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Abstract

Self-financing has often been seen as an important source for research-and-development (R&D) funding. However, an in-depth comparison between the determinants of self-financing in the case of traditional investments versus those in R&D has not been provided yet. We use a comprehensive data set of Italian manufacturing firms to investigate this issue. We analyse the role of a wide number of financial variables in driving the rate of self-financing of firms, in both traditional and R&D investments, and we focus on public subsidies and firm size as critical factors explaining heterogeneity. First, we perform logit and logistic regressions separately for traditional and R&D self-financing, finding that they are positively correlated, and that the availability of public subsidies reduces self-financing. Subsequent poolability tests show that public subsidies and firm size are crucial discriminating factors for self-financing behaviour. Our main finding is that, in the absence of public subsidies, no internal or external market variable is able to explain the firms'

financing decisions. Furthermore, our analyses generally show that credit constraints and banking relationship variables are relevant in determining traditional investment self-financing, while no clear statistical evidence is found in the R&D case. Credit rationing is not significant for R&D self-financing, which may be explained by rationed firms being left out of our sample.

Keywords: SMEs; R&D investments; Corporate structure; Poolability test.

JEL Classification: D45, D82, E51, G21, G32, O32.

1. Introduction

In the economic literature, self-financing has often been analysed as an important source for research-and-development (R&D) funding. However, to our knowledge, an in-depth comparison between the determinants of self-financing in the case of traditional investments versus those in R&D has not been provided yet. In fact, information asymmetries, relationship lending, firm size, geographic localization and the availability of public subsidies may have a crucial role in driving both internal and external sources of finance. What is not adequately discussed in the literature is how such characteristics may have a differentiated influence on the decision to self-finance traditional or R&D investments.

The firms' market value and real decisions are usually considered independently from their financial structure and financing policies, because in the theoretical framework based on Modigliani and Miller's (1958) model financial markets are perfect and characterized by fiscal neutrality, thus external and internal funds are considered to be perfectly substitutable. However, in the presence of information asymmetries, some of the above conclusions could not appropriately explain the different financial preferences of small-medium enterprises (SMEs) involved in traditional investments as compared to those in R&D. As a result of high information opacity, firms involved in R&D investments have greater difficulty in obtaining external funds. As suggested by Myers and

Majluf (1984), information asymmetries lead to a hierarchical preference for internal financial resources, justifying the commonly observed higher self-financing rates of R&D (Hall 2002).¹

According to the pecking order theory (Myers and Majluf, 1984), the cost of funding increases with information asymmetries. The cost of information asymmetries – more relevant in the case of SMEs, particularly if R&D-oriented – implies that firms choose the least expensive form of financing in terms of information disclosure (Bhattacharya and Chiesa 1995).² As a consequence, new investments are initially financed with internal capital and then by bank loans, followed by bonds and, only as a last resort, through public placement of shares. Likewise, Berger and Udell (1998) reiterate that firms' financial sources change with their outward informative capacity. Small, new and innovating firms primarily make use of internal capital and commercial loans. The development of such firms requires higher information transparency, which thus makes it easier to obtain external equity. The hierarchy of financial resources, partially oriented towards growth, is best adapted to SMEs that invest in R&D.³

Given the above theoretical context, the aim of the present paper is to identify the potentially different role played by funding in traditional and R&D investments, using information from a highly detailed survey of Italian manufacturing firms collected in 2004 by the Italian bank Capitalia. In particular, we focus on self-financing of investments and on the conditions allowing (or forcing) firms to choose it. This issue is analysed separately for traditional investment (e.g., in infrastructure) and R&D investment (e.g., in research facilities and personnel). R&D, defined as a creative activity implemented to improve know-how and its utilization in new applications (Capitalia, 2005), is quite distinct from other types of investment because of its well-known high rate of information opacity. Thus, coherently with asymmetric information theory, R&D-oriented

¹ For a review of the literature supporting the Myers and Majluf (1984) theory of hierarchical funding resources, see, among others, Harris and Raviv (1991), Myers (2003) and Frank and Goyal (2007).

² Even when possible from a legal standpoint, SMEs show a limited interest in the equity market, because it is more expensive in terms of information disclosure. SMEs seem to be generally less prone to share control of the firm with third parties, fearing a loss of autonomy and flexibility in the management of their activities.

³ An exclusive relationship with a few banks would guarantee firms investing in R&D against the risk of losing their intellectual property in favour of competitors (*infra* Bhattacharya and Chiesa 1995).

firms will have greater difficulties in collecting external funding. The higher risk which is inherently tied to R&D projects may indeed involve forms of financial constraint. However, signaling mechanisms such as self-financing could correct such a market imperfection.

The purpose of this paper is twofold. First, we investigate which factors contribute to determining the patterns of financing of traditional and R&D investment. Second, we investigate whether the latter faces greater difficulty in attracting external financial resources compared to the former. In order to answer the above research questions, we model the decision to fund an investment – and its intensity – through debt or self-financing both by means of univariate and bivariate logit models, and by logistic regression models.

Our results offer a comparative analysis of the peculiarities of R&D financing versus traditional investment financing. To investigate potential heterogeneity in financing behaviour, we apply, for the first time in this framework, poolability analyses to investigate the stability of our findings over different data subsamples.

The remainder of the paper is organized as follows. Section 2 reviews the main theoretical and empirical literature on the financial preferences of SMEs. Section 3 describes the data set, while the econometric approach and empirical results are described in Section 4. Section 5 contains the conclusions.

2. Theoretical Background and Empirical Issues

As suggested in the literature (Myers and Majluf 1984; Berger and Udell 1998), the financial structure of a firm depends strongly on asymmetric information. To overcome this problem, some authors (Fazzari *et al.* 1988) suggest that self-financing can be a good solution to both solve external credit rationing problems and to signal good internal firm quality.

On the latter point, Piga and Atzeni (2007) provide a further interpretation, focusing on the role of self-financing as a way of addressing the problems arising from information asymmetry, and thus

from the potential risk of credit rationing. However, a high rate of self-financing could cause the project to be extremely confidential, and conversely create the undesired effect of limiting access to external financial resources. Furthermore, credit rationing depends on the intensity of R&D investment. Firms which are strongly oriented towards R&D do not seem to experience credit constraint problems and *vice versa*.

Further details on relationship lending and R&D investment are provided by Herrera and Minetti (2007), who find that the duration of the credit relationship increases the probability that firms engage in innovation. This result is in line with the view that sound banking relationships can foster innovation. The authors find that such strong relationships benefit innovation not just by fostering R&D, but also by channelling funds for the introduction and acquisition of new technologies.⁴

Ughetto (2008) shows that Italian firms obtain a significant share of their financing from debt. This result is strongly reversed in the case of R&D, for which the main financing source is internal cash flow. A subsample analysis between small and medium-large firms suggests that small innovative firms are more credit-constrained than larger companies. It appears that firm size exerts a significant impact on the availability of external financial sources to be channelled into R&D. Size and credit rationing are then key variables to explain different financing approaches for traditional and R&D investments.

A further important factor for R&D investment is the lack of collateral, which could partially or entirely cover the project's default risk. Bester (1985) argues that there is no rationing if banks compete with each other by simultaneously establishing the collateral and interest rate levels. A firm's choice of one contract over another is a self-selection mechanism. For instance, a firm with a low insolvency probability is ready to provide higher collateral in exchange for a lower interest rate.⁵ As suggested by Ozkan (2002, p. 827), 'one important distinction between R&D investment and investment in physical capital is that the result of R&D investment can not serve as collateral,

⁴ This evidence suggests that banks are more prone to finance traditional investments in new technology rather than assisting firms in the R&D activities to develop new technology in-house.

⁵ Contrary to the prevailing literature on collateral, Berger and Udell (1990) argue that this is frequently associated with risky debtors, risky loans, and risky banks.

as it may be impossible to put a lien on R&D capital'. R&D investment has generally little rescue value: at the R&D stage, investments consist mostly of salaries and intangible assets; at the adoption stage, assets that embody new technology are then specific to the firm (with the exception of patents). This implies that collateral has a limited role in mitigating incentives to add risk (Herrera and Minetti 2007). Evidence suggests that collateral is more likely to be pledged in the presence of significant information asymmetries between borrowers and lenders. However, this result cannot be easily verified in the case of R&D, since intangible assets are difficult to collateralize (Gonas *et al.* 2004).

On this point, Czarnitzki and Hottenrott (2011) underline that banks prefer physical and redeployable assets as security for their loans, since they can be liquidated, at least partially, in case the project fails, or if the firm goes bankrupt. The authors further investigate the role of external credit rationing on R&D expenditure, taking into account the age and size of the financed firms. Explicitly considering that R&D investments differ from capital investments with respect to financing constraints, Czarnitzki and Hottenrott show that the availability of internal funds is more decisive for R&D than for capital investment. Moreover, smaller firms suffer more from external constraints on R&D investment than larger firms. In this respect, Czarnitzki and Hottenrott try to measure external credit rationing via a credit rating index that directly measures credit access. Again, a higher external rating implies a positive effect over the decision to invest in both physical capital and R&D. However, the impact of external rating is more important in the second case. This analysis suggests that smaller and younger firms can experience more problems than larger and older firms in obtaining external funds, because of asymmetric information problems. These problems could become more severe in a regulating framework requiring banks to conduct detailed risk assessment based on standardized rating systems similar to those suggested by the 'Basel II Capital Accord' on banking capital requirements.

Focusing on this last point, Scellato and Ughetto (2010) show that the Basel rules could imply a negative impact on lending conditions for those SMEs that are relatively younger, smaller and

showing positive R&D expenditure. The evidence based on a sample of Italian manufacturing SMEs suggests that investments in R&D increase the probability to be denied credit. Moreover, belonging to the R&D sector increases the probability of belonging to a low-rating class.

The absence of collateral from physical assets implies that banks and other debt holders are reluctant to finance projects involving substantial R&D investments. Therefore, these arguments justify public market intervention in R&D. As suggested by Czarnitzki (2006) the positive externalities argument is usually considered to regard the funding of basic research, while the second argument on the wedge between the internal and external cost of capital is used as a rationale for supporting SMEs activities.⁶

A further strand of literature shows that public subsidies to R&D alleviate debt and equity gaps for small firms' innovation projects. Innovations are expected to generate positive externalities, but because firms can appropriate only private returns, they will launch only privately profitable innovation projects. Thus, underinvestment in R&D entails the risk that socially useful projects are not privately implemented. On this point, many scholars have studied the effect of public R&D policies on R&D expenditure and financing, but there is no consensus on its sign and extent (David *et al.* 2000; Klette *et al.* 2000). David *et al.* (2000) show an unstable relationship between public funding and private R&D expenditure.⁷ The meta-analysis carried out by García-Quevedo (2004, p. 96) finds that 'there are no specific study characteristics that lead to a particular result complementarity or substitution effect between public funds and private financing of R&D'. There is only weak evidence for the existence of crowding-out effects between subsidies and self-financing. For example, Meuleman and De Maeseneire (2008) suggest that the collection of subsidies, as a positive signal, leads to better credit access, therefore reducing self-financing. On the contrary, more recently Carboni (2011) rejects the hypothesis of crowding-out between private and

⁶ Also in European studies, subsidies show a positive impact on R&D activities and performances, independently of their source (private or public) or nature (local, national or European) (Czarnitzki and Lopes Bento 2012).

⁷ The authors state (p. 500): 'The econometric results [...] tend to be running in favour of findings of complementarity between public and private R&D investments but that reading is simply an un-weighted summary based upon some 30 diverse studies: it is not a conclusion derived from a formal statistical meta-analysis'.

public R&D funds; furthermore, he shows evidence of a positive relationship between public funding and the use of internal sources, that is, a negative relationship between public funding and credit access. From a technical viewpoint, public funding attribution does not require a formal investment screening based on internal sources, differently from what happens in the case of private funding (Brealey *et al.* 1977).

In the rest of the paper, we further investigate this aspect with the aim to better understand the determinants of R&D self-financing compared to those of traditional investment self-financing. After establishing the relationship between self-financing and public subsidies, we proceed in the attempt to understand if the banking variables and public subsidies play a different role on the basis of the type of investment being financed.

3. Data and descriptives

The data used in this paper come from the Survey of Manufacturing Firms (SMF) carried out by the Area Studi of Capitalia Bank (Capitalia, 2005) in 2004. This survey is a key source of mainly questionnaire-based information, and it involves a sample of 4,289 Italian firms with 11 to 500 employees. It also includes all manufacturing firms with more than 500 employees. The firms were stratified according to the number of employees, the industry and the geographical location. The survey data is matched with the AIDA-Bureau van Dijk financial accounting data which provide greater historic depth.

Firms declaring expenditure in both R&D and other investments are 1,357 and constitute our sample.⁸ The sample is strongly unbalanced towards small firms,⁹ and companies in the first age quantile are on average five years old.

⁸ It was necessary to identify a homogeneous sample group regarding all the structural variables characterizing firms that carry out both types of investments (R&D > 0 and Investment > 0). Some attention should be paid to the fact that the need to select firms engaged in both activities (investments and R&D) certainly reduces the sample size. Therefore, we exclude firms that are severely rationed to such an extent that it would hamper any form of

Our study focuses on the survey section dedicated to the different contributions of each financial source to investment, technological innovation and research and development for both R&D expenditure and traditional investments (see Table 1).¹⁰

Table 1 shows that self-financing is on average much more important in R&D expenditure than in traditional investments. In traditional investments, leasing and banking debt are the most significant alternatives to self-financing. In R&D, in contrast, credit appears to be just as important as public funding among external sources of financing.¹¹

We investigate both the determinants of the choice to self-finance and of the share of self-financing. The aim of the following exploratory analysis is to verify if financial constraints (external rationing) exist and force the firms to self-finance R&D, with respect to what can be observed for traditional

In table 1, the variable for public subsidies is used to split the sample in two groups to study the financial behaviour of firms. In the first case, we consider traditional investment financing: subsidized companies exhibit a lower use of internal funds compared to unsupported firms (–19.4 per cent), but public funding does not change the relevance of short term debt. As expected, a specific debt financing – favourable credit – is correlated with public subsidies.

investments.

investments or R&D expense, or firms that, for the given period, deliberately preferred to rule out any investment or R&D expense.

⁹ Fifty per cent of firms have total assets of less than €12 million and 68 employees. Given the size of the firms included in our sample, the use of equity is marginal related to the investment financing operations.

¹⁰ Section C – “Investment, Technological Innovation and Research and Development”. In particular, questions relevant for our analysis are: C1.1: “Over the period 2001–2003, did the firm invest in installations, machinery or equipment?”; C1.2: “How much did it spend?”; C1.5: “How were the investments made during 2001–2003 financed?”; C2.2.1: “Over the period 2001–2003, how much did the firm spend on R&D?” and C2.2.2: “How much did it spend?” (Capitalia 2005).

¹¹ Public funds appear on average more important in financing R&D expenditure compared to other investments. Nevertheless, the literature seems to suggest that public financing does not explain a greater R&D expenditure. We observe a sort of ex ante self-selection of firms: only firms that really intend to undertake an innovative project ask for public funding (Czarnitzki 2006; Meuleman and De Maeseneire 2008).

Table 1 - Public subsidies and source of finance: investments versus R&D

	Public subsidies					Yes vs No Mean difference	
	All Mean	Yes Mean	SD	No Mean	SD		
Traditional investments							
Equity	1.2	1.2	7.7	1.1	9.5	0.1	
Self-financing	51.2	44.2	37.4	63.6	40.6	-19.4	***
Short term loans	6.4	6.5	17.9	6.4	19.4	0.1	
Long term loans	11.7	11.4	24.3	12.2	26.3	-0.8	
Subsidized interest loans	6.7	10.2	21.9	0.6	5.7	9.6	***
Full subsidized incentives	3.1	4.8	11.7	0.0	0.0	4.8	***
Fiscal incentives	3.7	5.7	13.5	0.2	1.7	5.6	***
Leasing	14.1	14.1	26.1	14.0	28.8	0.1	
Intergroup loans	1.6	1.6	10.9	1.7	11.1	-0.1	
Other firms' loans	0.1	0.0	0.6	0.2	4.5	-0.2	
Other	0.2	0.3	3.2	0.2	2.6	0.1	
No. obs	1,415	908		507			
R&D investments							
Equity	0.7	0.9	8.1	0.3	4.9	0.5	
Self-financing	79.4	72.7	36.7	91.2	26.5	-18.5	***
Short term loans							
Long term loans	6.1	5.9	19.8	6.4	22.5	-0.5	
Subsidized interest loans	3.4	5.2	18.2	0.2	4.5	5.0	***
Full subsidized incentives	6.2	9.6	22.2	0.1	1.8	9.5	***
Fiscal incentives	3.0	4.7	15.6	0.0	0.0	4.7	***
Leasing							
Intergroup loans							
Other firms' loans							
Other	1.3	1.1	9.1	1.8	12.5	-0.7	
No. obs	1,415	908		507			

*** denotes 1% significance for F-test on equal means.

In the second case, R&D financing supported by public subsidies exhibits again a lower use of internal funds (72.7 per cent), in favour of increased credit and other public incentives. When we consider firms without subsidies, the self-financing relevance increases to 91.2 per cent. In summary, with different amplitude related to the kind of investment (traditional/R&D), public subsidies reduce self-financing, increase other financing sources, while no effect is found on the debt. As shown in Table 1, R&D uses a considerably larger amount of internal funds compared to traditional investments. These preliminary results suggest to explore the rationale of R&D financing compared to traditional investments and to evaluate the specific impact of public subsidies.

3.1 Specification of Dependent and Independent Variables

The SELFFIN_A/B binary dependent variables for the decision to self-finance are described in Table 2 and defined as SELFFIN_A in the case of presence of self-financing and SELFFIN_B in the case of full self-financing. As such, SELFFIN_B is a special case of SELFFIN_A.

Self-financing is also measured by the continuous variables INV_SELFFIN_% and R&D_SELFFIN_%, which account for the firm's share of self-financing over total financing. They are obtained directly from the questionnaire, as the answer to questions C.1.5 and C.2.2.4 pertaining to the distribution of financing sources. Both these variables are used to analyse the potential existence of a correlation between investments and R&D self-financing decisions. If such a correlation is negative, a crowding out effect is observed, whereas a common feature in the use of self-financing is observed if the correlation is positive.

The independent variables can be grouped into four sets: i) structural and financial characteristics of the firm; ii) factors pertaining to relationship lending and information asymmetries; iii) characteristics of the banking markets', and iv) within-firm correlated self-financing decisions (INV_SELFFIN_% and R&D_SELFFIN_%).

Table 2 – Description of variables

		Source	Year	N	Mean	SD	Min	Q1	Median	Q3	Max
Dependent variables											
INV_SELFFIN_A	Dummy variable; = 1 if self-financed investments > 0	Capitalia	2003	811	0.78	0.42	0.00	1.00	1.00	1.00	1.00
INV_SELFFIN_B	Dummy variable; = 1 if investments are fully self-financed	Capitalia	2003	811	0.51	0.50	0.00	0.00	1.00	1.00	1.00
R&D_SELFFIN_A	Dummy variable; = 1 if self-financed R&D > 0	Capitalia	2003	811	0.89	0.31	0.00	1.00	1.00	1.00	1.00
R&D_SELFFIN_B	Dummy variable; = 1 if R&D is fully self-financed	Capitalia	2003	811	0.83	0.37	0.00	1.00	1.00	1.00	1.00
INV_SELFFIN_%	Proportion of investment covered by self-financing	Capitalia	2003	811	0.50	0.39	0.00	0.10	0.50	0.95	1.00
R&D_SELFFIN_%	Proportion of R&D covered by self-financing	Capitalia	2003	811	0.80	0.34	0.00	0.70	1.00	1.00	1.00
Explanatory variables											
<i>Firm's financial and structural characteristics</i>											
NO INTERNAL RATIONING	Categorical variable: = 0 if Cash flow-1 > (Investmentst + R&Dt) for three years	Capitalia	2003	811	0.38	0.49	0.00	0.00	0.00	1.00	1.00
LOW INTERNAL RATIONING	Categorical variable: = 1 if Cash flow-1 > (Investmentst + R&Dt) for two years	Capitalia	2003	811	0.26	0.44	0.00	0.00	0.00	1.00	1.00
MEDIUM INTERNAL RATIONING	Categorical variable: = 2 if Cash flow-1 > (Investmentst + R&Dt) for one year	Capitalia	2003	811	0.17	0.37	0.00	0.00	0.00	0.00	1.00
STRONG INTERNAL RATIONING	Categorical variable: = 3 if Cash flow-1 is never > (Investmentst + R&Dt)	Capitalia	2003	811	0.19						
LEVERAGE	Debt / Total assets	Aida	2001–03	811	0.72	0.18	0.07	0.59	0.75	0.86	0.99
PUBLIC SUBSIDIES	Dummy variable = 1 if the firm received fiscal or public subsidies	Capitalia	2003	811	0.67	0.47	0.00	0.00	1.00	1.00	1.00
TURNOVER	% turnover variation in 2002–03	Aida	2002–03	811	0.01	0.19	-1.00	-0.08	0.01	0.09	1.38
ROI	Return on investment	Aida	2001–03	811	5.50	4.84	-12.04	2.80	4.90	7.48	27.77
STD_ROI	Ln ROI standard deviation 1996–2003	Aida	1996–2003	811	0.62	0.97	-3.18	-0.02	0.71	1.29	2.94
TOTAL ASSETS	Ln of total assets	Capitalia	2003	811	9.46	1.21	6.81	8.72	9.33	10.11	14.31
AGE	Ln of the years of the firm	Capitalia	2003	811	3.34	0.53	1.61	3.00	3.33	3.71	5.18
GROUP	Dummy variable; = 1 if the firm belongs to a group	Capitalia	2003	811	0.36	0.48	0.00	0.00	0.00	1.00	1.00
HI-TECH	Dummy variable; = 1 if the firm belongs to Hi-Tech industry	Capitalia	2003	811	0.06	0.23	0.00	0.00	0.00	0.00	1.00
HIGH_R&D	Dummy variable = 1 if R&D / Total asset > 4.5%	Capitalia	2003	811	0.09	0.28	0.00	0.00	0.00	0.00	1.00
HIRING	Dummy variable = 1 if the firm hired people in 2001–03	Capitalia	2003	811	0.92	0.28	0.00	1.00	1.00	1.00	1.00
<i>Relationship lending and information asymmetries</i>											
MULTIPLE BANKING	Ln number of bank relationships	Capitalia	2003	811	6.65	3.51	2.00	4.00	6.00	9.00	23.00

		Source	Year	N	Mean	SD	Min	Q1	Median	Q3	Max
LOCAL BANKING	Dummy variable = 1 if main bank has registered office in the same province as firm	Capitalia	2003	811	0.54	0.50	0.00	0.00	1.00	1.00	1.00
MAIN BANK	Proportion of debt with the main bank	Capitalia	2003	811	30.82	23.97	0.00	15.00	30.00	45.00	100.00
DURATION	Ln age of relationship with the main bank	Capitalia	2003	811	2.59	0.78	0.00	2.30	2.71	3.18	4.58
CREDIT RATIONING	Dummy variable = 1 if the firm would desire more credit	Capitalia	2003	811	0.13	0.34	0.00	0.00	0.00	0.00	1.00
OPACITY	Intangible assets / Tangible assets	Aida	2001–03	811	0.47	0.15	0.05	0.37	0.47	0.57	0.98
<i>Market structure characteristics</i>											
HHI_LOANS	Ln Loans Herfindal index by region	Bank of Italy	2003	811	-2.68	0.27	-3.44	-2.71	-2.70	-2.54	-1.32
SOUTH_NORTH	Dummy variable = 0 if the firm belongs to the South; 1 otherwise	Bank of Italy	2003	811	0.73	0.45	0.00	0.00	1.00	1.00	1.00

Within the first group, that is, the variables describing the financial and structural firm characteristics like AGE, TOTAL_ASSETS and GROUP, we also define a proxy for internal rationing, by comparing the cash flows in the year $t - 1$ and the expenditures in traditional and R&D investments in the year t . If at the end of the year a firm has enough funds to (potentially) self-finance next year's traditional and R&D investments, then no form of internal rationing is observed in that period. Considering our three-year dataset, we map internal rationing by means of a set of binary variables described in Table 2. 'NO INTERNAL RATIONING' defines the case in which cash flow is larger than the subsequent year's investment and R&D expense for three years. Similarly, 'LOW INTERNAL RATIONING' refers to a two-year period, 'MEDIUM INTERNAL RATIONING', to one year; finally, we use as a reference level the case of 'STRONG INTERNATIONAL RATIONING', that is, when cash flow is always lower than the next year's investment and R&D expense. The internal rationing variable represents a way to calculate the potential internal liquidity sources in the short term, but it is also one of the most widely used bank indicators in the loan application evaluation process.

As suggested by previous empirical analyses (Hall 2002; Czarnitzki 2006; Meuleman and De Maeseneire 2008), public funding is an important source of financing in sustaining R&D activities. In our study, we identify the firms that received public funding by means of the binary variable 'PUBLIC SUBSIDIES'.¹

Among income variables, we first consider 'TURNOVER', which measures the capacity to produce resources and, indirectly, self-financing. Similarly, the return on investment ('ROI') measures the firm's capacity to generate resources; however, a high return variability measured by its standard error ('STD ROI') is generally linked to a greater difficulty in obtaining external funding.

¹ Section F3, Fiscal subsidies – Question F3.1: 'Has the firm used financial and/or fiscal subsidies in the period 2001–2003?'. The question was addressed without distinction to all firms, regardless of the type of investment made, although public subsidies may be expected to be more relevant in R&D than in traditional investments.

The literature stresses that high-R&D firms have different financial constraints. On the one hand, Piga and Atzeni (2007) shows that R&D intensive firms² are less financially binded. On the other hand, Li (2011) suggests that they indeed face stronger constraints. To investigate this empirical issue, we identify R&D-intensive firms by constructing a ‘HIGH_R&D’ binary variable.³ Since R&D is heavily dependent on human capital, a further proxy for the degree of R&D intensity can be given by the firm’s past recruitment, ‘HIRING’.⁴ A further control variable, HI-TECH, provides information on whether or not a firm belongs to the HI-TECH sector.

The degree of the bank-firm information asymmetry can be summarized by the following set of variables: (1) the number of banks from which the firm borrows (‘MULTIPLE BANKING’); (2) the main lending bank’s share of the firm’s total debt (‘MAIN BANK’); (3) two variables identifying the colocation (same province) and the duration of the relationship with the main bank (‘LOCAL BANKING’ and ‘DURATION’); (4) a binary variable (‘CREDIT RATIONING’) identifying credit-constrained firms;⁵ and (5) the degree of ‘OPACITY’ proxied by the ratio between intangibles over tangibles.

Finally, the degree of banking competition is measured by the loan regional-market concentration (‘HHI_LOANS’), which can be expected to alter information gathering and loan economic profitability, while the geographic regional diversification of firms belonging to the North and the South is captured by a dummy variable SOUTH_NORTH.

² Firms belonging to the last distribution decile of the ratio between expenditure in R&D and total assets.

³ Similarly to Piga and Atzeni (2007) we find an inverse U-shaped relationship between self-financing and R&D intensity: R&D-intensive firms invest more than 4.5 per cent of their total assets in R&D activities. Consequently, we generate ‘HIGH_R&D’ binary variable that assumes value equal to 1 if a firm’s R&D expenditure over total assets is greater than 4.5 per cent.

⁴ This variable was obtained directly from the questionnaire’s Section B on LABOUR FORCE. Question B.2.1: ‘Did the company recruit in the years 2001–2003?’ (see Capitalia 2005). 90 per cent of firms in our sample reported that they recruited during the period considered.

⁵ Questionnaire Section F — Question F1.5: ‘In 2003, would the firm have liked to have obtained more credit at the interest rate agreed with the bank?’ (see Capitalia 2005).

4. Methodology and Results

4.1 Poolability Analysis

This section illustrates the empirical application carried out on the case study of Italian firms. Both logit and logistic regressions are estimated in order to investigate the self-financing decisions of firms with regard to traditional and R&D investment. While details for such analyses are given in Sections 5.2 and 5.3, it is first worth exploring a methodological aspect related to the second research question of this paper: can the findings on the determinants of investment self-financing be generalized to our entire sample?

The concept of ‘poolability’, or ‘parameter stability’, is commonly used in applied economics. Tests aiming to assess a null hypothesis of poolability address the question of whether a single model should be employed to fit all the data available, or if different models should be specified for different subsets of the dataset. In particular, it may be of interest to know whether the estimated regression parameters for some variables are stable over data subsamples, that is, if for instance the income-related parameter that would be obtained for the lower half, income-wise, of a sample of individuals is significantly different from the one that would be estimated for the upper half. Extending this reasoning to the entire vector of betas is straightforward.

Formally, subsamples can be created according to an index $i = 1, \dots, I$, leading to a testable H_0 hypothesis of equal regression parameter vectors for all values of i . Consequently, the restricted model will be $y_{ig} = x_{ig} S + u_{ig}$ (with $S_1 = S_2 = \dots = S$), while the unrestricted model will be, for each i , $y_{ig} = x_{ig} S_i + u_{ig}$, where u_{ig} is the error term.

Common tests for poolability (such as the Chow test and the Roy-Zellner test) have been developed over the years, for example on the basis of different assumptions on the distribution of the errors (homoskedasticity/heteroskedasticity) (Baltagi 2001). However, model linearity and error normality are basic assumptions for the mainstream tests, and do not fit our modelling framework. Since all the subsequent logit and logistic regressions are estimated by means of maximum

likelihood, we follow Watson and Westin (1975) and Patuelli et al. (2010) and test for poolability by means of a likelihood ratio test:

$$\lambda = 2(\log L_u - \log L_r), \quad (1)$$

where $\log L_u$ and $\log L_r$ are the log-likelihoods of the unrestricted and restricted models, respectively; λ is asymptotically distributed as a χ^2 , the number of degrees of freedom being equal to the number of restrictions. If H_0 (the hypothesis of ‘poolability’) is rejected by the test, empirical evidence suggests that separate models should be estimated for the subsamples. This approach will be followed in the remainder of the paper.

4.2 The Self-Financing Decision

4.2.1 A Dichotomic Analysis of Self-Financing: Univariate Logit

As our first empirical analysis, we investigate the determinants of the dichotomic self-financing decision related to either traditional or R&D investment. For both the former and the latter, we analyse the presence of self-financing case and the full self-financing case (see Section 4.1). The variables $INV_SELFFIN_{A, B}$ and $R\&D_SELFFIN_{A, B}$ are treated by means of simple logit specifications:

$$\Pr(SELFFIN_i = 1) = \frac{1}{1 + \exp(-\gamma X_i)}, \quad (2)$$

where, for the generic firm i , X is the matrix of explanatory variables given in Section 4.2, and γ is a vector of regression parameters to be estimated (Greene 2003). Consequently, we estimate two logit models for traditional investment, and two for R&D investment.⁶

⁶ Following the procedure described in Section 4.1, we tested all logit models for poolability. Since no consistent rejection of the poolability hypothesis was found, we maintain, for the logit specification, the pooled models.

Table 3 presents our estimation results, with three relevant findings. First, PUBLIC SUBSIDIES negatively impacts self-financing decisions (SELFFIN_A). In other words, public subsidies, *ceteris paribus*, reduce internal funding or debt financing. Similarly, full self-financing (SELFFIN_B) is strongly influenced by the presence of public incentives in traditional and R&D financing choices as well.⁷ Second, the relationship lending variables (MULTIPLE BANKING, LOCAL BANK, MAIN BANK and DURATION), as well as CREDIT RATIONING, OPACITY, and HHI LOANS, are all statistically significant, and with the theoretically predicted signs, for traditional self-financing decisions. On the one hand, the probability of fully self-financing decreases as the bank increases the number of banking relationships; on the other hand, as the banking market becomes more concentrated, firms have greater opportunities for external funding, and thus self-financing decreases. These results are generally not confirmed for the self-financing of R&D investment, with the exception of MAIN BANK.

To better understand the firm self-financing behaviour, we also consider a proxy for the availability of internal liquidity, measured by the binary variables for MEDIUM, LOW and NO RATIONING. As expected, the results suggest that, if the firm holds liquidity in excess to current expenses, the probability of self-financing increases, even if this result appears to be statistically significant only in the case of INV_SELFFIN_B, that is, in the case of full self-financing.

In addition, other significant findings can be observed regarding the positive impact of LEVERAGE on INV_SELFFIN_A. In the case of traditional investment, this result is consistent with corporate structure theory. In fact, the trade-off theory suggests an optimal leverage ratio and, therefore, higher-leverage firms tend to employ less self-financing. This finding does not hold in the case of R&D_SELFFIN_A, where leverage cannot be considered as a complement of internal financial resources.

⁷ This result is stable and robust to all other models tested (univariate and bivariate).

Table 3 – Traditional versus R&D investments: logit models

Dependent variable	INV_SELFFIN		R&D_SELFFIN	
	INV_SELFFIN_A	INV_SELFFIN_B	R&D_SELFFIN_A	R&D_SELFFIN_B
LOW INTERNAL RATIONING	0.06	0.91***	0.42	0.06
MEDIUM INTERNAL RATIONING	-0.14	0.21	-0.38	-0.27
STRONG INTERNAL RATIONING	0.48	0.42	0.40	-0.12
LEVERAGE	-1.87**	-0.22	2.19**	0.20
PUBLIC SUBSIDIES	-0.08	-1.77***	-0.73**	-2.18***
TURNOVER	0.37	-0.29	-0.28	-0.11
ROI	0.06**	0.00	0.01	0.00
STD_ROI	-0.16	0.14	0.03	0.03
TOTAL ASSETS	0.33***	0.17*	-0.44***	-0.21**
AGE	0.18	-0.41*	0.04	-0.24
GROUP	0.19	-0.04	0.49	0.15
HI-TECH	1.50**	0.34	0.72	-0.12
HIGH R&D	0.57	1.16***	0.10	-1.07***
HIRING	-0.27	-0.28	1.37***	-0.09
MULTIPLE BANKING	-0.31	-0.61***	-0.04	-0.01
LOCAL BANKING	-0.04	-0.23	0.08	0.06
MAIN BANK	0.00	-0.01	-0.01	-0.01*
DURATION	0.20	0.29**	0.03	-0.02
CREDIT RATIONING	-0.42	-0.60*	-0.16	0.05
OPACITY	-0.21	-1.66***	0.39	-0.32
HHI_LOANS	-0.41	-1.01***	-0.41	-0.25
SOUTH_NORTH	-0.10	0.12	-0.87**	-0.57**
MIX_AR	1.81***	1.31***		
MIX_AU			3.33***	0.55**
(Intercept)	-3.24**	-3.32**	2.19	4.82***
Residual deviance (dof)	717.97 (787)	673.92 (787)	428.62 (787)	883.16 (787)
AIC	765.97	721.92	476.62	931.16
BIC	878.73	834.68	589.38	1043.92

***, **, * denote 1%, 5%, 10% coefficient significance, respectively.

Moreover, a higher profitability – here measured by the ROI variable – suggests a higher probability of self-financing in the case of INV_SELFFIN_A. This result supports the pecking-order theory, based on which higher profitability allows greater self-financing.

Corporate structure theory highlights the relevance of firm size on the financing attitude. In this respect, we find that larger firms tend to use more internal equity to finance their traditional investments. The contrary holds in the case of R&D. This result is consistent with the literature

suggesting that, when R&D firms become large, they can more easily fund their investments with external funds (Berger and Udell 1998).

The HI-TECH and HIGH R&D variables positively influence INV_SELFFIN. This result is coherent with the literature suggesting more difficulties in obtaining external funds for firms in the HI-TECH sector. However, for HIGH R&D, we find an opposite result in the case of R&D SELFFIN. As previously suggested in the literature – see, for example, Piga and Atzeni (2007) – it is necessary to make a distinction between low and high R&D investments. With regard to the latter, it has been shown that the high-R&D firm has gained enough reputation on the market and consequently can employ more external than internal funds.

Higher levels of HIRING may be related to increasing financing needs. Since R&D-oriented companies are often labour-intensive and informationally opaque, it is more likely that they satisfy their financing needs internally. Here, we observe a positive relation between HIRING and the probability of R&D self-financing. This result does not hold in the traditional investment case. Finally, the geographical variable SOUTH_NORTH is statistically significant, and with the expected sign, only in the case of R&D_SELFFIN.

In addition to the above control variables, we find that ‘symmetric’ variables (the R&D self-financing rate in the case of investments and vice versa the INV self-financing rate in the case of R&D investments) are strongly significant and positive. We expected self-financing of investments to decrease as self-financing of R&D increases (a crowding out effect), since both variables depend on the overall availability of internal funding. However, our sample suggests quite the opposite (i.e., an inertia effect). Firms with higher self-financing of investments tend to self-finance R&D – all other else being equal – to a greater extent as well. The latter result calls for a further exploration of the relation/interaction between internal funds used to finance R&D and those used for traditional investments.

4.2.2 Bivariate Logit

We investigate the latter point raised in Section 4.2.1 by jointly modelling the two types of investment decisions within the framework of bivariate logit models. Writing for notational simplicity the logit operator as ‘logit’, and following Yee (2008), we define the following model:

$$\begin{aligned} y_1 &= \text{logit } P(Y_1 = 1|x) = S_{(1)0} + f_{(1)}(x) \\ y_2 &= \text{logit } P(Y_2 = 1|x) = S_{(2)0} + f_{(2)}(x) \\ y_3 &= \log(\mathbb{E}) = S_{(3)0} + \dots, \end{aligned} \quad (3)$$

where Y_1 is INV_SELFFIN, Y_2 is R&D_SELFFIN, $S_{(j)0}$ is the intercept for the j th equation, $f_{(j)}(x)$ is generally indicating the linear combination of explanatory variables x and the related regression coefficients. Finally, models the dependency between INV_SELFFIN and R&D_SELFFIN for the average firm. More precisely, is the odds ratio $p_{00}p_{11}/p_{10}p_{01}$, in which, for example, $p_{11} = P(Y_1 = 1, Y_2 = 1|x)$.⁸ The third equation usually contains just the intercept term, that is, it is hypothesized that the relationship between y_1 and y_2 does not depend on the explanatory variables. The model is fully parametric and can be estimated by ML (Yee 2010).

In order to answer our first research question (i.e., if traditional and R&D investment self-financing are similar), a further restriction can be applied, by constraining the vectors of regression coefficients in the first two equations to be equal. We estimate a reduced-rank vector generalized linear model (RR-VGLM). An RR-VGLM is essentially a multivariate generalized linear model (VGLM) iteratively estimating unknown matrices of constraints in order to reduce the dimensionality of a problem.⁹

Finally, the hypothesis of ‘poolability’ (or, drawing a comparison to proportional odds models, ‘parallelism’) of the INV_SELFFIN and R&D_SELFFIN decisions can be tested by means of a likelihood ratio test between the constrained and unconstrained models. We find that the

⁸ It should be noted that the odds ratio is a truly probabilistic result, differently, for example, from the case of the bivariate probit, where a simple correlation coefficient is estimated.

⁹ We refer to Yee and Hastie (2003) for computational details.

unconstrained model is statistically superior for both SELFFIN_A and SELFFIN_B, although in the latter case the test is only 10 per cent significant. Consequently, we only present the results for the unconstrained estimation.

From the economic point of view, our main results for the univariate logit models are substantially confirmed. As a robustness test, the bivariate logit models confirm the structural differences between INV_SELFFIN and R&D_SELFFIN. Some minor differences with the univariate estimations emerge from the analysis of Table 4, which can be summarized as follows. Leverage, in the case of R&D_SELFFIN, does not play any role. Moreover, the new bivariate models imply minor differences in statistical significance with regard to GROUP, MAIN BANK, DURATION and CREDIT RATIONING. Finally, with respect to public subsidies, we find a strong effect in terms of less self-financing needs in all the models analysed. This result suggests the need to better disentangle the effects of public subsidies, which is a task that will be undertaken in the next sections.

4.3 The Level of Self-Financing

In this section, we aim to further investigate investment self-financing decisions. After analysing the binary decisions of whether or not to self-finance investments or to fully self-finance it, we focus on the percentage of self-financing. Because the number of investment decisions and their amount are unknown, we assume that the declared self-financing percentages emerge from the aggregation of (independent) binary decisions on self-financing (or not) each infinitesimal amount of investment (either traditional or in R&D) undertaken.¹⁰ From a statistical perspective, the analysis of self-financing percentages – a continuous variable – by means of logistic regressions allows to greatly increase the quantity of available information in comparison with the logit models.

¹⁰ We take the $(X/100)$ percentage of self-financing as the number of (X) successes over the number of (100) trials. As a consequence, with an equal number of trials per firm, the weight associated with each firm within the logistic regression is the same. This is indeed a desirable property for our study, since our focus is on the average behaviour of firms, and not, say, on the aggregate economic effects of self-financing.

Table 4 – Traditional versus R&D investments: bivariate logit models

Dependent variable	INV_SELFFIN_A		INV_SELFFIN_B		R&D_SELFFIN_A		R&D_SELFFIN_B	
	Coefficient	<i>t</i>	Coefficient	<i>t</i>	Coefficient	<i>t</i>	Coefficient	<i>t</i>
LOW INTERNAL RATIONING	0.17	0.58	0.94	2.81	0.51	1.31	0.11	0.40
MEDIUM INTERNAL RATIONING	-0.18	-0.69	0.19	0.57	-0.40	-1.17	-0.27	-1.04
STRONG INTERNAL RATIONING	0.46	1.50	0.42	1.18	0.43	1.03	-0.10	-0.36
LEVERAGE	-1.78	-2.11	-0.26	-0.36	1.14	1.14	0.01	0.02
PUBLIC SUBSIDIES	-0.41	-2.02	-1.95	-9.70	-0.96	-3.04	-2.25	-10.12
TURNOVER	0.24	0.50	-0.28	-0.56	-0.39	-0.61	-0.15	-0.33
ROI	0.06	2.66	0.00	0.12	0.04	1.38	0.00	0.11
STD_ROI	-0.13	-1.34	0.14	1.35	0.06	0.49	0.03	0.36
TOTAL ASSETS	0.25	2.43	0.14	1.48	-0.23	-1.77	-0.18	-2.05
AGE	0.11	0.55	-0.43	-1.97	0.00	-0.02	-0.25	-1.38
GROUP	0.23	1.04	-0.01	-0.05	0.50	1.66	0.15	0.78
HI-TECH	1.51	2.36	0.37	0.93	0.95	1.35	-0.08	-0.22
HIGH R&D	0.49	1.26	1.16	3.16	0.31	0.59	-1.01	-3.12
HIRING	-0.06	-0.17	-0.21	-0.60	1.08	2.99	-0.10	-0.34
MULTIPLE BANKING	-0.33	-1.54	-0.61	-2.88	-0.28	-1.01	-0.07	-0.36
LOCAL BANKING	-0.01	-0.08	-0.21	-1.07	0.05	0.22	0.05	0.27
MAIN BANK	0.00	-0.86	-0.01	-1.57	-0.01	-1.96	-0.01	-1.95
DURATION	0.21	1.60	0.29	1.95	0.12	0.69	0.00	0.01
CREDIT RATIONING	-0.42	-1.72	-0.62	-1.84	-0.27	-0.79	0.01	0.04
OPACITY	-0.37	-0.57	-1.69	-2.57	-0.23	-0.27	-0.39	-0.68
HHI_LOANS	-0.51	-1.53	-1.03	-2.67	-0.60	-1.40	-0.30	-1.01
SOUTH_NORTH	-0.19	-0.61	0.07	0.25	-0.83	-2.05	-0.57	-2.29
(Intercept)	-1.08	-0.70	-1.80	-1.10	2.43	1.25	4.90	3.55
Residual deviance (dof)	1185.12	(2386)	1573.75	(2386)	1185.12	(2386)	1573.75	(2386)
AIC	1279.12		1667.75		1279.12		1667.75	
BIC	1499.94		1888.57		1499.94		1888.57	

Additionally, as suggested in Section 4.1, our logistic regression analysis is first carried out for the entire (pooled) data set (see Section 4.3.1), on which poolability tests are subsequently carried out. The results obtained for the consequent unpooled models are given in Section 4.3.2. All empirical results are given with robust standard errors obtained by means of the sandwich estimator (Zeileis 2004, 2006).

4.3.1 Pooled Analysis

We investigate the determinants of self-financing of traditional and R&D investments. The continuous dependent variables INV_SELFFIN_% and R&D_SELFFIN_% are analysed by means of univariate logistic regression specifications, whose results are given in Table 5.

Consistently with all previous specifications, the PUBLIC SUBSIDIES variable is statistically significant, and its presence implies lower self-financing usage in both the traditional and R&D cases. Therefore, public incentives appear to be a useful ‘support’ to those firms that have limited internal financial sources.

Firms with LOW INTERNAL RATIONING have a higher probability of self-financing traditional investments. In the previous logit and bivariate specifications, this result was statistically significant only in the case of full self-financing (SELFFIN_B). However, as in the previous section, the internal rationing variable is not significant for R&D self-financing. Again, from a financing point of view, the presence of public subsidies appears to strengthen the internal rationing component.

In addition, public subsidies to R&D appear potentially as a necessary condition to gain access to the credit market, whereas self-financing seems weakly related to internal rationing conditions. Those firms taking advantage of public subsidies are engaged in less intensive investment and R&D self-financing, as shown in Table 5, and according to Table 1. However, the relationship between public subsidies and internal rationing cannot be tested here. In fact, we cannot ascertain whether

the presence of public subsidies is linked to low internal rationing or not. Further investigation on this aspect is provided in the next subsection, where we consider only subsidized firms.

Table 5 – Traditional versus R&D investments: logistic regression models

Dependent variable	INV_SELFFIN_%	R&D_SELFFIN_%
LOW INTERNAL RATIONING	0.41**	0.16
MEDIUM INTERNAL RATIONING	0.03	-0.29
STRONG INTERNAL RATIONING	0.20	-0.06
LEVERAGE	-1.33**	0.49
PUBLIC SUBSIDIES	-0.52***	-1.22***
TURNOVER	-0.17	-0.37
ROI	0.03**	0.01
STD_ROI	0.03	0.01
TOTAL ASSETS	0.25***	-0.30***
AGE	-0.09	-0.17
GROUP	0.02	0.17
HI-TECH	0.38	0.04
HIGH R&D	0.45*	-0.29
HIRING	-0.26	0.56**
MULTIPLE BANKING	-0.43***	0.02
LOCAL BANKING	-0.10	0.09
MAIN BANK	0.00*	0.00
DURATION	0.18**	0.02
CREDIT RATIONING	-0.31*	-0.05
OPACITY	-0.76*	-0.18
HHI_LOANS	-0.39*	-0.32
SOUTH_NORTH	0.11	-0.38
MIX_AR	1.42***	
MIX_AU		1.93***
(Intercept)	-2.44**	3.46***
Residual deviance (dof)	921.93 (787)	775.78 (787)
AIC	1006.21	841.13
BIC	1118.97	953.89

***, **, * denote 1%, 5%, 10% coefficient significance, respectively.

From an economic viewpoint, we may expect the return on investment (ROI) to be an important variable to explain the presence of investment self-financing. In Table 5, ROI appears to be statistically significant and with the expected positive sign.

A similar case is the one of the relationship lending variables (MULTIPLE BANKING, MAIN BANK, DURATION, CREDIT RATIONING, OPACITY and HHI_LOANS), which were

statistically significant, in the previous analyses, for full self-financing of traditional investment. This result holds in the case of INV_SELFFIN_%, while these variables do not seem to play a role in the case of R&D_SELFFIN_%. With reference to the banking sector, it should be noted that while LEVERAGE is statistically significant with a negative impact in the case of INV_SELFFIN_% it is not significant in explaining R&D self-financing.

In summary, by analysing our dependents as continuous variables we have exploited a different effect of relationship lending and information asymmetries factors on self-financing decisions. While in the preceding logit models (see Tables 3 and 4) the banking variables were statistically significant only in the case of full self-financing, the logistic regressions further disentangle the role of the banking variables, by providing results based on the full distribution of self-financing rates.

As seen in the univariate logit analyses, and as suggested by the probabilistic relationship estimated in the bivariate logit, there is a significant and positive relationship between percentages of self-financed traditional and R&D investment. Ideally, it could be convenient to develop – similarly to the bivariate logit case – a bivariate logistic regression estimation approach,¹ so to explicitly model the inertia, or dependence, between investment choices.

4.3.2 Unpooled Analysis

The results presented in Section 4.3.1 may now be investigated, as suggested above, from a parameter heterogeneity/poolability perspective. We carry out poolability tests for our two logistic regression models against a number of explanatory variables selected on the basis of economic theory considerations and anecdotic evidence. The variables tested are: HI-TECH, CREDIT RATIONING, LOCAL BANK, LEVERAGE, TOTAL ASSETS, SOUTH_NORTH and PUBLIC SUBSIDIES.

¹ To the best of our knowledge, no such estimation framework (bivariate logistic regression) is available in the literature for non-binary dependent variables. Estimates obtained from a seemingly unrelated regression (SUR) model, carried out on the self-financing percentage in a linear framework, generally confirm the findings obtained for the univariate logistic regressions. SUR results are not given here, but are available from the authors on request.

For each of these variables, we test the pooled model against the unpooled model by means of LRTs. In the pooled model, the variable to be tested for poolability is included in the standard way as a categorical variable, and therefore it affects – if significant – only the model intercept. In the unpooled model, the tested variable is interacted with all remaining variables, therefore generating two vectors of regression coefficients (including two intercepts). Continuous variables, such as TOTAL ASSETS, are transformed, only for testing purposes, into binary, by splitting at the median.

Only TOTAL ASSETS and PUBLIC SUBSIDIES are significant for both (pooled) models and render statistically significant LRTs, suggesting a doubly-unpooled model specification, and leading to a four-way split of our sample.² As a consequence, four subsamples, for which we estimate our model separately, emerge:

- i) above-the-median firms which received public subsidies ($N = 280$);
- ii) below-the-median firms which received public subsidies ($N = 264$);
- iii) above-the-median firms which did not receive public subsidies ($N = 125$);
- iv) below-the-median firms which did not receive public subsidies ($N = 142$).

The new structure of our data set requires some additional considerations. In the first place, the analyses presented in this section are potentially important in order to shed further light on self-financing choices: even within the firms which receive public subsidies, different financing schemes may emerge for investment and R&D. In the opposite case, where firms are not subsidized, we find that explanatory variables are all statistically non-significant, with the exception of the ‘symmetric variables’ (the inertia factor). This latter finding suggests that when subsidies are absent, financial and credit market variables become irrelevant, and we observe linked self-financing strategies, driven by unobserved factors.

² This finding is further supported by statistically significant ‘hierarchical’ LRTs, testing two-way models (split either by TOTAL ASSETS or PUBLIC SUBSIDIES) against the four-way model.

Focusing on subsidized firms only, our analysis suggests exploring self-financing decisions by splitting the data at the firm's size median. Our results, presented in Table 6, suggest that, consistently with Ughetto (2008) small firms behave differently from the large firms.

Table 6 – Traditional versus R&D investments: logistic regression models, unpooled (PUBLIC SUBSIDIES = YES)

Independent Variables	INV_SELFFIN_%		R&D_SELFFIN_%	
	Above	Below	Above	Below
TOTAL ASSETS (below/above median)				
LOW INTERNAL RATIONING	0.23**	0.61*	-0.25	0.25
MEDIUM INTERNAL RATIONING	0.23	0.04	-0.79**	-0.39
STRONG INTERNAL RATIONING	0.04	0.30	-0.23	-0.55
LEVERAGE	-2.84	-0.23	1.62	-2.12
TURNOVER	-0.58***	-0.12	-0.96	-0.54
ROI	0.06	0.03	0.05	-0.01
STD_ROI	-0.09**	0.19	0.15	-0.20
TOTAL ASSETS	0.33	0.59***	-0.23	-0.80***
AGE	-0.20***	0.08	-0.19	-0.13
GROUP	-0.01	0.00	0.54**	-0.18
HI-TECH	0.72	-0.37	-0.66	0.88
HIGH R&D	-0.08*	0.64*	-0.52	-0.32
HIRING	0.83	-0.54	-0.66	0.95**
MULTIPLE BANKING	-0.23*	-0.94***	0.06	0.23
LOCAL BANKING	0.13	-0.24	-0.15	0.42*
MAIN BANK	0.00	-0.02***	0.01	-0.02**
DURATION	0.12	0.21	0.02	0.06
CREDIT RATIONING	-0.50	-0.04	0.07	0.00
OPACITY	-0.52	-0.33	0.74	-0.09
HHI_LOANS	-0.30	-0.32	-0.45	-0.38
SOUTH_NORTH	0.28***	0.09	-0.74**	0.23
MIX_AR	1.21	1.15***		
MIX_AU			1.95***	1.27***
(Intercept)	-3.70	-5.78**	1.22	7.77***
Residual deviance (dof)	305.29 (257)	277.74 (241)	295.42 (257)	260.52 (241)
AIC	371.42	335.63	349.83	314.01
BIC	455.02	417.88	433.43	396.26

***, **, * denote 1%, 5%, 10% coefficient significance, respectively.

Our evidence suggests at least three important insights, related to: (i) the lack of leverage significance for the firm's self-financing decisions; (ii) the increased importance of the relationship

lending variables, for both INV and R&D self-financing; (iii) the varying influence of the firm's growing opportunities, measured by HIGH R&D and HIRING.

With reference to the first aspect, the pooled analyses of Section 4.3.1 suggest that leverage is generally statistically significant, determining lower levels of investment self-financing. However, for the sample of subsidized firms, LEVERAGE and CREDIT RATIONING lose their relevance in favour of the geographical component (SOUTH_NORTH): large(r) firms belonging to northern regions are more self-financed in the case of traditional investment; the opposite holds in the case of R&D expenditure. As shown in Piga and Atzeni (2007), this simple geographical variable may capture differences in business opportunities, leverage and other potential unobserved variables. For example, northern firms show, on average, a 25 per cent higher leverage than the southern ones, that is, lower self-financing. This North-South divide does not appear to be relevant for very small firms, which may be expected to be credit-constrained and with limited internal resources both in the North and the South. On the other hand, with regard to larger firms, the ones located in the North appear to follow the standard pecking order theory a la Myers and Majluf (1984), while the economic environment in the South makes firms, on average, less profitable and consequently more internally credit-constrained. With regard to R&D investment, instead, the lower share of self-financing of firms in the North is most likely due to the core-periphery effects of credit access, that is, firms located in the proximity of a nation's financial core may exploit closer informal relationships with bank headquarters (see, e.g., Alessandrini *et al.* 2009; Bernini and Brighi 2012).

Considering the second aspect, we observe that, as in the previous analyses, MULTIPLE BANKING impacts negatively over the self-financing decision for traditional investment. Furthermore, this effect is stronger in the case of small firms. Small firms involved in R&D self-financing show similar behaviour, which however is captured by the MAIN BANK variable. In other words, the banking variables appear to be more important in the case of smaller firms. This is coherent with the theory on asymmetric information (Berger and Udell 1998), for which small firms are more self-financed because of informative opacity.

The third set of variables – HIGH R&D and HIRING – measures the growth opportunities of a firm. The literature suggests that a firm with R&D investment projects is more likely to be denied credit, that is, firms engaged in innovative projects face a more difficult access to debt finance (Piga and Atzeni 2007). Moreover, in the case of R&D, there is a risk of innovation spillovers once the idea becomes common knowledge. In this respect, some authors suggest that the best way to preserve the firm's intangible capital is to self-finance it (Bhattacharya and Chiesa 1995). For the above reasons, we expect a positive relationship between variables proxying for R&D investment and the related self-financing propensity. According to Piga and Atzeni (2007), as a firm becomes larger and important in the R&D sector, it can achieve easier access to the credit market, and will be less credit-rationed. Within our empirical framework, as a firm becomes larger (above the median), its self-financing propensity will be less important. The contrary holds for small firms (below the median). With regard to HIRING, the level of R&D self-financing is positively related to small firms deciding to hire new employees. In the other case, the variable is not statistically significant.³

5. Conclusions

This paper analysed the main determinants of the self-financing behaviour pertaining to traditional and R&D investments, for a sample of firms engaged in both activities. We were interested in explaining the firms' decision to self-finance investments and the extent to which self-financing is resorted to. We estimated logit and logistic regression models for the self-financing choice and the level of self-financing, respectively. Separate models were carried out to explain self-financing of traditional and R&D investments, while explicitly considering the in-firm correlation between the two.

Our models showed that several economic variables can help explain the different patterns of traditional and R&D investment self-financing. The main results suggest that bank relationships and

³ We also observe that, while in the previous logit analyses HIGH_TECH was statistically significant in the case of INV_SELFFIN, in the present (unpooled) logistic regression analysis it is never significant.

credit constraints – coherently with the previous literature – are relevant only for traditional investments, while public subsidies and firm size play a key role in the case of R&D.

In this regard, a poolability analysis showed that public subsidies can be seen as the main discriminating factor for self-financing. In fact, when firms are not subsidized, their self-financing decisions are exogenous to any economic variable considered in our modelling framework. In other words, the absence of public subsidies implies the irrelevance of any other common determinant explaining the firm's self-financing decisions. From an economic rationale, public subsidies can be interpreted as signals used by firms to attract external funds in both traditional and R&D investments.

Focusing our discussion only on subsidized firms, further analyses also showed that, when the sample is split in four groups – by the availability of public subsidies and firm size (above or below the total assets median) – it is possible to identify specific effects on self-financing which would otherwise not be accounted for in the pooled model, because of unobserved heterogeneity. We found that, for smaller firms, selected banking variables (proxies for relationship lending) are significant, but only in the case of traditional investments. In contrast, firms deciding to engage in R&D self-financing show weaker benefits from banking relationships.

The unpooled analysis allowed to capture the importance of the firms' geographical location (North versus South of Italy), though only for larger firms. For the latter, firm age and turnover are associated with higher levels of traditional investment self-financing, as expected, while in the case of R&D, once the main determinant in the pooled model (public subsidies) is accounted for, no relevant variable emerges aside from the North-South divide. When smaller firms are considered, total assets are linked to self-financing of traditional and R&D investments, although with opposite signs: increasing in size implies an improved access to external finance when it comes to R&D, which is a particularly risky investment to fund (building a firm's reputation plays a crucial role in this regard); for traditional investments, instead, the standard pecking order rule, with a preference for the use of internal resources, applies as the firm's size grows. This final analysis suggests that

firms engaging in R&D face more severe constraints in attracting external sources, being subject to greater credit rationing problems than those oriented towards more traditional activities.

In summary, we found that, when it comes to firms investing in both traditional and R&D activities: (1) self-financing responds to different conditions for traditional and R&D investments; (2) such conditions differ also within the single investment typology, depending on firm characteristics (i.e., size and geographical variables); (3) the availability of public subsidies is by far the greatest discriminating factor in explaining the relationship between self-financing and its expected determinants; finally, (4) the banking variables influence only the self-financing of traditional investments.

Future research might, based on the same framework, focus on the role of subsidies in supporting investment and R&D self-financing during financial crises, which are characterized by a severe internal and credit rationing. In addition, classifying subsidies according to their source (e.g., regional, national, European) or their lending technology (e.g., labour or capital-based, fiscal deductions or cut-rate credit) would allow a more in-depth investigation on their role within the firm's self-financing decisions.

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Appendix

Table A1 – Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
1 LEVERAGE	1.00																			
2 PUBLIC SUBSIDIES	0.06	1.00																		
3 TURNOVER	0.07		1.00																	
4 ROI	-0.33*	-0.09*	0.06	1.00																
5 STD_ROI	-0.13*		-0.09*	0.10*	1.00															
6 TOTAL ASSETS	-0.11*		0.08*	-0.12*	-0.12*	1.00														
7 AGE	-0.07*				-0.06	0.08*	1.00													
8 GROUP	-0.06		0.07*	-0.14*		0.45*	-0.08*	1.00												
9 HI-TECH		0.06				0.09*		0.11*	1.00											
10 HIGH R&D		0.09*				-0.11*			0.21*	1.00										
11 HIRING			0.08*	0.06	-0.07	0.15*		0.08*		0.08*	1.00									
12 MULTIPLE BANKING	0.26*	0.08*	0.08*	-0.08*	-0.18*	0.37*	0.10*	0.14*		-0.06	0.14*	1.00								
13 LOCAL BANKING						-0.06	0.06	-0.07*		-0.07*			1.00							
14 MAIN BANK	0.11*			-0.13*		-0.07*						-0.17*	-0.08*	1.00						
15 DURATION	-0.07				-0.11*		0.47*	-0.14*					0.19*		1.00					
16 CREDIT RATIONING	0.22*		-0.08*	-0.18*		-0.10*								0.06		1.00				
17 OPACITY		0.11*	-0.07*	-0.18*	-0.11*	0.16*		0.09*	-0.07*			0.14*		0.07			1.00			
18 HHI_LOANS														0.07*			0.08*	1.00		
19 SOUTH_NORTH	0.64*			-0.25*	-0.11*							0.18*			-0.06	0.11*				1.00

* denotes 1% significance correlation coefficient (printed coefficient denotes significance at 10% level)



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