2 (prob.)	637.93 (0.000)	237.57 (0.00)	186.85 (0.00)	145.93 (0.00)
LR test for poolability ($\rho=0$) chi2 (prob.)		1331.68 (0.00)	1123.10 (.00)	865.4 (0.00)
Hausman xtprobit vs. probit (prob.) whole sample (H_0: diff. in coeff. not systematic)	67.93 (0.0000)		---	---
Estimated probability	0.48945	0.43964	0.3957	0.3388
LL	-3422.11	-2756.27	-2427.81	-1881.42
BIC	7059.1	5736.0	5075.2	3975.9
AIC	6894.2	5564.5	4907.6	3814.8

In the estimates, the constant is also included. The benchmark for regional areas is 'North-West', for sector is 'Supplier dominated', for bank size is 'very large' banks. (d) for discrete change of dummy variable from 0 to 1. * p<0.10, ** p<0.05, *** p<0.01

Tab. 6 – Intensity of R&D activity (dependent variable: ln(1+R&D/sales))

(Marginal effects on the latent variable y conditional on being observed and standard errors in parenthesis)*

	[1]	[2]	[3]
	Tobit estimates with random effects		
	Whole sample	Up to 500 emp.	Up to 200 emp.
Employment (log) (t-1)	0.00182***	0.00112**	0.00129
	(0.000)	(0.001)	(0.001)
White collars (t-1)	0.00280*	0.00157	0.00210
	(0.002)	(0.002)	(0.002)
Export (share of total sales) (t-1)	0.00538***	0.00503***	0.00529***
	(0.001)	(0.001)	(0.001)
Age	-0.00001	-0.00001	-0.00000
	(0.000)	(0.000)	(0.000)
Group (1/0) (d)	-0.00010	-0.00019	-0.00020
	(0.001)	(0.001)	(0.001)
Metropolitan areas (1/0) (d)	0.00228	0.00506**	0.00896***
	(0.002)	(0.002)	(0.003)
Industrial districts (1/0) (d)	0.00056	0.00086	0.00117
	(0.001)	(0.001)	(0.001)
Leverage (t-1)	0.00599***	0.00470**	0.00325
	(0.002)	(0.002)	(0.002)
Cash flow (t-1)	0.00181	0.00355**	0.00461***
	(0.001)	(0.002)	(0.001)
Financial markets (1/0) (d)	0.00207*	0.00335***	0.00406***
	(0.001)	(0.001)	(0.002)
Herfindahl (t-1)	0.00242	0.00010	-0.00004
	(0.002)	(0.002)	(0.002)
Length (t-1)	0.00025**	0.00027**	0.00030**
	(0.000)	(0.000)	(0.000)
Bank debt (share of total financing at t-1)	0.00017	0.00012	0.00106
	(0.001)	(0.001)	(0.001)
Short term bank debt (share of total bank debt at t-1)	-0.00043	-0.00004	0.00036
	(0.001)	(0.001)	(0.001)
Pavitt - Scale intensive (d)	-0.00057	-0.00074	-0.00070
	(0.001)	(0.001)	(0.001)
Pavitt -Specialised suppliers (d)	0.00517***	0.00451***	0.00415***
	(0.001)	(0.001)	(0.001)
Pavitt -Science based (d)	0.01794***	0.01165***	0.00947***
	(0.003)	(0.003)	(0.003)
North-East	0.00188*	0.00200*	0.00235*
	(0.001)	(0.001)	(0.001)
Centre	-0.00007	0.00044	0.00055
	(0.001)	(0.001)	(0.001)
South	-0.00371***	-0.00262***	-0.00188*
	(0.001)	(0.001)	(0.001)
Bank size - large	-0.00197*	-0.00398***	-0.00503***
	(0.001)	(0.001)	(0.001)
Bank size - medium	-0.00039	-0.00079	-0.00059
	(0.001)	(0.001)	(0.001)
Bank size - small	-0.00100	-0.00124**	-0.00122*
	(.)	(0.001)	(0.001)
Bank size - very small	-0.00078	-0.00070	-0.00081
	(0.001)	(0.001)	(0.001)
N obs. (N. of groups)	5036 (1781)	4453 (1578)	3456 (1254)
Rho (variance due to panel over total variance)	0.6394	0.5910	0.6440
LR test for poolability (*ρ=0)* chi2 (prob.)	1533.02 (0.00)	1046.18 (0.00)	947.88 (0.00)
Chi2 (prob)	309.13 (0.00)	222.50 (0.00)	184.13 (0.00)
Estimated expenditure (conditional y*>0)	0.010727	0.009123	0.008508
LL	3726.2974	3141.6164	2294.6607
BIC	-7222.4	-6056.4	-4369.3
AIC	-7398.6	-6229.2	-4535.3

In the estimates, the constant is also included. The benchmark for regional areas is 'North-West', for sector is 'Supplier dominated', for bank size is 'very large' banks. (d) for discrete change of dummy variable from 0 to 1. * p<0.10, ** p<0.05, *** p<0.01