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Funding Gaps? Access To Bank Loans By High-Tech Start-Ups

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ABSTRACT. This paper aims to shed new light on start-up financing of new technology-based firms (NTBFs) and the existence of credit constraints that may negatively affect their activity. For this purpose, we analyze the different sources of start-up financing used by NTBFs and investigate several characteristics that may influence the extent of recourse to bank loans. In the empirical section, we consider a sample composed of 386 Italian NTBFs that operate both in manufacturing and services. We estimate double-censored tobit and bivariate tobit models so as to highlight the determinants of (i) the financial leverage, measured by the ratio of bank debt to total capital, and (ii) the amounts of personal capital and bank loans of firms at start-up, respectively. Our findings support the view that the credit market is imperfect and there exists a financing hierarchy. In fact, only a minority of firms resorts to outside financing, and especially to bank debt. In addition, the level of financial leverage is not random; it increases with an increase of the predicted amount of firms' total initial capital, while it decreases with variables such as the number of owners and the work experience of founders that are indicative of greater personal wealth available to finance firms' start-up. Lastly, the size of the bank loans obtained by firms generally is small and it is quite insensitive to demand-side factors that instead determine the amount of personal and total capital, with the notable exception of scale economies in the industry of the start-up. In other words, in accordance with the argument that credit to NTBFs is rationed, the loan supply curve is highly inelastic, even though not perfectly so.

KEY WORDS: new technology-based firms, start-up financing, bank loans, credit rationing.

JEL CLASSIFICATION: G32, M13, O30

1. Introduction

As it has long been recognized in the economic literature, capital markets are a driving force for economic development (see among others Schumpeter, 1911; Goldsmith, 1969; King and Levine, 1993; Rajan and Zingales 1998). Therefore, whether they are efficient or not is a crucial issue in the economic debate. In particular, over the last two decades several authors have argued that due to adverse selection and moral hazard problems and high-transactions costs, firms face financing constraints that negatively affect investment decisions (see Hubbard, 1998, for a survey).

For reasons that will be examined in detail in the following section (Carpenter and Petersen, 2002a), new technology-based firms (NTBFs) are those most likely to suffer from capital market imperfections. In turn, the existence of financial constraints hindering the creation and growth of high-tech start-ups is very worrisome because of the key role such firms play in assuring dynamic efficiency and employment growth in the economic system (Audretsch, 1995; Acs, 2004). So the analysis of factors that favor or hinder use of debt to finance the creation of NTBFs deserves careful examination. In fact, even though for NTBFs equity financing allegedly has advantages over debt (see again Carpenter and Petersen, 2002a), empirical work has shown that there is a substantial wedge between the costs of internal and outside equity financing (see for instance Asquith and Mullins, 1986; Lee et al., 1996). This inhibits access to seed and start-up equity capital for most new high-tech ventures, especially in countries with a less developed and/or bank-based financial system (Berger and Udell 1998).[1] Therefore, poor access to bank loans may seriously damage the NTBF sector.

In spite of the importance of this issue, it has been given insufficient attention in the empirical literature. While some previous studies have analyzed the financial structure of start-ups

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(Storey, 1994a; Åstebro, 2002; Cassar, 2004; Huyghebaert and Van de Gucht, 2004), to our knowledge no large scale econometric evidence has so far been provided on the determinants of the extent of use of bank loans to finance the creation of NTBFs. The present study aims to fill the gap in the literature. For this purpose, we consider a sample composed of 386 Italian firms, that operate in high-tech industries both in manufacturing and services, were created in 1980 or later, and were independent at start-up time. Data are provided by the Research on Entrepreneurship in Advanced Technologies (RITA) database developed at Politecnico di Milano. In order to detect the existence of imperfections in the credit market, we first analyze the different sources of financing used by entrepreneurs at start-up time.[2] We consider three sources of financing: founders' personal capital, that includes savings by entrepreneurs, family members and friends; outside equity capital (private equity), and bank debt. In this latter category we also include personal bank loans obtained by founders. We show that most firms did not resort to bank loans at start-up time. Personal capital was by far the most important source of start-up financing; this holds true even for firms that got access to bank debt. A very small number of firms obtained private equity financing, in accordance with the high cost of this source of financing. Nevertheless, for these latter firms, private equity accounted for a substantial percentage of total capital; in particular, the mean amount of private equity was considerably larger than the mean amount of bank loans obtained by firms that resorted to debt financing.

In addition, we consider several factors that may favor or hinder use of bank debt. For this purpose, we focus on a sub-sample composed of 371 firms that did not obtain outside equity financing. We estimate a double-censored tobit model of the level of financial leverage (i.e., the ratio of bank debt to total capital) conditioned on the amount of total start-up capital, and a bivariate tobit model of the extent of use of bank loans and personal capital. The findings of the econometric analysis reject the hypothesis of a perfect credit market, in favor of the existence of a "financing hierarchy" (Fazzari et al., 1988). In fact, firms are found to increasingly resort to debt financing the smaller the amount of personal capital available to finance operations at the desired scale. Furthermore, in contrast with the results relating to personal capital, the amount of bank loans is quite insensitive to factors that reflect firms' demand for capital, with the notable exception of the extent of scale economies in the industry of the start-up. In other words, the loan supply curve turns out to be very inelastic, even though not perfectly so.

The paper proceeds as follows. In Section 2 we briefly review the theoretical literature relating to the functioning of the credit market for NTBFs; we also examine the findings of previous empirical studies. In Section 3 the data set is presented. In Section 4 we illustrate descriptive statistics as to the use of bank debt and other financing sources by sample firms. Section 5 is devoted to the econometric analysis. Some summarizing remarks in Section 6 conclude the paper.

2. Access to bank loans by high-tech start-ups

In this paper, we focus attention on bank loans obtained by NTBFs at start-up time. Actually the literature on entrepreneurial finance (see for instance Denis, 2004) argues that debt is a quite unsuitable source of financing for NTBFs. In principle, outside equity capital provided by venture capitalists, other firms or angel investors enjoys several advantages over debt. In fact, these investors while specializing in early stage financing of high tech firms, develop superior capabilities in coping with the adverse selection and moral hazards problems (see *infra*) that allegedly deter other investors (see Sahlman, 1990; Gompers and Lerner, 2001). Nevertheless, it is important to emphasize that the high-tech early stage private equity-financing segment was almost inexistent in Europe up to the mid nineties. While it experienced considerable growth in the 1995–2000 period, it remained much less developed than in the U.S. Since then there has been a dearth of this type of financing in Europe as a consequence of the burst of the so-called "Internet bubble" and unfavorable macroeconomic conditions. This especially applies to countries like Italy with a bank-based financial

system.[3] As a matter of facts, in these countries access to outside seed and start-up equity capital is inhibited for most new high-tech ventures and bank loans still are the most important source of outside financing. Therefore, it is important to understand to what extent imperfections in the credit market constraint the operations of these firms at start-up time.

In a frictionless credit market, a firm can freely borrow and lend at the market interest rate, with this latter being determined by the aggregate demand for and supply of capital. Given the level of the interest rate, a firm's equilibrium quantity of capital depends only on the location of its demand for capital (D) curve; in turn, this is determined by firm's investment opportunities. Internal and outside sources of financing are perfect substitutes. As a consequence, factors that drive the D curve to the right also lead to an increase of the amount of bank debt of the firm.

In accordance with this argument, new firms that operate in industries with greater scale economies and so have a greater desired initial scale of operations (Mata, 1996; Mata and Machado, 1996; Görg et al., 2000; Colombo et al., 2004) will ask for and obtain greater bank loans. On the contrary, greater uncertainty deters investments, as there is greater risk of incurring sunk costs (Pindyck, 1991; Dixit and Pindyck, 1994; see also Cabral 1995); therefore uncertainty in the business environment will have an opposite effect on the equilibrium quantity of debt. Following a similar reasoning, firm-specific characteristics that influence the expected profitability of invested capital will also affect the amount of bank loans of a new firm. In particular, the literature on entrepreneurship (Evans and Jovanovic, 1989; Cressy, 1996; Xu, 1998; Åstebro and Bernhardt, 1999) has argued that physical capital and founders' entrepreneurial ability are complements. New firms founded by individuals with greater entrepreneurial talent have greater optimal initial scale of operations.[4] Hence, these individuals will ask banks for greater loans; as the quality of their business ideas is recognized by banks, they will obtain the requested financing.

In addition, as was originally argued by Modigliani and Miller (1958), in a frictionless capital market there is no relation between a firm's investment decisions and its financial structure. Accordingly, the personal wealth of entrepreneurs plays no role in their investment decisions and has no effect on the quantity of debt obtained at start-up time by the firms they founded. Under such circumstances, the level of financial leverage of firms, that is the ratio of bank debt to total capital, will follow a random process. Therefore we obtain the following hypotheses:

> *Hypothesis H_{1a}. With a perfect credit market, the amount of bank loans obtained by NTBFs at start-up will depend only on industry-specific (economies of scale, business uncertainty) and firm-specific (entrepreneurial talent) factors that shift the capital demand curve of firms.*
>
> *Hypothesis H_{1b}. With a perfect credit market, the level of financial leverage of firms is random.*

Since the seminal work by Jaffee and Russell (1976) and Stiglitz and Weiss (1981), the argument that there are imperfections in capital markets that render outside financing expensive and constraint firms' investment decisions, has been gaining ground in the economic literature (see Fazzari et al., 1988 and the literature mentioned in Hubbard, 1998; see also Carpenter and Petersen, 2002b). In accordance with such view, high-tech start-ups are likely to suffer most from capital market imperfections. In particular, access to bank loans is often difficult for these firms (Carpenter and Petersen, 2002a). First, business prospects are very uncertain for NTBFs; as creditors do not share in firms' returns in good states of nature, the interest payments they obtain in such states are unlikely to compensate for the high risk of failure in bad states of nature. Second, information asymmetries are likely to be very pronounced for NTBFs. From one side, high-tech entrepreneurs generally are better informed than lenders as to the risks and returns of their projects; in fact, it is quite difficult for banks to ascertain *ex-ante* the quality of the innovative investments of firms that lack a track record. From the other side, debt financing can lead to moral hazard

problems as it modifies the incentive structure of entrepreneurs in comparison with a situation in which they only resort to personal capital. Since for a bank it also is very difficult to monitor *ex-post* the behavior of high-tech entrepreneurs, there is room for them to replace low risk-low return projects with high risk-high return ones, to the detriment of lenders.

It has been argued in the literature that collateral may be used by banks both as a signaling device to separate high-quality from low-quality borrowers[5] and as an incentive device to deter entrepreneurs' opportunism (see Berger and Udell, 1998, for a survey). Nevertheless, most of high-tech investments is in intangible and/or firm-specific assets that provide little collateral value. Unless outside collateral (i.e., personal assets that can be used by founders to secure bank loans) is available, high-tech start-ups may find it difficult to resort to debt financing.

In fact, absent collaterizable assets, the supply of capital (S) curve will be horizontal only up to an amount of capital that coincides with the available quantity of personal capital; after this threshold, the S curve will be upward-sloping. The greater the imperfections in the credit market, the steeper the S curve. In a limit situation, banks may be unwilling to provide debt financing beyond a low level of leverage; credit rationing will then cause the S curve to become vertical after this threshold.

If the S curve is upward-sloping, there will be a financing hierarchy. Since the marginal cost of debt financing exceeds the opportunity cost of personal capital, entrepreneurs will ask for a bank loan to start a new company only if personal capital is not sufficient to finance the new venture at the desired scale. As a consequence, the equilibrium amount of debt financing and the financial leverage of NTBFs will be negatively related to the personal wealth of firms' founders. In addition, in the extreme situation in which credit is rationed, a shift of the D curve will have a negligible impact on the equilibrium quantity of bank loans. The above reasoning leads to the following hypotheses:

Hypothesis H_{2a}. If there are imperfections in the credit market leading to a financing hierarchy, the amount of bank loans of NTBFs will be inversely related to the amount of personal capital available to founders.

Hypothesis H_{2b}. If there are imperfections in the credit market leading to a financing hierarchy, the level of the financial leverage of NTBFs will be inversely related to the amount of personal capital available to founders.

Hypothesis H_3. The greater the imperfections in the credit market and the steeper the loan supply curve, the smaller the impact on the amount of bank loans of NTBFs of industry-specific, location-specific and firm-specific factors that shift the capital demand curve of firms.

Whether the credit market is imperfect and fair access to bank loans is inhibited to high-tech start-ups, are a matter of empirical testing.

Previous studies on entrepreneurship have provided evidence consistent with the argument that new firms suffer from financial constraints. For instance, both cross-sectoral (Meyer, 1990; Blanchflower and Oswald, 1998) and longitudinal (Evans and Jovanovic, 1989; Evans and Leighton, 1989; Black et al., 1996) studies have shown that the likelihood of being self-employed increases with individuals' net worth. Lindh and Ohlsson (1996), using Swedish microdata, have found that the probability of being self-employed increases when individuals receive windfall gains in the form of lottery winnings and inheritances. Holtz-Eakin et al. (1994a) have similarly analyzed reception of an inheritance. Their results indicate that the likelihood of establishing a new enterprise and the initial capital committed to the enterprise by the founder significantly increase with the size of the inheritance and that such effect is more pronounced for low net-worth individuals. In addition, the greater the amount inherited the greater the likelihood of survival and the growth rate of the new venture (Holtz-Eakin et al., 1994b). Åstebro and Bernhardt (1999) have shown that the predicted household income of

U.S. entrepreneurs positively affects the amount of capital committed to a new venture. Lastly, the analysis of the evolution over time of the size distribution of Portuguese firms performed by Cabral and Mata (2003) indicates the presence of binding financial constraints that prevent new firms from attaining their optimal initial size.

Nonetheless, the view that new firms face tight financial constraints is not unanimously shared in the literature. In particular, it has been argued that the fact that the wealth of individuals is positively correlated with firm creation and post-entry performance may be the effect of a spurious correlation: if wealth and human capital are correlated, failure to include into econometric models a proper specification for founders' human capital may lead to the erroneous detection of a capital market imperfection (see Cressy, 1996).[6]

A limited number of empirical studies have provided evidence on recourse to debt financing by newly created firms. Levenson and Willard (2000) while documenting that the extent of credit rationing in the U.S. is fairly limited,[7] show that constrained firms are smaller and younger than unconstrained ones. Chittenden et al. (1996) analyze the financial structure of a sample composed of 3,480 small U.K. firms. In contrast to the view of perfect capital markets, they show that use of debt (especially short-term debt) provided by banks and other sources is negatively related to the profitability and age of firms. Conversely rapidly growing unlisted firms and firms that possess collaterizable assets are more likely to have recourse to debt. These findings are confirmed by Michaelas et al. (1999) through estimates of a panel data model. Similarly, Huyghebaert and Van de Gucht (2004) find that the percentage of bank debt out of total debt of Belgian start-ups is greater in high-growth industries. Storey (1994a) analyzes use of bank loans for start-up financing by U.K. firms through estimates of logit models. With a few exceptions, the independent variables have no explanatory power; in particular, none of the personal characteristics of founders capturing education and prior employment experience, is significantly related to recourse to debt financing. On the contrary, use of personal savings has a negative effect, suggesting that they replace bank loans. Åstebro (2002) considers a sample of 893 U.S. firms created in 1987. 34.4% of them obtained a bank loan. He tries to distinguish the decision of entrepreneurs to seek a loan at start-up time and the decision of a commercial bank to grant it. His findings suggest that a considerable number of start-ups do not ask for any bank loan; out of applicants, a large proportion does receive a loan. Entrepreneurs with greater human capital are more likely to self-select out of the credit market and to resort to loans from family and friends. However, the same human capital variables that lead individuals not to seek a loan, induce banks to grant it if there is an application. Lastly, Cassar (2004) analyzes the financial structure of 292 new Australian firms at a date between 0 and 12 months from tax registration. The estimates of a tobit model indicate that the ratio of bank debt to total assets increases with the amount of collaterizable assets of firms and their propensity to expand operations. Conversely, after controlling for firm size which is positively related to the extent of use of bank loans,[8] the human capital characteristics of the major decision maker do not have any effect.

In the present study we depart from the above surveyed literature in that we focus attention on NTBFs. In fact, empirical evidence on use of bank loans by high-tech ventures in the early period of their existence is fairly limited; as a consequence, whether they suffer from credit constraints or not still is an open question. While some studies have documented that high-technology small firms are financially constrained (see for instance Oakey, 1995; Egeln et al., 1997; Westhead and Storey, 1997; Giudici and Paleari, 2000), others have proposed an opposite view (see Monck et al., 1988; Moore, 1994). In addition, almost all previous empirical works on the financial structure of NTBFs rely on descriptive statistics relating to specific and/or small size samples (see for instance Bruno and Tyebjee, 1985; Freear and Wetzel, 1990; Manigart and Struyf, 1997). Carpenter and Petersen (2002a) is an exception. They analyze a panel of over 2,400 publicly traded U.S. firms that operate in high-technology manufacturing industries and are observed over the period 1981–1998. Most of these firms went public

during this period, were small at the time of the IPO, and obtained little debt financing prior to the IPO; moreover, the amount of debt is negligible in comparison with the new equity raised through the IPO. Nevertheless, as their sample includes only firms that went through an IPO, their results cannot be generalized. This especially holds true for countries with a bank-based financial system (see again footnote 1), as in these countries the number of listed NTBFs is fairly limited. As far as we know, this is the first large scale empirical study based on econometric estimates of access to the credit market by NTBFs. As in several countries banks are the main source of financing for these firms, we believe that this study offers a valuable addition to the extant literature.

3. The data set

The sample analyzed in the present study is composed of 386 Italian start-ups (see also Colombo et al., 2004; Colombo and Grilli, 2005a). Sample firms were established in 1980 or later, were independent at start-up time (i.e., they were not controlled by another business organization) and operate in the following high-tech sectors, in manufacturing and services: computers, electronic components, telecommunication equipment, optical, medical and electronic instruments, biotechnology and pharmaceuticals, multimedia content, software, Internet services (e-commerce, ISP, web-based services), and telecommunication services.

The sample was extracted from the RITA database, developed at Politecnico di Milano. The RITA database was created in 1999 and enlarged and updated in 2001. The present release contains detailed information on more than 400 NTBFs and more than 1,000 of their founders.[9] The development of the database went through a series of steps. First, Italian target firms that complied with the above mentioned criteria relating to age, independence at start-up time, and sector of operations were identified. For the construction of the target ''universe'' a number of sources were used. These included lists of members of national industry associations, on-line and off-line commercial firm directories, and lists of participants in industry trades and expositions. Information provided by the national financial press, specialized magazines, other sectoral studies and regional Chambers of Commerce was also considered. Altogether, around 2,000 firms were selected for inclusion in the database. For each firm, a contact person (usually, one of the owner-managers) was also identified. Unfortunately, data provided by official national statistics do not allow us to obtain a reliable description of the universe of Italian NTBFs.[10] Note also that for obvious reasons, the selection procedure led to the oversampling of growth-oriented firms. Second, a questionnaire was sent to the target firms either by fax or by e-mail. The aim of the questionnaire was to collect both quantitative information relating to the activity, structure and performance of firms and the characteristics of their founders, and qualitative judgments of firms' founders on specific issues. The first section of the questionnaire contains information on characteristics of the entrepreneurs such as age, education, and prior work experience. The second section comprises further questions concerning the characteristics of the firms at start-up time, including the amount of initial capital and the financial structure of the firm. Lastly, answers to the questionnaire were examined by educated personnel; when it was deemed necessary, phone and/or face-to-face follow-up interviews were made with firms' owner-managers. This final step was crucial in order to obtain missing data and ensure that answers were reliable.

Note that there is no presumption here to have a random sample. From one side, as was mentioned above, absent reliable official statistics, it is very difficult to identify unambiguously the universe of Italian NTBFs. From the other side, the sample was drawn in 1999; so only firms having survived up to the survey date were included. In principle, attrition may generate a sample selection bias that is difficult to control. In so far as failure rates are related to a firm's initial financial structure, there may be a sample selection bias in our data set that we cannot correct.[11] This notwithstanding, the sample is sufficiently large and heterogeneous to provide adequate coverage of the financial structure of Italian NTBFs and its determinants. In addition,

the information in our data set especially as regards the human capital of the founding team is much more detailed than in previous data sets of similar size.

4. Use of bank loans by Italian high-tech start-ups: descriptive statistics

The aim of this section is to provide an overview of the sources of start-up financing to which Italian NTBFs resorted, with particular attention to the use of debt financing. In particular, we distinguish between three sources: (i) personal capital, that includes personal savings of entrepreneurs, family members and friends; (ii) private equity provided by venture capital firms, other financial intermediaries, other firms (i.e., corporate venture capital), and business angels; and (iii) bank debt (both short-term and long-term). This latter category also includes personal bank loans obtained by founders to finance firms' start-up.

With a 84% share personal capital is by far the main source of start-up financing of Italian NTBFs. Both bank loans and private equity account for a 8% share. The percentage of NTBFs that at start-up time resorted to debt financing is fairly limited (22%, see Table I), even though it is much larger than that of firms that obtained private equity capital (3.9%). As a consequence, at 47,000€ the mean amount of bank loans obtained by debt financed firms is almost six time smaller than the mean amount of private equity of firms that resorted to this latter source of financing; it also is less than half the mean amount of personal capital.[12] The lack of external financing is consistent with the existence of a substantial wedge between the cost of personal capital and that of outside financing (Carpenter and Petersen, 2002b). Note also that the correlation between the amount of personal capital and that of bank loans though positive, is very small; the Pearson correlation coefficient is equal to 0.065 and it is not statistically different from null at conventional confidence levels. The correlation coefficient between the quantities of bank debt and private equity again is statistically insignificant but negative (it equals −0.007). Since most sample firms resorted to neither bank loans nor outside equity financing, such evidence suggests that in accordance with the results of previous studies (see for instance Audretsch and Lehmann, 2004) outside equity replaces debt financing for new firms that are able to gain access to it.

In Table II we focus more directly on the use by NTBFs of debt financing. We distinguish firms according to their sector of operations and initial size, measured by the number of employees inclusive of founders (i.e., owners who at start-up time had managerial positions in the new firm). For comparison purposes we also report statistics on the total amount of initial capital. This latter is considerably larger in manufacturing than in services; the same holds true for the percentage of firms that obtained debt financing at start-up time, and the mean amount of bank loans. On the contrary, the mean value of the financial leverage of firms that relied on debt financing does not substantially vary across sectors, with the partial exception of Internet and telecommunication services where it

TABLE I
Sources of start-up financing of Italian NTBFs

Financing source	Firms		Amount of capital ('000 €)	
	N	%	Mean[a]	SD[a]
Personal capital	378	97.9	107.0	265.3
Private equity	15	3.9	274.5	660.4
Bank debt	85	22.0	46.8	92.0
Total[b]	386	100	125.8	303.1

Source: RITA database. [a] For every source of financing, mean and standard deviation refer only to firms that obtained that particular type of financing. [b] The sum of the number of firms that resorted to the different sources of financing is greater than the total number of firms as some firms used more than a single financing source. Mean and standard deviation refer to total amount of capital (i.e., the sum of personal capital, private equity and bank debt).

TABLE II
Sources of start-up financing of Italian NTBFs, by industry and firm size

Industry/firm size (n. of employees)	All firms	Amount of total initial capital ('000 €)		Firms obtaining debt financing		Amount of bank loans[a] ('000 €)		Leverage[a] (%)	
	N	Mean	SD	N	%	Mean	SD	Mean	SD
Internet and TLC services	156	85.6	235.0	28	17.9	27.1	19.4	54.9	24.5
Multimedia content	23	54.4	35.6	7	30.4	17.8	14.7	44.7	29.1
Software	112	66.8	93.9	20	17.9	37.5	83.7	47.5	30.4
ICT manufacturing	76	309.7	536.9	23	30.3	89.0	151.3	47.9	26.5
Biotechnology/ pharmaceutics	19	153.7	215.3	7	36.8	42.8	20.9	44.4	22.2
1–2	107	30.9	55.1	22	20.6	11.0	5.6	52.4	29.0
3–5	162	84.9	152.6	38	23.5	30.8	28.4	51.8	27.7
6–10	73	154.4	294.1	16	21.9	86.4	166.5	42.0	18.2
11–20	27	329.4	634.3	7	25.9	106.3	99.1	44.7	17.8
>20	17	665.9	672.5	2	11.8	221.4	238.2	54.5	64.3
Total	386	125.8	303.1	85	22.0	46.8	92.0	49.6	26.4

Source: RITA database. [a] Statistics refer only to firms that have obtained bank debt financing.

is above the sample average. Quite unsurprisingly, the amount of total initial capital and the mean amount of bank loans increase monotonically with firms' start-up size. Conversely, there is no consistent pattern as to the share of debt financed firms out of the total number of firms and the level of leverage of debt financed firms; in particular, the largest size class (i.e., firms with a number of employees greater than 20) exhibits the smallest share of debt financed firms (less than 12%). As several firms in this size class obtained seed and start-up equity capital, this evidence again points to a possible substitution between outside equity and debt financing.

5. The econometric evidence

5.1. *The specification of the econometric models*

The aim of the econometric analysis is to shed light on the existence of imperfections in the credit market, which may constraint the operations of NTBFs. For this purpose, we follow two methodological approaches.

First, we consider the level of financial leverage of firms; in order to highlight its determinants, we estimate a double-censored tobit model conditional on the amount of total initial capital. This in turn depends on factors that shift the demand (D) for and supply (S) of capital curves. Note that the amount of start-up capital and the level of financial leverage are simultaneously determined by firms. In order to correct for the endogeneity bias due to unobserved heterogeneity across firms, we resort to a two-step estimating procedure. It is important to remind that with perfect capital markets, debt and equity are perfect substitutes. Therefore, in accordance with Hypothesis H_{1b}, the financial leverage at start-up time should be independent of firms' characteristics. In particular, neither the predicted amount of total initial capital nor other variables reflecting the amount of personal capital available to founders should be related to the level of leverage. Conversely, as is suggested by Hypothesis H_{2b}, if it is difficult for NTBFs to have access to the credit market and the cost of bank debt is greater than the opportunity cost of personal capital, the above mentioned variables should have positive and negative effects on financial leverage, respectively. Note that the choice of a double-censored tobit model was driven by the nature of the dependent variable that takes continuous values within a lower (0) and an upper (100) limit.[13] Using a latent variable framework, let y^* denote the firms' propensity to use the financial leverage, let y indicate the observed financial leverage, let x denote the vector of explanatory variables, and finally let u

TABLE III
The explanatory variables of the econometric models

Variable	Description
DManager	One for firms with one ore more founders with a prior management position in a large or medium company (i.e., number of employees greater than 100)
Specworkexp	Average number of years of work experience gained by founders in the same sector of the start-up before firm's foundation
Techworkexp	Average number of years of technical work experience gained by founders in the same sector of the start-up before firm's foundation
Comworkexp	Average number of years of commercial work experience gained by founders in the same sector of the start-up before firm's foundation
Education	Average number of years of founders' education
Ecoeducation	Average number of years of founders' economic, managerial and political science education at university level
Techeducation	Average number of years of founders' scientific or technical education at university level
Genworkexp	Average number of years of work experience gained by founders in other sectors than the one of the start-up before firm's foundation
LOwners	Logarithm of the number of individuals who provided equity capital to start the new firm
Mes	Minimum efficient scale in the sector of the start-up in the year in which the firm was created (or in the nearest year for which data were available) measured by the log of the average number of employees[a]
Uncertainty	Industry average of the normalized standard deviation of the market price of newly listed firms in the 50 days following the IPO
DIncubated	One for firms located in a technology incubator
DMother company	One for firms that at start-up time, received some kind of aid by a "mother" company
Infrastructure	Value of the index measuring economic development in 1989 in the county where the new firm was located (mean value among Italian counties = 1)
Rreal	Real interest rate in the year of firm's foundation
Defaults	Ratio between the number of firms' defaults (multiplied by 10) and the number of firms in the county where the new firm is located

[a] Data are available for 1981, 1991 and 1996. Data source is ISTAT Census.

be an i.i.d. normally distributed error term with mean zero and variance σ^2. Then the model can be expressed as follows:

$$y_i^* = \beta' x_i + u_i; \tag{1}$$

where

$$\begin{aligned} &y_i = 0 \xrightarrow{if} y_i^* \leq 0 \\ &y_i = y_i^* \xrightarrow{if} 0 < y_i^* < 100 \\ &y_i = 1 \xrightarrow{if} y_i^* \geq 100. \end{aligned} \tag{2}$$

The maximization of the likelihood function of the model (see Maddala, 1983, p. 161) yields maximum likelihood estimates of β, which is a direct measure of the impact of the explanatory variables on the latent dependent variable, while the unconditional expectation of y is given by:

$$\begin{aligned} E(y_i) = \beta' x_i \left[\Phi\left(\frac{100-\beta' x_i}{\sigma}\right) - \Phi\left(\frac{-\beta' x_i}{\sigma}\right)\right] \\ + \sigma\left[\phi\left(\frac{-\beta' x_i}{\sigma}\right) - \phi\left(\frac{100-\beta' x_i}{\sigma}\right)\right] \\ + 100\left[1 - \Phi\left(\frac{100-\beta' x_i}{\sigma}\right)\right]. \end{aligned} \tag{3}$$

The second methodological approach consists in the estimation of a bivariate tobit model. In this case the dependent variables are the amounts of bank loans and personal capital used by firms at start-up. As unobserved factors are likely to influence both variables, following Maddala (1983, ch. 7) the simultaneous estimation of the two tobit equations permits us to exploit a possible correlation among the error terms so as to improve the efficiency of the estimates (see also Czarnitzki, 2002). Again we can define two

latent equations underlying firms' propensity to use personal capital (y_1^*) and bank debt (y_2^*):

$$y_{1i}^* = \beta_1' x_{1i} + \varepsilon_{1i}$$
$$y_{2i}^* = \beta_2' x_{21} + \varepsilon_{2i} \quad (4)$$

we indicate with y_1 and y_2 the actual amounts of personal capital and bank debt invested in the new firm, respectively. It will be:

$$y_{1i} = 0 \xrightarrow{if} y_{1i}^* \leq 0$$
$$y_{1i} = y_{1i}^* \xrightarrow{if} y_{1i}^* > 0$$
$$y_{2i} = 0 \xrightarrow{if} y_{2i}^* \leq 0$$
$$y_{2i} = y_{2i}^* \xrightarrow{if} y_{2i}^* > 0 \quad (5)$$

The model is estimated simultaneously assuming that the two dependent variables are jointly normally distributed and the likelihood function to be maximized is composed by four parts defined by four different parameter regimes ($y_{1i} = y_{1i}^*$ and $y_{2i} = y_{2i}^*$; $y_{1i} = y_{1i}^*$ and $y_{2i} = 0$; $y_{1i} = 0$ and $y_{2i} = y_{2i}^*$; $y_{1i} = 0$ and $y_{2i} = 0$. See again Czarnitzki, 2002, for further details). In this case, the estimation of β_1 and β_2 yields a direct measure of the impact of the explanatory variables on the propensity to use personal capital and bank debt, respectively. The estimate of the correlation term between the stochastic errors ϵ_1 and ϵ_2 indicated by parameter ρ, provides a measure of the interrelatedness between the two equations. If there are no financial constraints and bank loans and personal capital are perfect substitutes, the covariates that reflect firms' demand for capital and determine the amount of total capital committed to a new venture should have the same effects on personal capital as on bank loans (Hypothesis H_{1a}). In addition, in so far as other unobserved factors shift the D curve, the correlation coefficient between the error terms of the two equations ρ should be positive, testifying that firms' unobserved heterogeneity similarly affects both types of financing. On the contrary, if credit is rationed, firms will rely on bank loans only when personal financial resources are exhausted. Hence variables that proxy founders' wealth and thus shift the S curve to the right will have a negative impact on the size of bank loans (Hypothesis H_{2a}). Moreover the correlation coefficient ρ will be negative, indicating that unobserved factors that lead firms to use a greater amount of personal capital have an opposite effect on bank loans. Lastly, demand side variables will have a negligible effect on the amount of bank loans, but they will positively affect the amount of personal capital. Accordingly, as stated by Hypothesis H_3, the impact of these variables on the size of bank loans inversely measures the extent of credit constraints.

5.2. *The explanatory variables*

The explanatory variables of the econometric models are illustrated in Table III. They can be subdivided in three different groups. The first group encompasses variables that reflect the human capital characteristics of a firm's founding team. As will be described below, all these variables are expected to shift the capital supply (S) curve; some of them may also shift the capital demand (D) curve. The second group of variables includes other factors that are likely to shift the D curve, but allegedly have no bearing on the S curve. In the last group we consider other variables in addition to founders' characteristics that may shift the S curve only.

The first group includes variables that proxy the *specific* and *generic* human capital of founders. Following Becker (1975), specific human capital consists of the capabilities that individuals can directly apply to the entrepreneurial job in the newly created firm; it is related to the industry-specific skills that founders learned in the organization by which they were formerly employed (*Specworkexp*) and to the "leadership experience" they gained through a managerial position in a medium or large company[14] (*DManager*). We also distinguish according to whether industry-specific experience relates to the technical (*Techworkexp*) or to the commercial sphere (*Comworkexp*). Generic human capital encompasses measures of the general knowledge acquired by entrepreneurs through both formal education (*Education*) and professional experience matured in other sectors respect to the one of the start-up (*Genworkexp*). As concerns university education, we also distinguish between economic studies (*Ecoeducation*)

and technical and scientific studies (*Techeducation*).[15] As is documented by the empirical literature on the post-entry performances of start-ups (for a survey see Storey, 1994b; see also Colombo and Grilli, 2005b, and the literature mentioned there), variables reflecting founders' generic human capital are no predictors of firms' success; hence, in so far as they are unrelated to firms' investment opportunities, they should have no effect on the *D* curve. Previous studies also report that these variables are positively related to the amount of personal financial resources of founders (see for instance Xu, 1998; Åstebro and Bernhardt, 1999). If there is a financing hierarchy due to capital market imperfections, generic human capital variables will drive the S curve to the right. On the contrary, we expect variables capturing the specific component of founders' human capital to drive to the right both the *D* and *S* curves.

Let us now consider other variables that shift the *D* curve but have no effect on the *S* curve. *Mes* is the minimum efficient scale of the industry in which firms operate;[16] it is positively related to the demand for capital. On the contrary, greater business uncertainty (*Uncertainty*) will lead founders to limit initial commitment of resources so as to avoid sunk costs (Pindyck, 1991; Dixit and Pindyck, 1994; Cabral, 1995).[17] Location in a technology incubator (*DIncubated*) should force firms to operate at a relatively small scale, given the limited physical space available in Italian incubators; so they will require less financial resources. *Infrastructure* is an index provided by Confindustria Centro Studi (1991) that reflects the level of economic development in the county of firm's location.[18] Location in a highly developed area may make founders more confident on the future prospects of the new firm and convince them to start operations at greater size. Support of a sponsoring firm that provides a new venture with tangible and intangible assets (*DMother company*) is likely to have a similar effect.[19]

In the last group we consider other variables in addition to founders' characteristics, that may shift the *S* curve but not the *D* curve. *LOwners* is the log of the number of individuals who provided equity capital to start the new firm. With all else equal, the amount of available personal financial resources is likely to increase with the number of owners. *Rreal* is the real interest rate in the year of firms' foundation (Source: Banca d'Italia). *Defaults* is the ratio between the number of firms' defaults and the number of existing business activities in the county where NTBFs are located (Source: Istituto G. Tagliacarne). These two variables proxy the cost of debt capital at the time of firms' foundation.[20]

A final remark relating to outside private equity financing is in order. In principle, this variable should be considered in the econometric estimates. In fact, the decisions of founders as to the use of different sources of external financing at start-up time clearly are interdependent (see for instance Audretsch and Lehmann, 2004). Nevertheless, in the dataset only 15 firms resorted to external seed equity capital. Therefore, we decided to exclude these firms in the econometric analysis, thus reducing the number of observations to 371 firms.[21]

In Table IV we illustrate descriptive statistics and the correlation matrix of the independent variables. Correlation across variables are generally low, suggesting absence of any relevant problem of multicollinearity.

5.3. *Results of the estimates*

The results of the econometric estimates are illustrated in Tables V and VI. In the former table we report the double-censored tobit estimates of the level of financial leverage and the OLS estimates of the equation relating to the amount of total initial capital. In the tobit model we consider among the covariates the predicted quantity of total initial capital. We also report marginal effects evaluated at the sample mean. In the latter table we present the estimates of the bivariate tobit model of the amounts of personal capital and bank loans used for start-up financing.

Let us first consider the amount of total initial capital (see Table V); our results indicate that this variable is quite sensitive to factors that allegedly shift the *D* and *S* curves. With the only exception of *Uncertainty*, which has negative though insignificant coefficients, factors that drive to the right (left) the *D* curve have a statistically significant, positive (negative) effect on the quantity of start-up capital of Italian NTBFs. In fact, initial capital is greater in

TABLE IV
Descriptive statistics and correlation matrix of the explanatory variables

	Mean	S.D.	*DManager*	*Specworkexp*	*Techworkexp*	*Comworkexp*	*Education*	*Ecoeducation*	*Techeducation*
DManager	0.09	0.29	1						
Specworkexp	4.44	6.96	0.12	1					
Techworkexp	2.88	5.92	0.09	0.80	1				
Comworkexp	1.27	3.84	0.06	0.50	−0.06	1			
Education	14.78	2.56	0.15	−0.15	−0.13	−0.06	1		
Ecoeducation	0.34	0.89	0.02	−0.15	−0.12	−0.09	0.28	1	
Techeducation	1.45	1.92	0.15	0.01	0.03	0.01	0.75	−0.13	1
Genworkexp	7.90	8.47	0.14	−0.43	−0.34	−0.21	−0.06	0.08	−0.09
LOwners	0.88	0.53	0.09	−0.13	−0.14	−0.04	0.08	0.01	0.05
Mes	0.97	0.37	0.09	0.19	0.15	0.08	0.04	−0.09	0.10
Uncertainty	0.03	0.01	−0.09	−0.19	−0.18	−0.06	−0.07	0.12	−0.19
DIncubated	0.12	0.33	−0.01	−0.04	0.01	−0.06	0.15	−0.02	0.14
DMother company	0.10	0.31	0.01	0.13	0.13	0.03	0.13	−0.02	0.14
Infrastructure	1.16	0.27	0.09	0.01	0.2	−0.02	0.03	0.13	−0.02
Rreal	5.08	1.88	−0.01	−0.01	0.04	−0.02	−0.01	−0.03	0.01
Defaults	0.31	0.07	0.04	−0.01	0.01	−0.07	0.04	0.08	0.03

	Genworkexp	*LOwners*	*Mes*	*Uncertainty*	*DIncubated*	*DMother company*	*Infrastructure*	*Rreal*
Genworkexp	1							
LOwners	−0.09	1						
Mes	0.01	−0.11	1					
Uncertainty	0.06	0.07	−0.45	1				
DIncubated	0.09	0.09	0.13	−0.10	1			
DMother company	0.01	−0.05	0.06	−0.08	0.03	1		
Infrastructure	0.09	−0.10	0.11	−0.06	0.11	0.02	1	
Rreal	−0.03	0.01	0.01	−0.04	0.09	−0.02	−0.05	1
Defaults	−0.01	0.05	−0.02	0.01	−0.10	−0.06	−0.14	0.07

high-tech industries characterized by greater minimum efficient scale, in highly developed counties, and for firms that at start-up time benefited from support provided by a "mother" company. On the contrary, firms located in a technology incubator start operations with less capital. As to factors that are expected to shift the *S* curve, the greater the number of individual owners of a new firm captured by *LOwners*, the greater the amount of total start-up capital. The level of the real interest rate turns out to negatively affect the amount of capital initially committed to NTBFs. Conversely, failure rates in the county where NTBFs are located have negligible effects.

Let us now consider the human capital characteristics of founding teams. As to work experience, the quantity of total initial capital increases with founders' professional experience in the same sector of the new firm, while work experience in other sectors plays a negligible role. In particular, what seems to matter is industry-specific technical experience. In fact, the coefficients of *Specworkexp* in model I and *Techworkexp* in model II are positive and statistically significant at 99%. As to the remaining human capital variables, the coefficient of *DManager* is positive as predicted but insignificant. The unexpected negative coefficient of *Education* also is insignificant. In addition, if one focuses attention on university education, firms created by individuals with degrees in economics, management and political sciences start operations with greater capital. Contrary to expectations, the opposite holds true for firms established by individuals with technical and scientific degrees. Altogether, the econometric findings indicate that the characteristics of the founding team have a considerable effect on start-up capital.

TABLE V
Determinants of total start-up capital and financial leverage

Variables	Model I			Model II		
	OLS	Tobit		OLS	Tobit	
	Start-up capital (log)	Financial leverage	(Marginal effects)	Start-up capital (log)	Financial leverage	(Marginal effects)
Costant	3.849***	−116.076*		3.995***	−136.422**	
	(0.737)	(63.774)		(0.679)	(53.230)	
DManager	0.069	0.428	0.084	0.105	−5.219	−1.026
	(0.158)	(21.350)	(4.203)	(0.154)	(21.438)	(4.215)
Specworkexp	0.022***	−0.529	−0.104	–	–	–
	(0.008)	(1.016)	(0.200)			
Techworkexp	–	–	–	0.029***	−0.175	−0.034
				(0.008)	(1.098)	(0.216)
Comworkexp	–	–	–	0.007	−0.085	−0.017
				(0.012)	(1.524)	(0.300)
Education	−0.018	−1.732	−0.341	–	–	–
	(0.018)	(2.272)	(0.447)			
Ecoeducation	–	–	–	0.124**	−0.250	−0.049
				(0.049)	(6.560)	(1.290)
Techeducation	–	–	–	−0.057**	1.691	0.333
				(0.024)	(3.051)	(0.599)
Genworkexp	0.004	−1.384*	−0.272*	0.002	−1.146	−0.225
	(0.006)	(0.822)	(0.160)	(0.006)	(0.800)	(0.156)
LOwners	0.417***	−34.799***	−6.851***	0.425***	−34.140***	−6.714***
	(0.085)	(12.190)	(2.330)	(0.084)	(11.660)	(2.332)
Mes	1.049***	–	–	1.079***	–	–
	(0.132)			(0.130)		
Uncertainty	−17.76	–	–	−24.339	–	–
	(15.00)			(14.971)		
DIncubated	−0.259*	–	–	−0.244*	–	–
	(0.137)			(0.135)		
DMother company	0.563***	–	–	0.584***	–	–
	(0.143)			(0.140)		
Infrastructure	0.351**	–	–	0.262	–	–
	(0.160)			(0.160)		
Rreal	−0.042*	–	–	−0.046**	–	–
	(0.023)			(0.023)		
Defaults	−0.003	–	–	−0.121	–	–
	(0.547)			(0.543)		

TABLE V (Continued)

Variables	Model I			Model II		
	OLS	Tobit		OLS	Tobit	
	Start-up capital (log)	Financial leverage	(Marginal effects)	Start-up capital (log)	Financial leverage	(Marginal effects)
Start-up capital (predicted value)	–	25.990** (12.098)	5.117** (2.346)	–	23.497** (11.660)	4.621** (2.261)
R^2	0.31	–		0.33	–	
Log-likelihood	–	564.535		–	564.928	

* Significance level greater than 90%; ** significance level greater than 95%; *** significance level greater than 99%. Number of observations is 371. Standard errors in parentheses.

Let us now turn attention to the financial leverage equation. The results of the estimates clearly support the view that personal capital and bank loans are no perfect substitutes. First of all, the null hypothesis that all covariates have no explanatory power is rejected at 99% in both models I and II by a LR test ($\chi^2_{(6)} = 66.9$ and $\chi^2_{(8)} = 66.1$, respectively). In other words, in contrast to the contention that there are no imperfections in the credit market, financial leverage is not random; so Hypothesis H_{1b} is rejected. In fact, its level increases with the predicted value of firms' total start-up capital, with the coefficient of this variable being significant at 95% in both models. In addition, the log of the number of owners exhibits negative coefficients, significant at 99%. *Genworkexp* also has a negative coefficient significant (at 90%) in model I and close to significance in model II. The values of the marginal effects indicate that the level of financial leverage is quite sensitive to the predicted value of start-up capital and the number of owners, while it is less affected by founders' generic work experience. The other human capital variables have negligible effects on the level of financial leverage, even though their coefficients generally are negative. These results highlight that with all else equal, the larger the amount of total initial capital, the greater the likelihood that operations cannot be financed by personal capital alone; a greater level of financial leverage follows. Conversely, this situation is less likely for firms that are created by several highly experienced and probably wealthy individuals. This argues in favor of the existence of a financing hierarchy, thus supporting Hypothesis H_{2b}.[22]

The evidence illustrated above is confirmed by the results of the estimates of the bivariate tobit model reported in Table VI. First of all, the correlation parameter ρ between the error terms of the two equations is statistically significant at conventional confidence levels lending support to the bivariate specification,[23] and it is negative, which again is coherent with the existence of a financing hierarchy. *Ceteris paribus*, the greater the amount of personal financing used by firms, the lower the amount of bank loans; this result supports Hypothesis H_{2a} against Hypothesis H_{1a}.

TABLE VI
Determinants of the amounts of personal capital and bank loans at start-up time

Variables	Model III		Model IV	
	Personal capital (log)	Bank loans (log)	Personal capital (log)	Bank loans (log)
Costant	3.858***	−4.959	4.334***	−5.364
	(1.298)	(6.248)	(1.234)	(5.951)
DManager	0.027	−0.230	0.107	−0.479
	(0.231)	(1.283)	(0.233)	(1.297)
Specworkexp	0.025**	0.043	–	–
	(0.010)	(0.059)		
Techworkexp	–	–	0.030**	0.089
			(0.013)	(0.077)
Comworkexp	–	–	0.005	−0.045
			(0.015)	(0.110)
Education	−0.006	−0.084	–	–
	(0.025)	(0.146)		
Ecoeducation	–	–	0.156*	0.373
			(0.087)	(0.439)
Techeducation	–	–	−0.075**	0.071
			(0.036)	(0.218)
Genworkexp	0.015	−0.036	0.011	−0.028
	(0.010)	(0.054)	(0.010)	(0.051)
LOwners	0.491***	−1.300	0.499***	−1.271
	(0.129)	(1.021)	(0.127)	(1.004)
Mes	0.885***	2.615**	0.925***	2.606**
	(0.200)	(1.340)	(0.201)	(1.313)
Uncertainty	−23.539	72.311	−33.282	64.522
	(28.002)	(132.440)	(28.368)	(131.679)
DIncubated	−0.061	−2.686	−0.019	−2.901
	(0.275)	(1.702)	(0.274)	(1.789)
DMother company	0.376*	0.221	0.430**	0.084
	(0.195)	(1.218)	(0.207)	(1.270)
Infrastructure	0.198	0.058	0.088	−0.209
	(0.281)	(1.469)	(0.272)	(1.498)
Rreal	−0.050	−0.038	−0.055	−0.070
	(0.037)	(0.167)	(0.038)	(0.170)
Defaults	−0.033	−2.682	−0.147	−3.645
	(0.936)	(5.339)	(0.938)	(5.600)
σ_{11}	1.151***	–	1.133***	–
	(0.036)		(0.038)	
σ_{22}	–	4.961***	–	4.922***
		(1.616)		(1.614)
ρ	−0.447***		−0.466***	
	(0.098)		(0.095)	
Log-likelihood	−919.871		−910.659	

Standard errors in parentheses. * Significance level greater than 90%; ** significance level greater than 95%; *** significance level greater than 99%. Number of observations is 371.

As to the personal capital equation, the coefficients of all covariates in models III and IV have the same sign (and with few exceptions similar significance levels) as those in the corresponding total start-up capital equation illustrated in Table V. In other words, factors that explain the amount of total initial capital of Italian NTBFs also explain the amount

of personal capital committed to such firms. Conversely, this argument does not apply to bank loans. As to variables that capture founders' human capital, those that have a positive statistically significant effect on both personal capital and total initial capital (i.e., *Specworkexp, Techworkexp* and *Ecoeducation*), are insignificant in the bank loan equation. In addition, *LOwners* which has a positive, statistically significant effect on the amount of personal capital (as was the case for total initial capital, see again Table V), exhibits a negative albeit statistically insignificant coefficient in the bank loan equation. A Wald test run on the difference between the estimated coefficients of such variable in the personal capital and bank loan equations turns out to be statistically significant at 90% in both models III and IV ($\chi^2_{(1)} = 2.72$ and $\chi^2_{(1)} = 2.76$, respectively). *Genworkexp* that has a positive impact on personal financing has a negative effect on the amount of bank loans. However the coefficients of this variable in both equations are insignificant and the difference between them is again found to be insignificant by a Wald test ($\chi^2_{(1)} = 0.78$ in model III and $\chi^2_{(1)} = 0.50$ in model IV). Altogether these findings support the view that prospective high-tech entrepreneurs resort to bank debt to set up a new venture only when personal financial resources are exhausted, as is argued by hypothesis H_{2a}.

Lastly, industry-, location-, and firm-specific factors that allegedly shift the D curve generally have limited effects on the amount of bank loans. In accordance with Hypothesis H_3, this suggests that credit is rationed to NTBFs. In fact, *Uncertainty*, *Infrastructure* and *DMother company* have insignificant coefficients in the bank loan equation. However, the loan supply curve turns out not to be perfectly inelastic. *Mes* has a significant coefficient of the same sign (positive) as in the corresponding personal capital equation. Similarly, *DIncubated* has a negative and close to significance coefficient.[24]

6. Concluding remarks

The aim of this paper was to shed new light on the financing of NTBFs and the existence of credit constraints that may negatively affect their activity. For this purpose, we have analyzed the sources of financing used at start-up time in a sample composed of 386 young, independent Italian firms that operate in high-tech industries, both in manufacturing and services. Particular attention has been devoted to use of bank loans. The main findings can be summarized as follows.

First, we have provided clear evidence of the existence of a financing hierarchy. Italian NTBFs resort to outside financing and particularly to bank loans only when personal financial resources are exhausted. In fact, a relatively small number of sample firms (22%) relied on debt financing at start-up time (and only 15 firms resorted to outside private equity financing). In addition, the level of financial leverage turns out not to be random. In fact, it decreases with variables that are indicative of a greater amount of available personal wealth to finance firms' start-up. Lastly, unobserved factors that lead firms to use a greater amount of personal capital have an opposite effect on the amount of bank loans.

Second, firms that managed to get access to bank debt obtained on average an amount of bank loans (47,000€) that was less than half the mean amount of personal capital and almost six times smaller than the mean amount of private equity obtained by firms that resorted to this latter source of financing. These findings are consistent with those of previous work relating to the impact of financial constraints on the growth rates of small firms (see again Carpenter and Petersen, 2002b). They suggest that NTBFs indeed suffer from credit rationing. Even if they manage to get access to bank loans, the amount of debt is hardly sufficient to start operations at the desired scale.[25] In accordance with such view, the econometric estimates show that with few exceptions, factors that shift the capital demand curve of firms and thus have a significant effect on the amounts of personal capital and total initial capital committed to a new venture have negligible effects on the amount of bank loans. Nonetheless, this latter amount is found to be relatively greater for firms that operate in industries with considerable scale economies, while it is smaller for firms that being located in a technology incubator, face physical

constraints which hinder achievement of a large scale of operations. Moreover, the financial leverage of NTBFs increases with the (predicted) value of total initial capital. Altogether, these results support the view that the loan supply curve is highly inelastic, but not perfectly so.

We think that this paper offers an interesting contribution to the empirical literature concerned with the financial structure of NTBFs. Nonetheless, we are aware that this only is a preliminary step. In particular, there are two avenues for future research that seem to us especially promising. On the one hand, in this paper we analyzed access to different sources of start-up financing, but we did not consider firms' investment decisions. Therefore, we are unable to determine to what extent the likely existence of financial constraints actually binds NTBFs' operations. In order to gain further insights into such issue, it would be helpful to investigate the relation between use of different sources of financing at start-up time and in the early years after firms' foundation, and firms' investments, growth and survival rates. On the other hand, it is often claimed by the capital market imperfections literature that it is difficult to discriminate *ex-ante* between "constrained" and "unconstrained" firms (see for instance Hubbard, 1998, p. 200). While all NTBFs are potentially constrained in that they face high information costs, the implications of such constraints for their financing and investment behaviors are likely to differ according to the nature of firms' investment opportunities and the amount of personal financial resources founders may be able to collect. In other words, financial constraints are likely to be binding especially for firms that face promising investment opportunities but are unable to collect a sufficient amount of personal capital. In our data set we only have indirect proxies of the personal wealth on which entrepreneurs can tap to finance the creation of a new firm. A more direct assessment of whether personal capital is sufficient to face the financial needs of a new venture would allow a more informative analysis of the financing decisions of firms and a more precise assessment of the extent of financial constraints.

In spite of the above-mentioned shortcomings, we think that our findings have important implications for both the financial community and policy makers. First, as regards the bank system, they confirm that collateral based lending poses serious problems to NTBFs. Actually use by banks of efficient screening procedures that would allow them to check the soundness of new firms' business plans and the entrepreneurial talent of their founders, would be an important step forward. In this perspective, the new framework for capital adequacy of banks connected with the Basel II agreement clearly poses a challenge. In fact, banks will be forced to adopt rating procedures so as to be able to classify clients according to their risk. On the one hand, this may render even more binding the financial constraints from which NTBFs suffer; in fact at least in the short term, banks may try to match the Basel II criteria by further limiting loans to small firms that operate in very volatile high-tech sectors (Ade et al., 2003). On the other hand, the agreement may favor the above-mentioned transition towards proactive screening, thus benefiting the NTBF sector.

As regards technology policy, our results indicate that in bank-based countries, measures aimed at dealing with the funding gap of NTBFs are quite urgent. In this regard we think that the situation in Italy does not radically differ from that in most other countries in Continental Europe. The selection of the specific support measures is a quite delicate task for policy makers. Measures providing indiscriminate direct support to the NTBF sector are both unfeasible and inefficient, and are likely to have negative implications for social welfare. In fact, policy makers generally suffer from information asymmetries to an even greater extent than private financial intermediaries (de Meza, 2002; Lerner, 2002; Santarelli and Vivarelli, 2002); moreover they often are the target of an intense lobbying activity on the part of firms aimed at influencing the allocation of funds (Lerner, 1999).[26] Therefore, we argue in favor of *indirect* policy measures that stimulate an increase of the supply of outside capital to NTBFs, but leave to financial intermediaries the task of screening firms (for a similar view see Huyghebaert, 2004). First and foremost, these measures should target the development of an efficient venture capital industry (and angel investor segment)

so as to provide adequate seed and start-up equity financing to NTBFs (see Da Rin et al., 2005). Nevertheless, as a matter of facts in bank-based countries banks constitute by far the most important source of outside financing to NTBFs. This situation is unlikely to change in the short term. Therefore, measures aimed at reducing information asymmetries, thus rendering the loan supply curve more elastic will greatly benefit the NTBF sector. These include regulatory measures making the operations of high-tech firms more transparent. Incentives favoring use by banks of proactive screening procedures of entrepreneurial projects and adoption of a more risk-oriented attitude should also be part of a technology policy aimed at effectively dealing with the funding gaps from which NTBFs suffer.

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Notes

[1] As to the distinction between bank-based (Japan, Germany, France, Italy) and market-based (U.S., U.K., Canada) financial systems, see Rajan and Zingales (1995, 2003). As to Italy, this latter study shows that the ratio of the market value of listed firms to GDP was 13% in 1990, while it was 54% in the U.S. and 84% in the U.K. Conversely, the ratio of bank deposits to GDP was 40% in Italy, 33% in the U.K. and only 19% in the U.S.

[2] Actually we analyze the financial structure of firms 12 months after they were given a tax registration number. In fact, some time generally elapses from the date in which a firm is officially created up to the beginning of operations, as firms need time to hire personnel and organize activity. On this issue see also Reynolds and Miller (1992), Carter et al. (1996), Alsos and Kolvereid (1998), and Cassar (2004).

[3] According to data reported by Bottazzi and Da Rin (2002), in 1991 Europe invested in venture capital a considerably smaller share of GDP than the U.S. (0.01% against 0.04%), a gap that widened in 2000 (0.17% against 0.78%). In addition, in 1991 the shares of early stage investments and investments in high-tech industries (i.e., information and communication technologies and biomed) out of total venture capital investments were 10% and 17% in Europe against 32% and 73% in the U.S., respectively. While in 2000 the former share was greater in Europe than in the U.S. (32% vs. 24%), the latter one remained much lower (41% vs. 89%). In Italy, the values of all the above indicators were considerably lower than the European average. In particular, in 2004 with 23 million EURO, early stage financing (both in high-tech and other industries) accounted for a negligible share of GDP. On these issues see also Schertler (2001) and Bertoni et al. (2005).

[4] Previous empirical studies have shown that the initial size of firms increases with the human capital of founders (Mata, 1996; Åstebro and Bernhardt, 1999). In particular, Colombo et al. (2004) distinguishes between the generic and specific components of founders' human capital (for greater details see Section 5.2). They provide evidence that the latter component has a substantially larger positive effect on the start-up size of NTBFs than the former one.

[5] This argument relies on the assumption that banks can design lending contracts leading to a separating equilibrium; if there is only a pooling equilibrium, then recourse to collateral-based lending does not allow to effectively deal with adverse selection problems. For instance, Stiglitz and Weiss (1981) show that in spite of incentive aligning effects, use of collateral may also have adverse selection effects, thus lowering banks' profits. Cressy and Toivanen (2001) analyze micro-data on a large sample of loans granted by a U.K. major bank. Their results reject the existence of a pooling equilibrium, indicating that banks in fact manage to discriminate borrowers according to the quality of their investment projects.

[6] Even in the absence of any correlation between individuals' net worth and human capital, the positive relation between net worth and the likelihood of self-employment may be explained by the lower risk aversion of wealthier individuals (Cressy 2000).

[7] According to their estimates only 2.14% of U.S. firms did not get the funding for which they applied, while an additional 4.22% were discouraged from applying because of the expectation of denial. On "discouraged borrowers" see also Kon and Storey (2003).

[8] Note however that firm size is unlikely to be exogenous. On the one hand, it may be constrained by lack of external financing; this possibly leads to a reverse causality problem. On the other hand, the empirical literature documents that both the characteristics of founders (e.g., their education and professional experience) and those of the

industry of the start-up (e.g., the extent of scale economies) influence start-up size (see Colombo et al., 2004 and the studies mentioned there).

[9] In this work, a "founder" is defined as an individual who provided equity capital to and took a managerial position in a new firm. We use the term "owner" to refer to an individual who provided equity capital to a new firm independently of whether she also took an operating role in the new firm or not.

[10] The main problem is that in Italy, most individuals who are defined as "self-employed" by official statistics actually are salaried workers with atypical employment contracts. Unfortunately, on the basis of official data such individuals cannot be distinguished from entrepreneurs who created a new firm.

[11] For instance, Åstebro and Bernhardt (2003) show that failure rates of U.S. start-ups are higher for firms that did not obtain any bank loans at start-up time. Accordingly, the data we report in Section 4 possibly overestimate the extent of use of bank debt by Italian NTBFs. In our sample the likelihood of getting access to bank loans at start-up time and the size of bank loans are positively correlated with firm age at survey date. The values of the Pearson correlation index are equal to 0.11 and 0.14, respectively.

[12] In our sample, the share of personal capital out of total capital is considerably greater than the value reported by Berger and Udell (1998) for U.S. small firms in general and "infant" firms in particular. On the extent of recourse to bank debt by U.S. small firms, see also Cole and Walken (1995). Similarly, in the sample of new Australian firms examined by Cassar (2004), 43.5% had resorted to bank loans.

[13] For applications of the same model in a very similar context even if dealing with different topics, see for instance Kortum and Lerner (1998), Beugelsdijk and Cornet (2002), Heron and Lie (2002), Audretsch and Lehmann (2004), and Laursen and Salter (2005).

[14] In small family-owned Italian companies owner-managers generally keep control of strategic decisions, while salaried managers are assigned execution tasks (Colombo and Delmastro, 1999). So we assume entrepreneurial learning associated with such managerial positions to be fairly limited. Note also that we consider "leadership experience" irrespective of the sector on which it is gained as part of the specific component of human capital. In this respect, the first to acknowledge the non-sector specific nature of the managerial experience were Marshall and Paley Marshall (1879, p. 51).

[15] *Ecoeducation* measures years spent for the attainment of degrees in economics, management and political sciences, while *Techeducation* reflects years spent for obtaining degrees in engineering, physics, biology, chemistry, medicine, pharmaceutics, computer science and other technical subjects. In order to properly judge the effective level of competencies of founders, we consider the minimum length of time necessary to attain a certain degree. In order to attain an Italian graduate degree in economics, management, political sciences and most scientific degrees four years of studies are requested, while five years is the minimum time for a degree in engineering. Master and Ph.D. programmes require one and three additional years respectively, independently of the specific field.

[16] *Mes* is a proxy of the minimum efficient scale of the industry; it is computed as the log of average employment of firms (see Görg et al., 2000; Colombo et al., 2004). Data sources are the 1981, 1991, and 1996 ISTAT Census. Due to lack of data for the Internet sector, the minimum efficient scale in this sector was assumed to be the same as in the software sector. Alternative measures of *Mes* such as the one proposed by Caves et al. (1975) and Lyons (1980) could not be used because of lack of data.

[17] In order to create a proxy for industry uncertainty we had recourse to the database on European initial public offerings (IPO) that was jointly developed by Politecnico di Milano and Tilburg University. Such database includes data on 482 IPOs that occurred between 1996 and 2001 in five European new stock markets (*Neuer Markt*, *Nuovo Mercato*, *Nouveau Marchè*, *Euro NM*, *Nmax*). *Uncertainty* measures the industry average of the normalized standard deviation of the market price of newly listed firms in the 50 days following the IPO. Great variability of post-IPO stock prices in an industry signals great uncertainty on new firms' performance. Data on IPOs have been collected primarily through IPO brochures and companies' web sites, while data on market prices have been obtained from *Datastream* database and the web sites of the above-cited new markets. For further details see Giudici and Roosenboom (2002).

[18] This variable is calculated as the average of the following indexes: per capita value added, share of manufacturing out of total value added, employment index, per capita bank deposits, automobile-population ratio, and consumption of electric power per head.

[19] Note that once we condition on total initial capital, variables included in this group should not have any further effect on financial leverage; so they are not introduced as independent covariates in this latter equation. The estimates of the double-censored tobit model with the inclusion of these variables confirm that they have no explanatory power of financial leverage (the results are available from the authors upon request). In fact, the null hypothesis that the coefficients of *Mes*, *Uncertainty*, *DIncubated*, *Infrastructure* and *DMother company* be jointly equal to null cannot be rejected by a LR test ($\chi^2_{(5)} = 4.07$ and $\chi^2_{(5)} = 5.28$ in models I and II, respectively).

[20] According to the literature on the determinants of the financial structure of firms (see for instance Myers, 1977, 1984; De Angelo and Masulis, 1980; Harris and Raviv, 1991; see also Brealey and Myers, 2003, ch. 18), other variables should be introduced into the econometric models as controls. In particular, one should consider how the incentives to use the tax shield associated with the deductibility of interest payments vary across firms. Unfortunately, data relating to this aspect are not available in the RITA database. Nevertheless, in the early years of life, firms generally make no or very small profits. So the different tax treatment of different types of capital should have a negligible effect on their financial structure. In accordance with this view, Michaelas et al. (1999) show that for small

U.K. firms, the value of financial leverage is influenced neither by the effective tax rate nor by other non debt-based tax shields (i.e., depreciations). Similar results are obtained by Huyghebaert and Van de Gucht (2004) for Belgian firms.

[21] Inclusion of these 15 firms does not substantially alter the findings of the estimates. Results for the full sample are available from the authors upon request.

[22] If there are imperfections in the credit market, one may argue that the loan supply curve will be steeper the greater the uncertainty in the business environment, as information asymmetries between banks and high-tech entrepreneurs are amplified. In addition, the wedge between the costs of personal capital and bank loans may be sensitive to the level of interest rates. In accordance with such arguments, we introduced *Uncertainty*, *Rreal* and *Defaults* as additional covariates in the financial leverage equation. However, their coefficients turned out not to significantly differ from null. The results of the estimates are available from the authors upon request.

[23] A likelihood ratio test rejects the null hypothesis of a model specification given by two independent tobit equations in favor of the bivariate tobit specification ($\chi^2_{(1)} = 59.05$ and $\chi^2_{(1)} = 64.30$ in models III and IV, respectively).

[24] Relying on the estimates of model IV, we are able to illustrate the effects of these variables on the amount of bank loans of firms through a simple simulation exercise. For this purpose, we are forced to make a simplifying assumption, as is usual with this type of models that have a quite complicate likelihood function (see Greene, 2000, p. 854, for the case of a bivariate probit model). In fact, the econometric software package does not allow us to calculate the expected value of the two dependent variables of the bivariate tobit model. So we set at 0 the correlation coefficient between the error terms of the two equations. In this way the expected value of the amount of bank loans is given by the same expression as the expected value of the dependent variable of an individual tobit model. The results of the simulation should therefore be interpreted with caution and are presented purely for clarification purposes. Suppose that *Mes* be equal to the value corresponding to the first decile in ascending order (0.73); let continuous variables be equal to their mean value and dummy variables be equal to zero. Then the expected value of bank loans equals 1.724€. If Mes is equal to the value corresponding to the first decile in descending order (1.67), with all other variables at the same value, the expected value of bank loans increases to 3.401€. With the same assumptions, the expected value of bank loans is equal to 1.246€ and 1.975€ for a on-incubator firm and a off-incubator one, respectively.

[25] Accordingly, Huyghebaert and Van de Gucht (2004) show that in industries where problems of adverse selection and moral hazard are potentially high, start-ups exhibit a smaller share of bank debt out of total debt. The authors conclude that due to the difficulties and high costs of screening and monitoring high-tech new ventures, banks limit exposure to risk by reducing the size of loans.

[26] Nevertheless, there are examples of effective direct public support measures in favor of high-tech start-ups, as the "Small Business Innovation Research" (SBIR) program and the "Advanced Technology Program" (ATP) in the U.S. Previous studies mention the provision of "coaching" in addition to financing and the ability to stimulate rather than crowd out additional private financing as key success factors of these programs (Lerner, 1999; Audretsch, 2003; Cooper, 2003; Feldman and Kelley, 2003).

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