Knowledge for Growth – Industrial Research & Innovation (IRI)

R&D, Innovation and Liquidity Constraints

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Contributed paper for the 2nd Conference on corporate R&D (CONCORD - 2010)

CORPORATE R&D: AN ENGINE FOR GROWTH, A CHALLENGE FOR EUROPEAN POLICY

<CONFERENCE STRAND III>

File name: <Mancusi-vezzulli_concord2010>
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Status: <Draft>
Last updated: <December 13, 2009>
Organisation: <Department of Economics and KITeS-Cespri, Bocconi University, Milano>

Abstract

We study the effect of financing constraints on the decision to do R&D and on the level of R&D investment using survey data and complete financial accounting data on a large number of Italian manufacturing firms from 2001 to 2003.
We use a direct indicator of credit constraints and employ an econometric approach allowing for the existence of binding financing constraints to be endogenously determined. We find that there is a significantly negative effect on the probability to set up R&D activities due to the presence of financing constraints, ceteris paribus. We also find that ignoring the endogeneity of the financing constraints indicator and the sample selection originating from firms not interested in doing R&D induces a bias in the estimated effect, which turns out to be positive and significant. We find the same result when studying the effect of liquidity constraints on R&D spending and are able to show that its reduction due to liquidity constraints is largely to be associated with the reduction in the likelihood to do R&D (the R&D participation decision), rather than with a reduced level of investment.

Key words: R&D, financing constraints, bivariate probit, IV Tobit

JEL classification: G32, C35, O31

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1 - Introduction

The effects of financing constraints on R&D investment is a topic that has been widely studied in the economics literature, but for which there is still scope for empirical research because of the difficulties in matching available data with appropriate econometric instruments. Such difficulty has generated a wide variety of results: some contributions have found that R&D investment is not sensitive to financing constraints (Bond et al., 2003), while others have found that it is, but not significantly more than ordinary investment (Mulkay et al., 2001). A few recent contributions have claimed that the above ambiguity might be resolved if it is recognised that financing constraints might affect the (first step) decision to finance R&D activities rather than the (second step) decision of how much to invest in R&D. We follow this line of research and study the effect of financing constraints on the decision to do R&D and on the level of R&D investment using the fifth wave (2001-2003) of the Capitalia survey on a large number of Italian firms, focusing on SMEs, i.e. firms with up to 250 employees. This is justified on grounds that SMEs account for a large share of enterprises in most countries and because they have been found to have less access to external finance and to be more constrained in their operations (Beck and Demirguc-Kunt, 2006).

We employ a direct indicator of financing constraints, based on firm's desire for additional financing. While this indicator may be viewed as subjective, we compare it with the distribution of the Whited and Wu (2006) index of credit constraints, which is based on balance sheet data and proxies the shadow value of external funds, and find the two indexes are consistent. Indeed, we find that for constrained firms, as identified by our direct indicator, the distribution of the Whited and Wu index is shifted to the right with respect to unconstrained firms, the difference being more pronounced for R&D performing firms.

We then study whether financing constraints reduce firms' incentives to undertake R&D investment. We estimate the impact of financing constraints on the probability to do R&D allowing financing constraints to be endogenously determined and controlling for sample selection. Sample selection bias is well known to affect direct measures of liquidity constraints (Savignac, 2008; Hajivassiliou and Savignac, 2008). This is due to firms not perceiving themselves as being subject to liquidity constraints because they do not wish to undertake any R&D investment. To control for this, we focus on potentially innovative firms, by excluding firms with no current R&D investment, which both do not declare themselves to be subject to liquidity constrained and which have not introduced any innovation in the recent past.

We find that there is a significantly negative effect on the probability to set up R&D activities due to the presence of financing constraints, ceteris paribus. We also find that ignoring the endogeneity of the financing constraints indicator and the sample selection due to unconstrained firms not interested in engaging in R&D activities induces an upward bias in the estimated effect, which turns out not to be significant.

We find that controlling for endogeneity is also important when studying the effect of liquidity constraints on R&D spending and we are able to show that the percentage reduction in R&D investment as a consequence of the firm facing liquidity constraints is largely to be associated with the reduction in the likelihood to do R&D (the R&D participation decision), rather than with a reduced level of investment.

The paper is organized as follows. Section 2 reviews the main economic issues and empirical contributions on financing constraints and R&D investment. Section 3 describes the data and survey information used in the empirical analysis. Section 4 briefly describes the empirical model. Section 5 reports and comments the estimation results. Section 6 concludes.

2 - R&D Investment and financing constraints

From the mid-sixties to the mid-eighties most applied research isolated real firm decisions from purely financial factors. The theoretical justification for this approach resided in the seminal work by Franco Modigliani and Merton Miller (1958) and in the neoclassical theory of investment, according to which the firm faces a user cost of capital that does not depend on its financial structure, hence its choice of the optimal capital stock can be obtained with no reference to financial factors[1]. Given the absence of any influence of financial factors, much of the empirical research worked under the assumption of a representative firm and was devoted to test the relative success of various investment demand models.

[1] The q-theory approach, pioneered by James Tobin (1969) and extended by Fumio Hayashi (1982) offers another formulation of the neoclassical model, where the ratio of the market value of the firm's capital stock (which summarizes investment opportunities) to its replacement cost is the key determinant of investment demand under certain assumptions.

Over the past two decades, a number of studies have extended conventional models of business fixed investment to explicitly incorporate and account for the influence of financing constraints. Theoretical models, departing from the conventional representative firm assumption, have provided foundations for the imperfect substitutability between external and internal funds and have thus justified the influence of financial factors on firm's investment decisions. These models have illustrated the effects of informational asymmetries on investment in a moral hazard or adverse selection setting, where costs arising from private information on project risk or quality induce a substantial difference between the cost of new debt and equity and the opportunity cost of internal finance generated through cash flow and retained earnings. Hence information costs and the internal resources of a firm influence the shadow cost of external funds for fixed investment, holding underlying investment opportunities constant[2].

Recent studies have argued that R&D investment might expected to be even more sensitive to financial factors than other types of investment[3]. This is because outsiders may find it more difficult to make accurate appraisals of the value and risk of investment in intangible assets and in innovation-based physical investment. In addition, even if firms could costlessly transmit information to outsiders, strategic considerations may induce them to actively maintain information asymmetries, so to avoid the leaking of information to rivals which would reduce the prospective value of innovation. Furthermore, it has also been noted that adverse incentive and selection problems are compounded by the absence of collateral value for investments like R&D[4].

Although plausible, not much evidence has been found on the higher sensibility of R&D investment to liquidity constraints (e.g. low retained earnings) than ordinary investment. This might be the consequence of two key features of R&D investment: (i) establishing an R&D program involves significant sunk costs and (ii) large fluctuation in the level of spending in existing research programs are very costly, as a consequence of the expenditures in R&D being predominantly payments to highly trained scientists, engineers and other specialists. These workers are not perfectly elastic in supply: firing and hiring them in accordance with temporary changes in business conditions would be extremely costly because they require a great deal of firm-specific knowledge, and training new

[2] Together with asymmetric information, another source of investment sensitiveness to the source of financing, and hence to the capital structure of the firm, relies in the tax system.
[3] See Hall, 2002, for a review.
[4] See, for example, Himmelberg and Petersen, 1994, note 2 on page 38.

workers is expensive, and because fired specialists are able to transmit valuable knowledge to competitors who hire them.

The existence of high adjustment costs for R&D might then imply that firms set the level of R&D investment in accordance with the "permanent" level of internal finance, so to minimize both the current and future adjustment costs. Thus R&D should be relatively unresponsive to transitory movements in internal funds. Financial constraints should then affect the decision to set up R&D facilities (*the R&D participation decision*), rather than the decision about yearly level of spending in existing research programs (*the level of R&D spending decision*)[5].

The prevailing methodology in the empirical literature on financing constraints and investment has focused on the estimation of a standard investment equation using either a neoclassical accelerator model or the Euler equation approach. A variable for the availability of internal finance is then added to the model (usually cash flow) and its significance (and correct sign) should signal the relevance of financing constraint in the firm's investment decisions.

Himmelberg and Petersen (1994) estimate the relationship between R&D investment, physical capital and internal finance on a sample of 179 US small firms in high-tech industries. The results indicate that internal finance is an important determinant of R&D expenditures.

Harhoff (1998) uses German data and estimates a structural Euler equation and two non structural accelerator and error-correction specifications for a panel of 236 large manufacturing German firms over the period 1990-1994. The results show important sensitivity of R&D to cash flow for the accelerator and error-correction equations, though significant results are found for small firms only for the latter specification. No conclusion for R&D can be drawn from the Euler equation model.

Bond, Harhoff and Van Reenen (2003) try to identify whether differences exist in the impact of financial variables on R&D between German and British firms, using two panels of 263 British and 246 German high-tech firms over the period 1985-1994. Their empirical findings indicate that financial constraints are significant in the UK economy while no effect is found for German firms which can be explained by the institutional differences across the financial systems in the two countries.

[5] See Bond et al (2003).

Using a sample of Belgian firms over the period 1991-2000, Cincera (2002) finds a positive impact of cash flow in the firms' investment decisions, although these effects appear to play a considerably more important role for investment in physical capital than for R&D investments. Furthermore, firms that perform R&D on a permanent basis and that receive public funds, large firms, firms listed on the stock market, subsidiaries of foreign MNE's are all found to be less subject to liquidity constraints. Conversely younger and to some extent older firms appear to be more liquidity constrained. Finally the impacts of these constraints are rather differentiated according to the firm's industry sector and region.

A major problem with using cash flow as a proxy for liquidity constraints is that the interpretation of cash flow is ambiguous because it contains information about expected future profitability, which may be relevant for investment decisions even with perfect capital markets[6]. Recent econometric exercises have then relied on finding differential sensitivity to cash flow between sub-samples of firms that are thought of being differentially affected by financing constraints a priori[7], and/or on structural econometric models which control for the influence of expected profitability under restrictive assumptions. The main problem with this methodology is that the allocation of firms to "constrained" and "unconstrained" regimes is often based on outcomes which are at least partially chosen endogenously by firms (e.g. dividend payments, employment size, ...). Second, Kaplan and Zingales (1997 and 2000) have argued that sensitivity of investment to cash flow does not necessarily signal financing constraints.

Some recent contributions have overcome the above problem by using a direct indicator of financing constraints, thanks to the availability of new data. Savignac (2008) and Hajivassiliou and Savignac (2008) analyze the existence and impact of financing constraints as a possibly serious obstacle to innovation by firms employing three direct measures of financing constraints from survey data collected by the Banque de France and the European Commission: (i) unavailability of new financing; (ii) searching and waiting for new financing; (iii) too high costs of new financing. Savignac (2008) accounts for the endogeneity of the financing constraints variable and finds that it significantly reduces the likelihood that firms have innovative activities. Hajivassiliou and Savignac (2008) further account for mutual endogeneity of the direct indicator of financing constraints and innovation decisions by firms and find that binding financing constraints

[6] For an example, see Bond et al. (2003), pp. 15-16.

[7] The two groups are usually obtained using a priori information on the relevance of financing constraints according to some characteristics.

discourage innovation and that innovative firms are more likely to face binding financing constraints.

Tiwari et al. (2007) use data from the fourth Dutch Community Innovation Survey and present evidence that, controlling for traditional factors as size, market share, cooperative arrangement, and expected profitability, financial constraints affect a firm's decision of how much to invest in R&D activities. The authors construct the financing constraints indicator as a binary variable that takes value 1 if the firm answers that, because of financial problems, some of its projects are (a) seriously delayed, (b) prematurely stopped or (c) did not start. Finally, Aghion et al. (2007) use a French firm-level data set and find that the share of R&D investment over total investment is countercyclical without credit constraints, but it becomes less countercyclical as firms face tighter credit constraints. Their direct indicator of credit restrictions is based on payment incidents (non-payments of trade credits).

3 - Data

Our data come from the Capitalia survey on Italian manufacturing firms undertaken in 2004 and covering the period 2001-2003[8]. The sample of the survey is stratified according to industry and geographical location for firms with 11 to 500 employees, while it includes all Italian firms with more than 500 employees. Here we will focus only on small and medium enterprises, i.e. firms with less than 250 employees.

The focus on SMEs is not so much justified on grounds of their role for economic growth (Beck et al, 2005), but rather because they account for a large share of enterprises in most countries and because they are more likely to be financially constrained. Indeed, SMEs constitute over 60% of total employment in manufacturing in many countries and even more in Italy, where their share of total employment is 80% (Ayyagari et al, 2007). Furthermore, theory predicts that with fixed transaction costs and information asymmetries, SMEs will face higher costs of financing because they typically demand for smaller loans, thus facing higher relative transaction costs, they are less transparent and have less collateral to offer. Confirming the above prediction, both in developing and developed economies, SMEs have been found to have less access to external finance and to be more constrained in their operations, with financing obstacles having on them almost twice the effect on annual growth that large firms' financing obstacles do (Beck and Demirguc-Kunt, 2006).

The survey data is coupled with complete financial accounting data from AIDA[9] for each fiscal year from 2001 to 2003. Balance sheet data are not available for all the firms in the survey, hence our final sample of 2,144 SMEs[10] is smaller than the manufacturing sample of 2,991 SMEs firms included in the original Capitalia survey. Reducing the sample does not significantly alter the firms' distribution by size classes, industry and geographical location, as shown in Tables 1 to 3.

Table 1 – Firms' distribution by size classes

	Survey manufacturing sample		**Final sample**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
11-20	816	27.28	569	26.54
21-50	1,057	35.34	775	36.15
51-250	1,118	37.38	800	37.31
Total	2,991	100.00	2,144	100.00

Table 2 - Firms' distribution by industry

	Survey manufacturing sample		**Final sample**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Food/Tobacco	334	11.17	246	11.47
Textiles	462	15.45	359	16.74
Wood/Paper/Print	259	8.66	188	8.77
Chemicals/Coke	156	5.22	113	5.27
Plastic/Rubber	160	5.35	97	4.52
Glass/Ceramics	181	6.05	138	6.44
Metals	565	18.89	381	17.77
Machinery	392	13.11	276	12.87
Electrical/Medicals	214	7.15	140	6.53
Veichles	59	1.97	42	1.96
Furnitures	209	6.99	164	7.65
Total	2,991	100	2144	100

Table 2 - Firms' distribution by geographical area

	Survey manufacturing sample	**Final sample**

[8] The Capitalia survey sample includes 4114 firms from the manufacturing, agriculture and service sectors.

[9] These data come from the specialized information provider Honyvem BilancItalia, which purchases and revises all balance sheets stored by the Italian Chambers of Commerce.

[10] These also exclude a few firms with unreliable balance sheet information, a few outliers and firms with missing values for the relevant variables of interest.

	Frequency	Percentage	Frequency	Percentage
North-West	1,072	35.84	728	33.96
North-Est	930	31.09	690	32.18
Centre	547	18.29	408	19.03
South	440	14.71	318	14.83
No response	2	0.07	-	-
Total	2,991	100	2,144	100

In the section on bank-customer relationships and investment financing decisions, the survey includes a question that allows us to directly identify the existence of financing constraints. The question refers to 2003 – i.e. the last year covered by the survey – and asks the respondent to indicate whether the firm desired additional bank financing at the interest rate agreed with the main partner bank (Constrained = 1). This indicator has been recently used by Angelini and Generale (2008) to study the effect of financing constraints on firm's growth and provides a direct measure of financing constraints given by the firms themselves.

Note that, while our indicator does not account for sources of external finance other than bank financing, we claim this does not significantly limit the scope of our analysis with reference to our sample. First of all, based on the result from a survey conducted on over 10,000 firms in more than 80 countries, Beck and Demirguc-Kunt (2006) find that the gap in bank financing of investment for small and medium firms vs. large firms is negative, significant and large, while the difference is much smaller or not significant in other formal sources of financing (equity, lease, supplier credit, development finance). Second, and most importantly, it should be noted that the financial system in Italy is strongly centred around banks, with other sources of firm financing being much less developed[11]. As a consequence, Italian firms heavily rely on bank financing, as recently shown by Beck et al. (2008). Using survey data from 48 countries and comparing financing patterns across them, the authors find that Italy is the country with the highest proportion of investment financed by banks, having a share of 49.67, that accounts for 64% of external finance[12].

Finally, each firm participating to the survey is asked whether it has pursued any R&D investment in each of the three years covered by the survey. Table 4 reports frequencies

[11] In Italy, bank debts account for about 75% of financial debts and while differences in the financial structures of firms located in other EU countries are not significant, those with the US are still large, especially for what concerns the bond market.

[12] As a comparison, note that the corresponding figure for the US is 21.47 and accounts for about 45% of external financing.

of firms with R&D investment in 2003 for both the constrained and unconstrained groups and interestingly shows that the relative share of R&D active firms is not significantly different in the two groups. Once again, the table also shows that the reduction in the sample due to balance sheet data availability does not alter the picture.

Table 4 - Firms' distribution by financial constraint and innovative status
(row percentage in parenthesis)

		R&D=No	R&D=Yes	Total
Survey Manufacturing Sample	**Constrained=No**	1,537 (65.21)	820 (34.79)	2,357 (100)
	Constrained=Yes	267 (64.49)	147 (35.51)	414 (100)
	Total	1,804 (65.10)	967 (34.90)	2,771 (100)
Final Sample	**Constrained=No**	1,212 (65.94)	626 (34.06)	1,838 (100)
	Constrained=Yes	197 (64.38)	109 (35.62)	306 (100)
	Total	1,409 (65.72)	735 (34.28)	2,144 (100)

Each firm declaring active involvement in R&D is then asked to report yearly figures for R&D investment. As our direct indicator of liquidity constraints refers to 2003 our focus will be on R&D expenditures in 2003 and all financial variables used in the analysis will be predetermined and evaluated at 2002[13].

4 - Direct measurement of financing constraints

Our self reporting indicator of liquidity constraints is based on the firm's perception, which may be affected both by the firm's financial status and by market opportunities. We therefore try first to verify the quality of our index, by comparing it with an objective measure obtained from firms' accounting data. Although such objective measures are

[13] In order to check for consistency and to fill some missing values of the R&D expenditures figures in the Capitalia Survey we used additional information from another survey released yearly by the Italian Institute of Statistics (ISTAT) called "Ricerca e Sviluppo intra-muros (R&S) in Italia". This allowed us to replace 130 missing values in the original Capitalia R&D data.

themselves problematic as indicators of the firm's status (constrained vs. unconstrained), we would still expect the two different kind of measures (direct and subjective vs. indirect and objective) to show some degree of consistency.

Several indirect measures of liquidity constraints have been proposed in the literature: two very popular indexes are the ones proposed by Kaplan and Zingales (1997) and Whited and Wu (2006).

The Kaplan and Zingales index (KZ) was originally computed using a sample of 49 firms and regressing an *ex-ante* rating of the firm's financial constraint status (ranging on a four points scale) on a set of observable firm's characteristics: Tobin's Q and other financial ratios like cash flow to total assets, total debts to total assets, total dividends to total assets and liquid to total assets.

The Whited and Wu index (WW) of financial constraints was computed by estimating a set of Euler's first order condition equations which solve a model for the dynamic maximization of the firm's expected present discounted value of future dividends. The final equation estimated by the authors (the dependent variable represents the relative shadow cost of raising new equity by external finance) is the following:

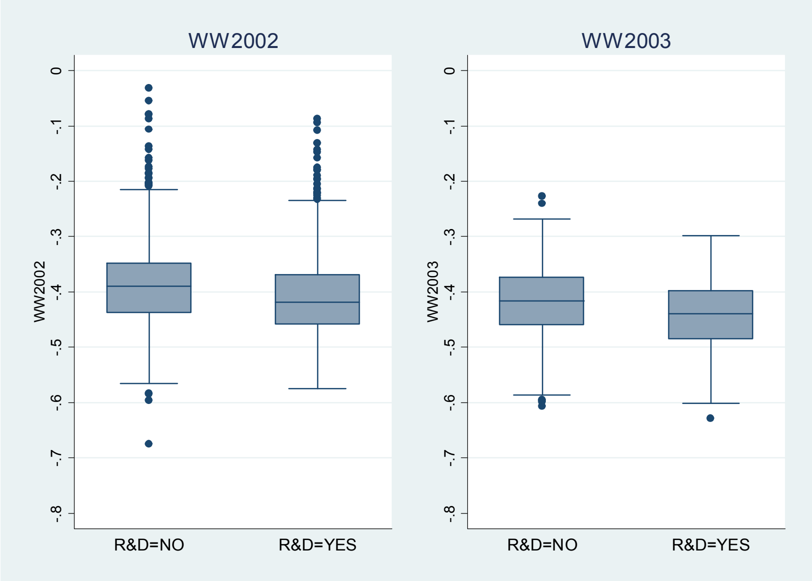
$$WW = -0.091*CF - 0.062*DIVPOS + 0.021*TLTD - 0.044*LNTA + 0.102*ISG - 0.035SG$$

where CF is the cash flow to total assets ratio, DIVPOS is a dummy which equals one when the firms pays cash dividends (zero otherwise), TLTD is the long term debt to total assets ratio, LNTA is the natural log of total assets, ISG is the firm's industry sales growth (here calculated at the SIC three-digit level from AIDA) and SG is the firm sales growth, both calculated with respect to the previous year. Lower values of the index are associated with better financial status and lower likelihood of being subject to financing constraints.

Whited and Wu (2006) show that their index outperforms the KZ index in the ability to identify firms with characteristics associated with financial constraints. We therefore focus our attention on such index and look at its distribution in the sample in order to relate our subjective indicator of financing constraints to an objective measure of financial status and to gain further insight on the relationship between credit restrictions and R&D decision[14].

[14] In calculating the WW index, we do not observe directly whether a generic firm *i* actually paid cash dividend in a given year *t*, but we retrieve this information by assuming that cash dividend are paid if the firm had positive net

Fig. 1 - Distribution of the WW index (years 2002 and 2003) between R&D and non R&D performing firms (final sample)



The Box-Plots in Figure 1 show that the WW index clearly shows a negative correlation with the R&D decision and such correlation appears stable over time: in both years the distribution of the index is shifted to the right for firms with no R&D investment in 2003, thus suggesting that firms with positive R&D investment are also characterized by a healthier financial status with a lower shadow cost for accessing to external finance[15].

Figure 2 then shows the distribution of the WW2002 index in the final sample amongst constrained vs. unconstrained firms for both firms with and without R&D investment. The difference in mean of the WW2002 index between constrained and unconstrained firms is 0.0108 (statistically significant at the 5% level) for firms not performing R&D and is 0.0346 for firms with positive R&D (statistically significant at the 1% level). Thus a higher likelihood of being liquidity constrained as evidenced by the WW index translates in the firm's own perception of being liquidity constrained, even more so for R&D performing firms.

Fig. 2 - Distribution of the WW index amongst constrained (Constrained) and R&D performing firms in the final sample

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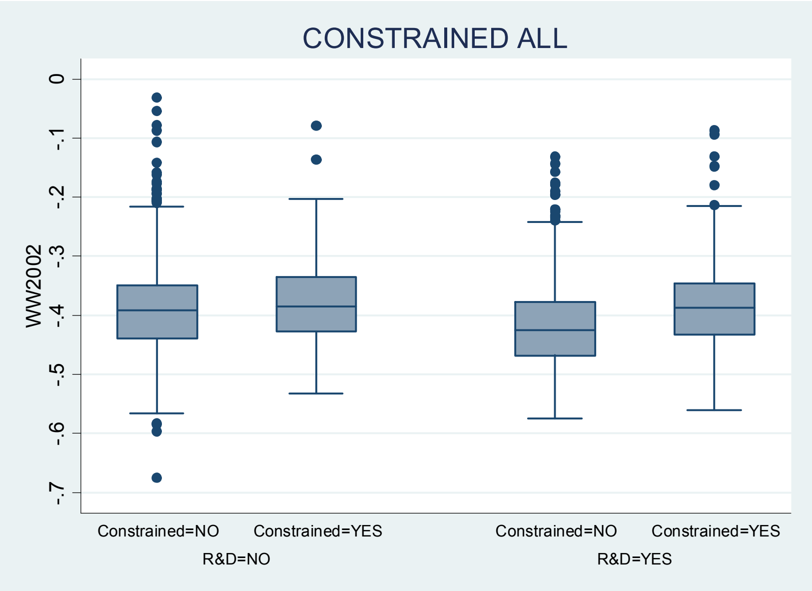
profits in year *t* and if the amount of net assets at the end of year *t* is less than the sum of net profits at year *t* plus the amount of net assets at year *t-1*.

15 The difference in mean of the WW index between firms not performing R&D and firms with positive R&D (0.0221 for WW2002 and 0.0267 for WW2003) is statistically significant at the 1% level.



The evidence presented above suggests that the association between our direct indicator of liquidity constraints and the WW index of financial constraints is good and thus increases our confidence in using the firm's desire for additional finance to identify financially constrained firms. Furthermore, such association will prove extremely useful in finding a good instrument for our financing constraints indicator, once we explicitly account for the endogeneity problem associated with it. Indeed, the above results suggest that the WW index calculated in 2002 can be used as an instrument for our Constrained variable (which reports the firm's perception of credit restrictions in 2003).

5 - Empirical analysis

5.1 The R&D investment decision: Preliminary results

We first employ a simple univariate probit model where the decision to invest in R&D (y_{1i}) depends on traditional determinants proposed by the literature (x_{1i}) and on our direct indicator of liquidity constraints (y_{2i}, i.e. our Constrained variable):

$$y_{1i} = I(\alpha y_{2i} + \beta_1 x_{1i} + \varepsilon_i) \quad (1)$$

where *I* is an indicator function that takes the value of 1 when its argument is true and 0 otherwise. Our dependent variable is equal to 1 if the firm invests in R&D in 2003 and is equal to zero otherwise. Traditional determinants of the decision to undertake R&D investment include firm size, market share as well as indicators of the environment in which the firm operates.

As first suggested by Schumpeter (1942), firm size is likely to be a significant determinant of the decision to invest in R&D. One of the reasons is that R&D investment induces sunk costs. Large firms are therefore likely to be less reluctant to engage in R&D activities because they can spread such costs on more units of output (Cohen and Klepper, 1996). In addition, it may be easier for large firms to finance R&D investments as they may enjoy better relations with external investors. Among others, Crépon et al. (1998) and also Bond et al. (2003) find a positive significant effect of firm size on the likelihood to undertake R&D.

The impact of market structure and market shares on R&D investment and innovation has also been largely emphasized by the literature, starting, once again, with Schumpeter (1942), who argues that a firm has higher incentives to engage in R&D activities if it enjoys a monopoly position. On the contrary, Arrow (1962) shows that under perfect ex-post appropriation, profit margins are larger in an ex-ante competitive industry. Blundell et al. (1999) also find a positive relationship between firms' ex ante market share and innovation.

We control for the likely effect of firm's environment on its decision to undertake R&D investment through a complete set of industry dummies and with geographical dummies[16]. These are meant to capture the potentially relevant role of technological opportunities and appropriability conditions and the associated role of spillovers.

We control for firm's age by introducing dummies corresponding to the decade in which the firm was founded (starting from the 1970's), for a set of dummies related with the firm's governance (foreign) and its relationships with other firms (grouphead) We finally introduce a measure of the intensity of investment in physical assets to account for the

[16] In the final specifications reported in Tables 6 through 9 we include three geographical dummies, which identifies firms located in the North-East , in the Centre and in the South of Italy. The excluded category is North-West. This is easily justified by the industrial divide in Italy between northern vs. southern regions.

potential trade-off or complementarity between R&D and physical investments and a measure of firm's debt leverage (DEBT_EQUITY2002).

The list of variables employed in the analysis and their definition is reported in Table 5.

Table 5 – Variables description

Variable	Range	Description
dumRD2003	dummy(0,1)	=1 if invested in R&D in 2003; 0=otherwise
Constrained	dummy(0,1)	=1 if desired additional financing in 2003; 0=otherwise
*log*EMP2002	continuous	Log. of firm's total Employees in 2002
INV_EMP2002	continuous	Physical Investments /Total Employees in 2002
Mktshare2002	continuous	(Firm turnover/Sector turnover[17])*100 in 2002
DEBT_EQUITY2002		Long term debts /Firm's equity in 2002
North_East	dummy(0,1)	=1 if located in North-East Italy
Centre	dummy(0,1)	=1 if located in Centre Italy
South	dummy(0,1)	=1 if located in South Italy
fy_71_80	dummy(0,1)	=1 if established in 1971-1980
fy_81_90	dummy(0,1)	=1 if established in 1981-1990
fy_91_03	dummy(0,1)	=1 if established in 1991-2003
grouphead	dummy(0,1)	=1 if is the leader of a group of firms
foreign	dummy(0,1)	=1 if foreign participation in firm's capital.
WW2002	continuous	Whited and Wu's index calculated in 2002
Collateral2002	continuous	Net Tangible Assets / Total liabilities in 2002

Estimation results for the univariate probit model are reported in Table 6, columns (1) and (2). With reference to the results on the final sample we find that the probability to do R&D increases with firm size and physical investment intensity and, as expected, is lower for firms located in the south of Italy. Industry differences (not reported) are found to be significant. Interestingly, the coefficient of the liquidity constraints indicator is weakly significant. Furthermore, it has an unexpected positive sign. This is in line with the results obtained in Savignac (2008) and Hajivassiliou and Savignac (2008) and might be the result of the positive correlation originated by a potentially relevant endogeneity bias associated with the liquidity constraints indicator. In the next section we deal with this.

[Table 6 about here]

[17] Calculated at the ATECO 2002 (NACE rev. 1.1) 2 digits level.

5.2 Dealing with the endogeneity of the "Constrained" indicator.

The unespected sign of the financing constraints indicator is likely to be generated by the bias due to the potential endogeneity of "Constrained". Indeed, as pointed out by Savignac (2008) and Hajivassiliou and Savignac (2008) several sources of endogeneity might affect the liquidity constraint indicator. The first one is the presence of latent heterogenous factors (such as firm's entrepreneurial behaviour and market innovative opportunities) that may affect both the probability of being liquidity constrained and the probability of performing R&D, the second one is the potential simultaneity in the firm's decision to engage in R&D projects and how to finance them (i.e. internal vs. external finance).

In order to deal with this kind of problem we follow the Full Information Maximum Likelihood approach proposed by Gouriéroux et al. (1980) and Maddala (1983) by estimating a recursive bivariate probit model. This approach has been proposed to model the endogeneity problem when both the dependent variable and the endogenous covariate are binary. The full model is specified as follows:

$$\begin{cases} y_{1i} = I(\alpha y_{2i} + \beta_1 x_{1i} + u_{1i} \geq 0) \\ y_{2i} = I(\beta_2 x_{2i} + u_{2i} \geq 0) \end{cases} \qquad (2)$$

where u_{1i} and u_{2i} are unobserved disturbances assumed to be normally distributed according to the following bivariate normal CDF:

$$\begin{pmatrix} u_{1i} \\ u_{2i} \end{pmatrix} \sim \Phi_2\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho_{1,2} \\ \rho_{1,2} & 1 \end{bmatrix} \right) \qquad (3)$$

where ρ=Cov(u_{1i},u_{2i}) measure the correlation between the unobservable terms (if ρ=0 then likelihood of the bivariate probit model is equal to the sum of the likelihoods of the two univarate probit models), y_{1i} and y_{2i} are our binary dependent variables representing respectively the presence of positive R&D investments (dumRS2003 = 1) and the presence of financial constraints (Constrained = 1), x_{1i} and x_{2i} are a set of observed covariates and (α, β_1, β_2) are parameters to be estimated via maximum likelihood techniques. For identification purposes the variances of the error terms on the main diagonal are standardized to 1 (see, for instance, Greene, 2003) and a set of "instrumental" variables (z_{2i}) included in x_{2i} are excluded from x_{1i} (Monfardini and Radice, 2004). Moreover, to meet coherency requirements (see Gouriéroux et al., 1980; Lewbel, 1997; Hajivassiliou and Savignac, 2008) we estimate a partial-recursive bivariate probit model by excluding y_{1i} from the second equation. The likelihood function contributions of each possible observed outcome are the following:

$$P(y_{1i}=1, y_{2i}=1)=\Phi_2[\alpha+\beta_1 x_{1i}, \beta_2 x_{2i}, \rho] \qquad P(y_{1i}=1, y_{2i}=0)=\Phi_2[\beta_1 x_{1i}, -(\beta_2 x_{2i}), -\rho]$$

$$P(y_{1i}=0, y_{2i}=1)=\Phi_2[-(\alpha+\beta_1 x_{1i}), \beta_2 x_{2i}, -\rho] \qquad P(y_{1i}=0, y_{2i}=0)=\Phi_2[-(\beta_1 x_{1i}), -(\beta_2 x_{2i}), \rho]$$

Table 6, columns (3)-(5), reports the covariates included in both the equations with the estimated coefficients and marginal effects when considering the final sample of 2144 firms.

The sign of the estimated coefficients associated with Constrained is now found negative: taking into account its endogenous nature, the presence of financial constraints negatively affects the decision to engage in R&D activities, by reducing its likelihood of about -22%.

Looking at the other regressors listed in columns (3) and (5) we notice that, consistently with the previous estimated probit model, the likelihood of performing R&D increases with firm's size and when considering firms located in the north of Italy. This location effect reflects the well documented divide between the more advanced and industrialized northern regions in Italy vs. the other regions (especially the less developed southern regions). Firms located in northern regions are indeed characterized by higher average R&D intensity, innovative performance and degree of internationalization. Finally, physical investment intensity is still positively correlated with the probability of performing R&D, suggesting the existence of a potential complementarity relationship between intangible investment and tangible investment intensity.

With reference to the equation explaining the probability of being liquidity constrained, the results show that this is lower for firms located in the north of Italy, due possibly to a better functioning of the credit market. Amongst the excluded regressors only WW2002 and collateral2002 are statistically significant and show respectively (as expected) a positive and negative influence on the probability of being liquidity constrained.

A formal test for the endogeneity of the variable Constrained is the statistical significance of the estimated parameter ρ. We indeed estimate a positive and significant correlation between the "unobservables" factors affecting both the probability of having positive R&D investments and the probability of being liquidity constrained.

With reference to the two aforementioned sources of endogeneity, the apparent positive impact of financing constraints on the firms' decision to invest in R&D when not controlling for endogeneity is likely to be generated by the important presence in the sample of firms not perceiving themselves as being subject to credit restrictions because they are not interested in innovation (either because of lack of entrepreneurial attitude or of promising technology and market opportunities) and hence do not wish to undertake R&D investment (Savignac, 2008; Hajivassiliou and Savignac, 2008). These firms, representing a relatively large share of the sample, are a source of positive correlation between our financing constraints measure and the R&D decision. This positive correlation may hide the negative impact of the first on the latter.

A way to overcome the selection problem is to study the effect of financing constraints on the decision to undertake R&D investment by focusing on a sample of firms potentially willing to do R&D, so to eliminate the source of the confounding positive correlation (Savignac 2008). We do that by excluding from our final sample 655 firms that do not undertake any R&D investment (R&D=0) and both do not desire additional financing (Constrained=0) and have not completed any innovative project in the recent past[18]. For this purpose, the survey includes a question asking whether in the last three years the firm has realized any (a) product innovation, (b) process innovation, (c) organizational or managerial innovation related to product or process innovations, (d) none of the above. Similarly to Savignac (2008) we refer to the resulting reduced sample as including potentially "innovative firms".

The estimation results for the "potentially innovative" firms sample are reported in Table 7. Interestingly, the coefficient of the liquidity constraints indicator is now negative and statistically significant also in the simple probit regression: potentially innovative firms facing financial constraints have a lower probability (of about -12.5%) to do RD. The effects of the other variables are confirmed, with the exception of the physical investment intensity, which is no longer found significant.

Columns (3)-(5) report estimation results from the bivariate probit regression. Results are consistent with those reported in Table 6 and those in the first two columns of Table 7. The

[18] Innovative activities are not necessarily associated with R&D investment in the survey, as they are treated in a different section.

parameter ρ, although still positive, is no longer significant. By controlling for sample selection we therefore take care of most of the endogeneity bias, although the larger marginal effect of the "Constrained" indicator in the bivariate probit regression compared to the simple probit regression suggests that other sources of endogeneity are not totally irrelevant.

[Table 7 about here]

5.3 Liquidity constraints and size of R&D investment

We now turn to the analysis of the effect of credit constraints on the level of R&D investment. We employ an instrumental variable Tobit (IV-Tobit) Model, to account for the endogeneity of our liquidity constraints indicator. The model is specified as:

$$\begin{cases} y_{1i}^{*} = \alpha y_{i2} + \beta_1 x_{1i} + u_{1i} \\ y_{2i} = \beta_2 x_{2i} + u_{2i} \end{cases} \qquad (4)$$

where y_{2i} is again our variable "Constrained". We then observe the (log of) R&D expenditures, when positive (y_{1i}) for firms with positive R&D expenditures:

$$y_{1i} = \begin{cases} y_{1i}^{*} = \alpha y_{2i} + \beta_1 x_{1i} + u_{1i} & \text{if } y_{1i}{*} > 0 \\ 0 & \text{if } y_{1i}{*} \leq 0 \end{cases} \qquad (5)$$

The endogeneity of y_{2i} is treated both via the two-step Newey procedure (see Wooldridge, 2002 pp.567-575) by inserting the fitted values of u_{2i} in the first equation and via full ML techniques by specifying a full variance-covariance matrix ∑ for the error terms (u_{1i}, u_{2i}).:

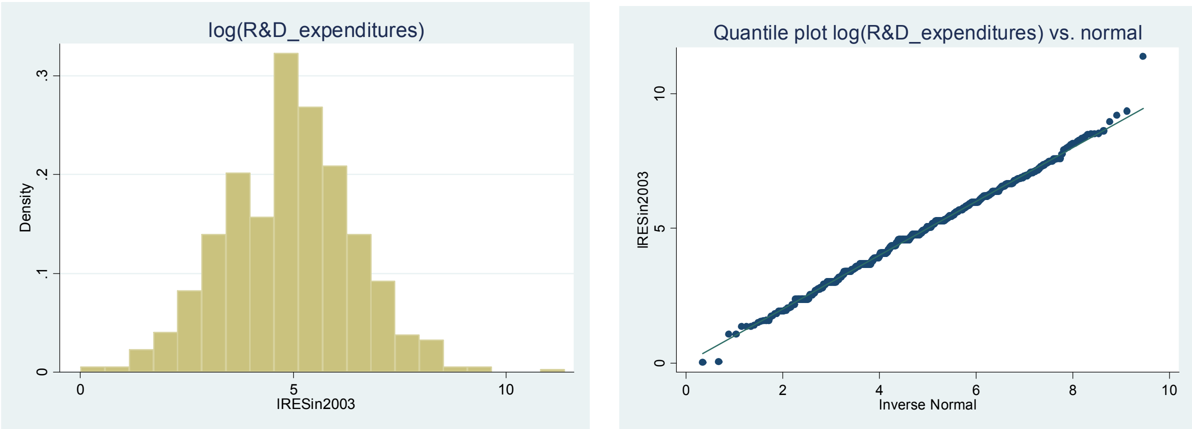
$$Var(u_{1i}, u_{2i}) = \Sigma = \begin{bmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{bmatrix} \qquad (6)$$

The procedure applies to any kind of endogenous variables, including binary variables, as in our case.

Figures 4 reports the distribution of the logarithm of R&D expenditures (over positive values) for the entire sample: the distribution is bell shaped and sufficiently close to Normal.

Table 8 reports the IV-Tobit estimation output for the final sample, using both the two-step (column (2)) and ML (columns (3) to (6)) procedures.

Fig. 4 - Distribution of log(R&D) in the final sample (only for fims with positive R&D) (N= 735; Mean= 4.90, Variance=2.32, Skewness= 0.039, Kurtosis = 3.3; Skewness/Kurtosis Normality test: 2.69 (P>chi2(2): 0.260)



In Table 8, the first column shows the output for the standard Tobit regression, which is reported for comparison, and confirms that ignoring endogeneity and sample selection induces a bias in the effect of credit constraints, which is found positive but not significant in the final sample. Once again, controlling for endogeneity, the effect of credit constraints on the level of R&D is found significant and has the correct sign. As for the R&D decision, among the other variables, the results confirm the complementarity between tangible and intangible investment, the positive effect of firm size and of firm location in northern Italy.

The probability of being liquidity constrained is again positively related to the Whited and Wu index and positively to firm's location in the south of Italy, while the size of collateral does not show any significant effect. The estimated variance of the error term for the standard The Wald test of exogeneity strongly rejects the null hypothesis of independence between the error terms of the two equations. Indeed we find a positive and strongly significant correlation between the errors in equation (4) (σ_{12}=15.584).

[Table 8 about here]

Table 9 reports similar estimation results for the subsample of potentially innovative firms. Analogously to the estimation results on the R&D decision for the same sample, liquidity constraints affect negatively and significantly the size of R&D investment also in the simple Tobit regression. The effects of the other variables are confirmed. Similarly with the previous bivariate probit model, we find a weaker (although still positive and significant) correlation between the error terms of the two equations when considering the subsample of potentially innovative firms (σ_{12}=6.428), confirming that, also in this case, most of the endogeneity bias can be accounted for by controlling for sample selection.

Both in Tables 8 and 9, column (5) reports marginal effects of all the variables, and in particular of the liquidity constraints indicator, on the probability of doing R&D, while column (6) reports marginal effects on the expectation on log(R&D) conditional on positive values. However, we're mostly interested in disentangling the negative effect of liquidity constraints on R&D into the reduction due to firms deciding not to pursue R&D effort and the reduction due to firms reducing their R&D effort. For this purpose we employ the decomposition proposed by McDonald-Moffitt (1980):

$$\frac{\partial E(y_1^* \mid \mathbf{x})}{\partial y_2} = \frac{\partial P(y_1^* > 0 \mid \mathbf{x})}{\partial y_2} E(y_1^* \middle| y_1^* > 0, \mathbf{x}) + P(y_1^* > 0 \mid \mathbf{x}) \frac{\partial E(y_1^* \middle| y_1^* > 0, \mathbf{x})}{\partial y_2} \quad (7)$$

The first component is the percentage reduction in R&D due to the reduced probability of pursuing R&D investment, while the second component is the percentage reduction in R&D due to the reduced level of R&D investment, by firms. For the full sample the two components are respectively -2.56 and -1.27. This result confirms that, in term of proportions, most of the negative effect of liquidity constraints on the observed level of R&D investment is due to the reduction of the proportion of firms doing R&D, rather than to the reduction in the expected level of R&D investment for firms already doing R&D. Furthermore, the first effect seems slightly weaker for the sample of potentially innovative firms.

6 - Conclusions

Using data from the Capitalia survey on Italian manufacturing firms undertaken in 2003 and covering the period 2001-2003, we first focused on the effect of financial constraints on the decision to engage new R&D projects at the firm level and then on the level of R&D investment.

We employ a bivariate probit model for studying how the probability to engage in R&D activity is affected by the presence of financing constraints, where the latter are assumed to be endogenous. Financial constraints are assumed to bind for firms that wished additional credit at the interest rate agreed with the main partner bank. This definition of financing constraints takes into account the fact that about 90% of Italian firms rely on banks as the main source of external funds for financing their investment plans.

The results of our analysis support our assumption that financing constraints are indeed endogenous, as they are found to significantly reduce the probability of doing R&D in a bivariate probit framework, while they unexpectedly show a positive effect when we model the decision to do R&D as a function of liquidity constraints in an univariate probit framework (i.e. financing constraints are assumed to be exogenous). The positive and significant correlation between the errors of the two equations in the bivariate probit model confirms the endogeneity of the financing constraints indicator and suggests the presence of unobservable firm characteristics (which we assume to reflect the firm's "propensity to innovate") that could simultaneously affect both the firm's decision to invest in R&D and its probability of being financing constrained. We then show that the apparent positive relationship between liquidity constraints and R&D decision is largely due to the sample selection originated by the relatively large number of unconstrained firms that are not interested in undertaking R&D activities.

We then employ an instrumental variable Tobit analysis to evaluate the effect of liquidity constraints on the level of R&D spending, always accounting for the endogenous nature of our liquidity constraints indicator. The most interesting result of the analysis is in line with what suggested, but not clearly shown by previous analyses. We measure the percentage reduction in R&D investment as a consequence of the firm facing liquidity constraints due to the reduction in the likelihood to do R&D (the R&D participation decision), and that due to a reduced level of investment and find that most of the reduction is due to the first effect.

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8 - Annex 1 – Tables

Table 6 – Estimation output – Final sample

	Simple Probit		Bivariate Probit		
	(1)	(2)	(3)	(4)	(5)
Dependent variable	**dumRS2003**	**dumRS2003**	**dumRS2003**	**Constrained**	**dumRS2003**
	Coefficients	**Marginal Effects**	**Coefficients**	**Coefficients**	**Marg. Effects**
constrained	0.159*	0.0588*	-0.716**		-0.224**
	(0.0838)	(0.0316)	(0.336)		(0.0872)
*log*EMP2002	0.313***	0.113***	0.283***	0.0574	0.103***
	(0.0390)	(0.0141)	(0.0428)	(0.0503)	(0.0153)
INV_EMP2002	0.00226*	0.000817*	0.00213*	0.000476	0.000774*
	(0.00120)	(0.000432)	(0.00117)	(0.00135)	(0.000425)
DEBT_EQUITY2002	0.00141	0.000510	0.00255	0.00484	0.000928
	(0.00372)	(0.00134)	(0.00364)	(0.00357)	(0.00132)
mktshare2002	0.603	0.218	0.397	-0.137	0.145
	(0.789)	(0.285)	(0.774)	(0.903)	(0.282)
North_east	-0.0783	-0.0281	-0.0561	0.123	-0.0203
	(0.0724)	(0.0258)	(0.0716)	(0.0889)	(0.0258)
Centre	-0.127	-0.0449	-0.0856	0.221**	-0.0308
	(0.0870)	(0.0302)	(0.0874)	(0.103)	(0.0310)
South	-0.380***	-0.127***	-0.248**	0.551***	-0.0864**
	(0.100)	(0.0308)	(0.117)	(0.111)	(0.0385)
fy_71_80	0.0417	0.0151	0.0274	-0.0792	0.0100
	(0.0797)	(0.0290)	(0.0783)	(0.0943)	(0.0287)
fy_81_90	0.0406	0.0147	0.0206	-0.132	0.00753
	(0.0802)	(0.0292)	(0.0790)	(0.0954)	(0.0289)
fy_91_03	-0.0362	-0.0130	-0.0342	-0.0581	-0.0124
	(0.0963)	(0.0344)	(0.0941)	(0.110)	(0.0339)
grouphead	0.402***	0.154***	0.350***	-0.208	0.134**
	(0.132)	(0.0522)	(0.132)	(0.178)	(0.0522)
foreign	0.0600	0.0219	0.0799	0.101	0.0295
	(0.126)	(0.0464)	(0.123)	(0.151)	(0.0462)
WW2002				2.733***	
				(0.576)	
collateral2002				-0.243**	
				(0.108)	
Constant	-1.583***		-1.324***	-0.0249	
	(0.189)		(0.227)	(0.265)	
Industry dummies	Yes		Yes		Yes
Observations	2144		2144		
Rho			0.490**		
Log Lik	-1235.6055		-2081.7459		

Robust standard errors in parentheses (Observed Information Matrix method).
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 7 – Estimation output – Innovative firms

	Simple Probit		Bivariate Probit		
	(1)	(2)	(3)	(4)	(5)
Dependent variable	**dumRS2003**	**dumRS2003**	**dumRS2003**	**Constrained**	**dumRS2003**
	Coefficients	**Marginal Effects**	**Coefficients**	**Coefficients**	**Marg. Effects**
constrained	-0.315***	-0.125***	-0.899**		-0.335***
	(0.0868)	(0.0336)	(0.354)		(0.115)
*log*EMP2002	0.247***	0.0987***	0.213***	-0.0192	0.0851***
	(0.0448)	(0.0179)	(0.0509)	(0.0556)	(0.0203)
INV_EMP2002	-0.000801	-0.000319	-0.00112	-0.00184	-0.000448
	(0.00127)	(0.000507)	(0.00126)	(0.00158)	(0.000504)
DEBT_EQUITY2002	0.000334	0.000133	0.00121	0.00455	0.000481
	(0.00402)	(0.00160)	(0.00399)	(0.00378)	(0.00159)
mktshare2002	0.631	0.252	0.483	-0.203	0.193
	(0.862)	(0.344)	(0.853)	(0.954)	(0.340)
North_east	-0.0469	-0.0187	-0.0260	0.154	-0.0104
	(0.0850)	(0.0339)	(0.0850)	(0.0984)	(0.0339)
Centre	-0.153	-0.0609	-0.120	0.226**	-0.0477
	(0.101)	(0.0398)	(0.102)	(0.114)	(0.0405)
South	-0.397***	-0.155***	-0.285**	0.642***	-0.112**
	(0.116)	(0.0437)	(0.137)	(0.125)	(0.0532)
fy_71_80	0.0146	0.00582	0.000725	-0.104	0.000289
	(0.0926)	(0.0369)	(0.0919)	(0.105)	(0.0367)
fy_81_90	0.0198	0.00792	-0.00169	-0.171	-0.000675
	(0.0945)	(0.0377)	(0.0943)	(0.107)	(0.0376)
fy_91_03	-0.0353	-0.0141	-0.0400	-0.0899	-0.0160
	(0.113)	(0.0452)	(0.112)	(0.124)	(0.0446)
grouphead	0.415***	0.162***	0.367**	-0.293	0.144**
	(0.156)	(0.0582)	(0.158)	(0.192)	(0.0598)
foreign	0.141	0.0563	0.162	0.142	0.0643
	(0.150)	(0.0595)	(0.149)	(0.166)	(0.0588)
WW2002				3.309***	
				(0.662)	
collateral2002				-0.299**	
				(0.129)	
Constant	-0.888***		-0.634**	0.785***	
	(0.220)		(0.276)	(0.299)	
Industry dummies	Yes		Yes	Yes	
Observations	1489		1489		
Rho			0.3499		
Log Lik	-920.00274		-1628.2647		

Robust standard errors in parentheses (Observed Information Matrix method).
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 8 – Tobit Estimation output – Final sample

	Tobit ML	Two-Step IV-Tobit	ML IV – Tobit			
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	logRS2003	logRS2003	logRS2003	Constrained	dumRS2003	E(logRS2003 | logRS2003>0)
	Coefficients	Coefficients	Coefficients	Coefficients	Marg. Effects	Marg. Effects
constrained	0.619 (0.389)	-13.67*** (4.912)	-14.49*** (5.251)		-0.485*** (0.076)	-3.160*** (0.797)
*log*EMP2002	1.836*** (0.201)	1.618*** (0.244)	1.608*** (0.260)	0.00861 (0.0117)	0.084*** (0.014)	0.503*** (0.082)
INV_EMP2002	0.0140*** (0.00460)	0.0136** (0.00666)	0.0136** (0.00592)	0.000132 (0.000291)	0.001** (0.001)	0.004* (0.002)
DEBT_EQUITY2002	0.00392 (0.0162)	0.0236 (0.0231)	0.0247 (0.0302)	0.00127 (0.00146)	0.001 (0.002)	0.008 (0.010)
mktshare2002	3.116 (3.910)	0.388 (4.865)	0.227 (4.588)	-0.0535 (0.331)	0.012 (0.240)	0.071 (1.434)
North_east	-0.415 (0.332)	-0.120 (0.442)	-0.104 (0.437)	0.0221 (0.0174)	-0.005 (0.023)	-0.032 -0.136
Centre	-0.540 (0.407)	-0.0309 (0.548)	-0.00254 (0.561)	0.0430* (0.0220)	-0.001 (0.029)	-0.001 -0.175
South	-1.967*** (0.507)	-0.348 (0.813)	-0.258 (0.853)	0.125*** (0.0268)	-0.013 (0.044)	-0.080 -0.263
fy_71_80	0.112 (0.366)	-0.0665 (0.478)	-0.0757 (0.478)	-0.0168 (0.0201)	-0.004 (0.025)	-0.024 (0.149)
fy_81_90	0.178 (0.375)	-0.0933 (0.487)	-0.108 (0.494)	-0.0216 (0.0199)	-0.006 (0.026)	-0.034 (0.154)
fy_91_03	-0.102 (0.458)	-0.0970 (0.574)	-0.0965 (0.586)	-0.00899 (0.0254)	-0.005 (0.031)	-0.030 (0.182)
grouphead	1.880*** (0.546)	1.323* (0.783)	1.293* (0.730)	-0.0322 (0.0288)	0.069* (0.040)	0.424* (0.251)
foreign	0.472 (0.601)	0.827 (0.761)	0.848 (0.823)	0.0218 (0.0350)	0.045 (0.044)	0.273 (0.274)
WW2002				0.580*** (0.129)		
collateral2002				-0.0280* (0.0152)		
InvMillsRD						
InvMillsFC						
Constant	-8.523*** (0.953)	-5.588*** (1.507)	-5.434*** (1.582)	0.364*** (0.0612)		
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-squared						
Observations	2144	2144	2144			
Censored	1409	1409	1409			
Uncesored	735	735	735			
Log Lik	-2973.096		-3724.821			
Wald test exogeneity ($\sigma_{12}=0$)		14.18 ***	8.46 ***			

Robust standard errors in parentheses * significant at 10%; ** significant at 5%; *** significant at 1%

Table 9 – Tobit Estimation output – Innovative firms

	Tobit ML	**Two-Step IV-Tobit**	**ML IV – Tobit**			
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	**logRS2003**	**logRS2003**	**logRS2003**	**Constrained**	**dumRS2003**	**E(logRS2003 | logRS2003>0)**
	Coefficients	**Coefficients**	**Coefficients**	**Coefficients**	**Marg. Effects**	**Marg. Effects**
constrained	-1.283***	-7.482***	-7.734***		-0.543***	-2.380***
	(0.338)	(2.535)	(2.659)		(0.131)	(0.646)
*log*EMP2002	1.328***	1.046***	1.035***	-0.00833	0.083***	0.406***
	(0.175)	(0.214)	(0.224)	(0.0156)	(0.01802)	(0.088)
INV_EMP2002	0.00167	-0.00204	-0.00219	-0.000353	-0.001	-0.001
	(0.00516)	(0.00525)	(0.00609)	(0.000332)	(0.001)	(0.002)
DEBT_EQUITY2002	-0.00144	0.00850	0.00891	0.00138	0.001	0.003
	(0.0173)	(0.0177)	(0.0239)	(0.00192)	(0.002)	(0.009)
mktshare2002	2.455	1.111	1.057	-0.0422	0.085	0.415
	(3.277)	(3.507)	(2.791)	(0.373)	(0.224)	(1.094)
North_east	-0.231	-0.0247	-0.0165	0.0326	-0.001	-0.006
	(0.292)	(0.348)	(0.342)	(0.0239)	(0.027)	(0.134)
Centre	-0.487	-0.201	-0.190	0.0550*	-0.015	-0.074
	(0.364)	(0.425)	(0.433)	(0.0296)	(0.035)	(0.167)
South	-1.680***	-0.645	-0.604	0.182***	-0.049	-0.231
	(0.461)	(0.636)	(0.666)	(0.0368)	(0.054)	(0.248)
fy_71_80	-0.0712	-0.207	-0.213	-0.0267	-0.017	-0.083
	(0.326)	(0.376)	(0.374)	(0.0271)	(0.031)	(0.145)
fy_81_90	0.0557	-0.162	-0.171	-0.0383	-0.014	-0.067
	(0.335)	(0.390)	(0.389)	(0.0276)	(0.031)	(0.151)
fy_91_03	-0.0666	-0.118	-0.120	-0.0205	-0.010	-0.047
	(0.403)	(0.458)	(0.456)	(0.0355)	(0.037)	(0.177)
grouphead	1.485***	1.097*	1.082**	-0.0531	0.085*	0.450*
	(0.458)	(0.591)	(0.535)	(0.0344)	(0.041)	(0.235)
foreign	0.708	0.952	0.962	0.0361	0.076	0.398
	(0.522)	(0.591)	(0.606)	(0.0462)	(0.047)	(0.263)
WW2002				0.877***		
				(0.175)		
collateral2002				-0.0546*		
				(0.0292)		
InvMillsRD						
InvMillsFC						
Constant	-4.160***	-1.757	-1.664	0.633***		
	(0.837)	(1.316)	(1.357)	(0.0838)		
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-squared						
Observations	1489	1489	1489			
Censored	754	754	754			
Uncesored	735	735	735			
Log Lik	-2608.9542		-3321.5525			
Wald test exogeneity ($\sigma_{12}=0$)		7.92 ***	6.08 **			

Robust standard errors in parentheses * significant at 10%; ** significant at 5%; *** significant at 1%

9 - Annex 2 – Further Tables

Table A1 – Descriptive statistics

	Final Sample (2144 obs.)				Innovative Firms (1489 obs.)			
Variable	**Mean**	**St. dev.**	**Min**	**Max.**	**Mean**	**St. dev.**	**Min**	**Max.**
dumRSin2003	0.343	0.475	0	1	0.494	0.500	0	1
constrained	0.143	0.350	0	1	0.206	0.404	0	1
IEMP2002	3.745	0.882	0	6.492	3.846	0.894	0	6.492
INV_EMP2002	12.519	26.273	0	553.042	14.432	28.772	0	553.042
DEBT_EQUITY2002	1.282	8.671	-195.47	180.873	1.471	8.703	-195	180.873
Mktshare2002	0.021	0.041	0	0.901	0.023	0.046	0	0.901
grouphead	0.051	0.220	0	1	0.058	0.235	0	1
foreign	0.054	0.226	0	1	0.057	0.232	0	1
WW2002	-0.398	0.073	-0.675	-0.032	-0.403	0.073	-0.59	-0.054
collateral	0.643	0.388	0.013	7.445	0.643	0.327	0.037	3.956

Table A2 – Correlation matrix for continuous indicators (Final sample)

	IEMP2002	INV_EMP2002	DEBT_EQUITY	mktshare	WW2002	collateral
IEMP2002	1					
INV_EMP2002	0.0315	1				
DEBT_EQUITY	0.0649	-0.0033	1			
mktshare	0.3905	0.0836	0.0194	1		
WW2002	-0.4939	-0.1347	-0.0309	-0.3654	1	
collateral	0.0439	0.0987	-0.0287	0.0079	-0.1066	1

Table A3 – Correlation matrix for continuous indicators (Innovative Firms)

	IEMP2002	INV_EMP2002	DEBT_EQUITY	mktshare	WW2002	collateral
IEMP2002	1					
INV_EMP2002	0.017	1				
DEBT_EQUITY	0.0557	-0.007	1			
mktshare	0.3774	0.0858	0.0068	1		
WW2002	-0.5066	-0.1319	-0.0279	-0.3522	1	
collateral	0.0648	0.1232	-0.0493	0.0146	-0.1196	1