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Venture capital financing and innovation in European New Technology-Based Firms: a longitudinal analysis on the role of the type of investor

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Impact of R&D on firm productivity and market performance

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Abstract

The aim of this paper is to analyze empirically the impact of Venture Capital (VC) financing on the innovation activity of European New Technology-Based Firms (NTBFs). In particular, we compare the TFP level of VC-backed and non VC-backed NTBFs to investigate the effect of VC financing. We further want to assess whether the typology of investors, i.e. Independent Venture Capitalists (IVCs) and Corporate Venture Capitalists (CVCs), has an influence on the productivity of VC-backed firms. We expect the effect of CVC and IVC financing to be different due to different characteristics of the two typology of investors, e.g. different objectives. To test these hypotheses, we consider a unique longitudinal dataset composed of 3,687 NTBFs from six European countries (Belgium, Finland, France, Italy, Spain, UK), 313 of which are VC-backed. Sample firms were established in 1984 or later, remained independent up to the end of 2008, and are observed from 1994. To analyse the determinants of firm TFP, we estimate different panel data models. The results show that Venture Capital financing positively affect subsequent productivity. Our findings reveal that IVC and CVC financing have the same impact on TFP in terms of magnitude. However we find preliminary, indirect, evidence that the means by which IVC and CVC boost productivity growth are different.

Key words: Venture capital, Total Factor Productivity, New technology-based firms, Innovation

JEL classification: G24, D24, D92, L26

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1 - Introduction

Since the seminal work by Jaffee and Russell (1976) and Stiglitz and Weiss (1981), the argument that there are frictions in capital markets that make it difficult for firms to obtain external financing and constrain their investment decisions has increasingly been gaining ground in the economic and financial literature (see Fazzari *et al.*, 1988 and the studies mentioned by Hubbard, 1998). New technology based firms (NTBFs) are those which are most likely to suffer from capital market imperfections. This applies especially apply to bank loans (Carpenter and Petersen, 2002). Banks generally do not possess the competencies to evaluate *ex ante* and monitor *ex post* the investment projects by young high-tech firms. While, in principle, adverse selection and moral hazard can be alleviated by collateralized loans (Berger and Udell, 1998), the value of high-tech firm is often in intangible and/or firm-specific assets that provide little protection as collateral. Poor access to external financing may limit the growth and threaten the survival of NTBFs, and this makes the design of correct support policies crucial given the key role they play in assuring dynamic efficiency and employment growth in the economic system (Audretsch, 1995; Acs, 2004).

Venture capital (VC) financing is generally considered by both academics and practitioners as the most suitable external financing mode for NTBFs. It is contended in the financial literature that VC offers a fundamental contribution to the success of high-tech entrepreneurial ventures (see for instance Sahlman, 1990; Gompers and Lerner, 2001; Kaplan and Strömberg, 2001; Denis, 2004).

Nonetheless, whether access to VC financing fosters the innovative activity of portfolio companies is a matter of empirical test. Previous evidence, deriving mainly from industry level analysis (Kortum and Lerner, 2000; Tykvova, 2000; Ueda and Hirukawa, 2006), shows that a positive relation between venture capital financing and patenting activity exists. Fewer studies analyze the effect at firm-level and find mixed evidence (Engel and Keilbach, 2002; Baum and Silverman, 2004).

In this work we contribute to the literature by analyzing the evolution of Total Factor Productivity (TFP), which we use as a proxy for firm's innovative activity. In order to capture the effect of VC financing on firm's innovative activity, we estimate econometric models that estimate the impact of VC financing on TFP on a longitudinal dataset composed of European NTBFs. The sample includes 3,687 companies from six European countries (Belgium, Finland, France, Italy, Spain and the UK) out of which 313 were invested by VC between foundation and 2004. In addition, we distinguish VC-backed firms according to whether VC financing is provided by independent VC firms (*i.e.* IVC) or corporate investors (*i.e.* corporate venture capital, CVC).

The results of the estimates strongly support the view that VC financing has a dramatic positive effect on firm's TFP even though, contrary to our expectations, no differences arise between IVC- and CVC-backed firms.

The paper is structured as follows. In the next section we survey the literature on the effects of VC financing on firm's innovative performances; we also consider differences between IVC and CVC investors. In Section 3 we describe the sample of firms that are considered in the empirical analysis. In Section 4 we illustrate the empirical methodology. Section 5 reports the results and Section 6 concludes.

2 - Literature review

The financial literature highlights several motives explaining why VC financing could stimulate the performances of invested NTBFs. First of all, these firms are likely to be financially constrained (see e.g. Carpenter and Petersen, 2002; Colombo and Grilli, 2007). Owing to their superior *screening* capabilities (Chan, 1983; Amit *et al.*, 1998), VC investors can identify firms with great innovative projects, the quality of which remains hidden to other investors, and provide them with financial resources (e.g. necessary to support R&D).

Second, VC firms actively *monitor* the behavior of entrepreneurs of portfolio companies (Lerner, 1995; Kaplan e Strömberg, 2003) and they make use of specific financial instruments and contractual clauses (e.g. stage financing) that protect their investments from opportunistic behavior on the part of entrepreneurs and create high powered incentives for them (Sahlman, 1990; Gompers, 1995; Hellmann, 1998; Kaplan and Strömberg, 2003, 2004).

Third, VC investors perform a key *coaching* function to the benefit of investee firms. In fact, they provide portfolio companies with advising services in fields such as strategic planning, marketing, finance and budgeting, and human resource management, in which these firms typically lack internal capabilities (Gorman and Sahlman, 1989; MacMillan *et al.*, 1989; Bygrave and Timmons, 1992; Sapienza, 1992; Barney and Busenitz, 1996; Sapienza *et al*., 1996; Kaplan and Strömberg, 2004).

Lastly, VC financing conveys a *signal* about the good quality of a NTBF to third parties. Therefore invested companies find it easier to get access to external resources and competencies that would be out of reach without the endorsement of the VC investor (Stuart *et al.*, 1999). Moreover, portfolio firms can take advantage of the *network* of social contacts of their VC investors with potential customers, suppliers, and alliance partners (Colombo *et al.*, 2006; Hsu, 2006; Lindsey, 2008).

The relaxation of financial constraints, monitoring, coaching, signaling and networking are all likely to increase R&D productivity. This notwithstanding, the empirical literature is not unanimous as to the positive effects of VC financing on innovation despite different measures of innovative performance (e.g. patents or TFP) and different level of analysis (e.g. industry- vs. firm-level) have been explored.

In the next Section we review the existing literature on this topic and in Section 2.2 we discuss why different VC investors, i.e. Independent Venture Capital and Corporate Venture Capital investors, might lead to dissimilar impacts on firm's performance.

2.1 The contribution of VC to innovation output (TFP)

TFP reflects how effectively firms use production inputs to produce output respective to other firms that operate in the same industry. The higher is TFP, the more a company is able to produce its output using less inputs (or more output from the same inputs), than other companies. TFP change is also a good indicator of innovative activity (see Colombo et al., 2009b, for a review). Innovation can come as either process or product innovation which, in turn, lead respectively to a more efficient use of resources and to higher revenues. Thus both product and process innovation lead to increases in TFP. Moreover, TFP directly takes into account the effects of potential technological shifts and organizational changes on the production function, which again is extremely pertinent in this context. In fact, measures of partial productivity, such as labor productivity, may fail in doing so, since they do not consider tradeoffs among input factors (as highlighted in the work of Hirukawa and Ueda, 2008a, 2008b).

TFP is not subject to some shortcomings of other innovation measures as those based on patenting, especially when, like in this sample, most sample firms operate in service sectors where patents are rarely used to protect innovations. Moreover, patenting is highly endogenous to VC. First, patent grants signal the quality of entrepreneurial ventures (Hsu and Ziedonis, 2007) and this signal may positively influence an NTBF's ability to attract VC financing (Chemmanur et al., 2008). Second, firms might decide to patent before they start negotiating with VC, to protect their innovation from possible moral hazard on VC's side (Ueda, 2004).

Still few works however address the relation between VC investments and firm's TFP. Two notable contributions are the works by Chemmanur and colleagues (2008), and Ueda and Hirukawa (2008b). Chemmanur *et al.* (2008) analyze the causality direction between VC investments and TFP growth in a large sample of US private firms. They find that VC-backed firms exhibit higher TFP than non-VC-backed firms prior to receiving VC. Moreover VC-backed firms' TFP growth is greater after receiving VC. They also try to disentangle the relative size of the "sorting" and "treatment" effects using endogenous switching regression and matching techniques. They document that VC financing boosts the TFP of sample firms, suggesting that venture capitalists provide significant value to portfolio firms. Ueda and Hirukawa (2008b) address the causality issue between VC investments and innovation at the industry level: they investigate whether it is VC that spurs innovation or if it is the arrival of a new technology that increases demands for VC by driving the birth of new firms. Using TFP as measure of innovation they find support for both of these hypotheses in computer and communication industries. On the contrary they find a negative relation between VC and TFP growth in drugs and scientific instruments.

Industry level evidence

Most of the early papers about VC and innovation perform industry level analysis of the patenting activity as a function of VC financing. The work by Kortum and Lerner (2000) is probably the first large-scale study dealing with this topic. They analyze patents data and VC financing across twenty manufacturing industries between 1965 and 1992 in the USA. They use a patent production function at industry level, controlling for the arrival of technological opportunities that could lead to a spurious relation between VC and patenting activity.[1] They document that VC does indeed spur patenting activity. Its effect is found to be even more positive than the one of traditional corporate R&D. They also conduct a firm level analysis on 122 VC-backed and 408 non VC-backed companies to check whether the effect of VC derives only from a change in firm's patent propensity (i.e. using patents more to protect their proprietary technology instead of relying on different appropriability mechanisms). The results suggest that VC-backed companies i) have patents that are more frequently cited, and so supposedly are of better quality, and ii) engage more in trade secret litigations than non VC-backed firms (i.e. they don't make less use of other appropriability mechanisms like trade secrets).

In a similar study, Tykvova (2000) uses the same patent production function; she finds that VC investments have a highly significant positive effect on patenting activity in a sample of ten German industries observed between 1991 and 1997. The estimated effect of VC is lower in comparison with Kortum and Lerner (2000). However, the extent of this effect might be underestimated due to the inclusion in the analysis of private equity investments in addition to classical VC investments.

[1] They use i) R&D expenditures to control for the arrival of technological opportunities that could be anticipated only by economic actors at that time and ii) a policy shift, that was unlikely to be related to the arrival of opportunities, in an instrumental-variable regression.

Another work by Ueda and Hirukawa (2008a) exploit once more the same methodological framework used by Kortum and Lerner (2000), extending the sample up to 2001, to include also the NASDAQ bubble period and they confirm the results of the previous works. However, they argue that these findings could be explained by a different patent propensity between VC-backed and non-VC-backed firms, and that the use of total factor productivity (TFP) growth, as a measure of innovative activity alternative to patents, may rule out this problem. To some extent, they do not find support for the argument that VC investments have a positive impact on TFP growth.

Firm level evidence

Unlike the abovementioned studies that are conducted mainly at industry level, other scholars move to the firm level for a more in-depth understanding of the relationship between VC and innovation activity and its causality direction. In particular, for what concerns patents one should acknowledge that they can be considered as a signal (Spence 1973) of firm's quality, since i) the examination process provides a certification function for the underlying invention, and ii) they are costly to obtain. This may have controversial effects on the likelihood of a firm in obtaining VC. On the one hand, VC investors may be attracted by firms with superior quality certified by the patents they have been granted. Moreover, patents may have a signaling function to outside investors other than VC investors, thus favoring the exit strategy of these latter through a trade sale or a IPO. On the other hand, to the extent that this signal alleviates adverse selection problems, it may destroy the real source of the competitive advantage in screening enjoyed by VC investors, with an opposite effect on the likelihood of the focal firm in obtaining VC. Whatever the net effect of these opposed forces, the above reasoning argues in favor of the need for adequate controls for the endogeneity of VC investments in assessing their innovation impact at firm level.[2]

Engel and Keilbach (2002) consider a sample of 142 German VC-backed companies that were established between 1995 and 1998 and rely on matched pair techniques to study the effects of VC on innovation output. Focusing on the very early stage of firms' life, they show through probit estimation that firms' pre-foundation patenting behavior and human capital characteristics do affect the probability of VC involvement. They then resort to the propensity score method to build their control sample. The average number of patents in the VC-backed group is (weakly) significantly higher than in the control group. Baum and Silverman (2004) directly address the causality issue between VC investments and firms' patenting activity. Their sample is composed of 204 biotechnology start-ups located in Canada. Relying on time series regression techniques, they find that the amount of pre-IPO financing is positively affected by patent applications and patents granted in the year before the receipt of VC finance. Furthermore they do not find support for the hypothesis that patenting activity, measured both by number of patent applications and patents granted, is positively related to the amount of VC financing in the previous year.

A recent work by Bertoni *et al.* (2009) analyzes the effect of VC financing on patent propensity using a sample of 351 Italian NTBFs operating in high-tech manufacturing

[2] Hsu and Ziedonis (2007) provide evidence that patents do signal the unobserved economic value of start-up firms to external investors. In fact, while examining 370 US semiconductor start-ups receiving VC, they find that pre-money valuation is positively affected by the stock of patent applications held by the firm. This relation is particularly significant in early funding rounds and when funds are provided by prominent VC investors. Moreover, they find that patent applications stock positively affects the probability of an investor exit through IPO. Similarly, Munari and Toschi (2007) using a sample of 332 VC-backed companies in the nanotechnology sector, document that the patent portfolio in nanotech patent classes is positively associated with the amount of VC financing.

industries and software. They perform a longitudinal econometric analysis, controlling for factors that may affect firm's patenting behavior other than the presence of VC, like founders' human capital and the use of other sources of financing. Their results show that VC investments positively affect subsequent patenting activity and that before receiving VC, VC-backed firms do not exhibit a higher patenting propensity than other firms.

Colombo et al. (2009a) analyze the effect of VC financing on TFP using a sample of 222 Italian NTBFs operating in high-tech manufacturing and services. They perform a longitudinal econometric analysis in the period 1994-2003, controlling for factors that may affect firm TFP other than the presence of VC, like the use of other sources of financing, bank debt, free cash flow. Independently of the specific econometric techniques, the results reveal that VC investments have a positive and significant impact on the productivity of NTBFs in accordance with other recent studies (e.g. Chemmanur et al., 2008).

Other studies have relied on innovation indicators other than TFP and patents. Hellmann and Puri (2000) analyze the impact of VC investments on product market behaviour in a sample of 173 start-up companies that are located in Silicon Valley. They find that pursuing an innovator strategy[3] positively affects the probability of obtaining VC. Moreover VC finance reduces time to market especially for innovator firms. Da Rin and Penas (2007) examine the innovation strategies of a sample of Dutch firms, out of which 91 are VC-backed. They contrast a "make" innovation strategy, based on internal R&D investments, with a "buy" strategy that relies on R&D outsourcing, and compare the effects of VC finance and public subsidies on firms' choice of R&D strategy. Interestingly, they find that public financing merely relaxes firms' financial constraints without shifting the balance between influencing the choice between "make" and "buy" R&D strategies. Conversely, obtaining VC shapes the subsequent innovation strategy of portfolio firms in favour of a "make" strategy, causing a permanent shift toward in-house R&D.

To sum up, the above mentioned studies are not unanimous as to the positive effect of VC investments on firm's innovation output and to the causality direction between the two. In this study we want to empirically test whether VC investments foster TFP of European NTBFs. As we illustrate in the next section, in this paper we also argue that the effects of VC on NTBFs' performances are likely to depend also on the typology of investor.

2.2 The contribution of different types of investors

Recently it has been argued in the literature that, especially in Europe, there is great heterogeneity across VC investors (Bottazzi *et al.*, 2004). In turn, the different characteristics of VC investors affect their behavior and the effect that they have on the performances of portfolio companies. In this paper, we focus attention on the distinction between independent venture capital companies (IVC) and corporate venture capital investors (CVC). As will be explained below, these two categories of investors differ along several dimensions. As a result, we expect that the effects on innovative performances of their presence as shareholders in the equity capital of portfolio companies to differ as well.

First of all, IVC and CVC investors are likely to pursue different objectives. The aim of IVCs is to realize the greatest possible IRR, that is, ideally, a conspicuous capital gain in the shortest possible time. Conversely, previous studies highlight that CVCs often pursue

[3]They measure innovator ex-ante strategy through interviews, trying to capture if firms are introducing a new product or service that i) is not a close substitute of a product/service already offered on the market, ii) is expected to outperform product/services already offered in the market, or iii) satisfies either of the two criteria above.

strategic objectives in addition to or even in substitution of financial objectives (Chesbrough, 2002; Dushnitsky and Lenox, 2005a). In a seminal work on CVC, Siegel *et al.* (1988) show that, according to the surveyed parent corporations, "*exposure to new technologies and markets*" is the most important motive for them to engage in CVC. Similarly, Ernst *et al.* (2005) document that CVC is used by large German firms for technology window purposes; in fact, it allows parent companies to closely monitor the development of promising technological innovations related to their core business on the part of young firms and then possibly to acquire them. In accordance with the view that CVC is mainly used by incumbent firms as a technology learning device and it is not merely driven by financial objectives, Dushnitsky and Lenox (2005a) while analyzing a large sample of US public firms observed over a 10 years period (1990-1999), show that CVC investment is mostly attracted by industries which exhibit great technological ferment, weak protection of intellectual property rights, and an intermediate level of technology proximity with the knowledge base of the corporate investor. Gompers (2002) highlights that in the US, CVCs have increasingly oriented their investments towards industries that are related to the core business of parent companies. Dushnitsky and Lenox (2006) find that CVC investments create value for the corporate investor, measured by the contextual increase in the Tobin's Q, only if CVC is pursued for strategic reasons (i.e. gaining a window on the novel technologies developed by portfolio firms). Dushnitsky and Lenox (2005b) document that CVC investments substantially boost the citation-weighted patent output of the corporate investor in the five years that follow the investment and that this effect is more pronounced when the investor has both great absorptive capacity (Cohen and Levinthal, 1990), proxied by the level of R&D expenses, and an intermediate technology proximity with portfolio firms (see also Winters and Murfin, 1988; Sykes, 1986, 1990; Block and MacMillan, 1993; Gompers and Lerner, 1998; Chesbrough, 2000, 2002; Ernst and Young, 2002). Moreover, the results obtained by Dushnitsky and Lenox (2005b) suggest that different objectives lead to different investment strategies. CVC financing is higher in industries characterized by low appropriability regimes due to their technology windowing (Dushnitsky and Lenox, 2005a).[4] In contrast focus on financial returns will push towards firms that can internalize the largest part of the returns from their innovations, thus increasing their value and financial returns of investors.

Second, the alleged superior performance of VC-backed firms relative to their non VC-backed counterparts depends on the scouting, monitoring and coaching activities carried out by external investors and the certification effect engendered by reception of VC financing. We also mentioned that the agency relation between the external investor and the entrepreneur may lead to inefficiencies (for documented evidence and references, see Colombo et al., 2009a). The extent of these positive and negative effects on the innovation of portfolio firms is likely to depend on the type of the external investors and the different objectives they pursue (Hellmann, 1998). Siegel *et al.* (1988) find that the strategic objectives of CVC investors often diverge from those of the entrepreneurs of portfolio firms. This possibly leads to conflicts between entrepreneurs and CVC investors that absorb entrepreneurs' time and energy to the detriment of firm performances (Chesbrough, 2000). Appropriability hazards also are greater with CVCs than with IVCs, especially if the parent company of the CVC operates in the same sector as the portfolio firm or in a closely related one (Block and MacMillan, 1993). Fear of expropriation may induce entrepreneurial firms with the most promising novel technologies to look elsewhere

[4] In weak intellectual property protection regimes, ventures might not be able to put a stop to knowledge spillovers to CVC investors, thus increasing returns from CVC investments (Dushnitsky and Lenox 2005a).

for external financing.[5] In addition, CVC may suffer from organizational deficiencies. Early stage financing of high-tech firms is the core business of IVC firms, while it is an ancillary activity for the parent company of CVCs. As a corollary, CVC investors are likely to benefit from learning by doing to a more limited extent than IVC firms. It may also be rather difficult for CVC parent companies to design an incentive structure for managerial personnel apt to attract highly qualified individuals (Block and Ornati, 1987). Hence the scouting, monitoring and coaching capabilities of CVC investors are likely to be inferior to the those of IVC firms.

On the other hand, some empirical studies (Holmstrom, 1989; Zwiebel, 1995; Aghion *et al.*, 1997; Czarnitzki and Kraft, 2004) suggest that firms controlled by managers have lower incentives to invest in R&D activities than companies controlled by the owners due to risk aversion and short-termism of managers. This is particularly relevant in case of an entrepreneurial NTBF involved in VC financing. Moreover, severe changes in the internal control system may occur if VCs put more emphasis on financial rather than strategic control. This may stifle the incentives to innovate since it focuses more on short-term ROI targets with less emphasis on long run projects (Hitt *et al.*, 1996). Due to the strict financial objectives, IVCs are likely to induct greater changes in management and internal control system of funded companies than CVC investors.

Moreover, the presence of a CVC investor in the equity capital of a high-tech start-up may engender benefits that cannot be provided by IVC firms, with this leading to superior firm innovative performances. In fact, through the CVC, invested firms may obtain access to the specialized irreproducible resources and distinctive competencies of the parent company (e.g. distribution channels, brand, production capacity, complementary technological competencies. See Block and MacMillan, 1993 and Dushnitsky, 2004). In addition, portfolio firms can benefit from the network of industry-specific contacts with potential customers and suppliers of the parent company of the CVC investor. Endorsement by a highly reputed firm is also very valuable and may help portfolio firms in establishing business relations with third parties (Stuart *et al.*, 1999; Maula, 2001; Maula and Murray, 2001).

To sum up, whether CVC financing has greater beneficial effects on portfolio firms than IVC financing is controversial and, to the best of our knowledge, no study as yet analyzed the differences between the effects of IVC and CVC on firms' productivity.

3 - The sample

In this work we analyze the pattern of TFP on a sample 3,687 NTBFs located in six European countries (Belgium, Finland, France, Italy, Spain and the UK). Companies in our samples are established between 1984 and 2004 and belong to the following sectors: Internet & TLC services, Software, ICT manufacturing, Biotech & Pharmaceuticals, Non-ICT manufacturing, Other R&D services. All companies in our samples have been established as independent entities (e.g. not as subsidiaries of national or multinational companies). For each company in the sample we collect accounting information since foundation (or since available) up to 2007 (or until available). We obtain a total of 18,054 firm-year observations (i.e. 4.8 yearly observation per firm) for which we have the complete set of information required by the analysis described in Section 4. Table 1 reports the distribution of sample companies. Of the 3,687 companies in our sample, 982 (i.e. 26.63%) are Italian, 721 (19.56%) are French, 677 (18.36%) are Finnish, 542

[5] For the same reason, CVC investors may be disadvantaged in reducing information asymmetries relative to IVC investors, as high-tech start-ups looking for external financing may be less inclined to reveal proprietary information (Dushnitsky 2005a).

(15.60%) are English, 542 (14.70%) are Belgian, and 190 (5.15%) are Spanish. The sample is thus quite balanced across the different countries with the exception of Spain for which some covariates needed for second-step analysis (namely those regarding financial structure) described in Section 4.2 were often not available.
The most numerous industries in our sample are Software with 1,764 companies (47.84%), ICT manufacturing with 783 companies (21.24%), and Internet & TLC services with 492 companies (13.34%). This reflects the industrial structure of NTBFs in Europe in the 1990s and early 2000s, characterized by the considerable importance of IT-related companies. Indeed almost 60% of our sample companies have been established after 1995 (31.68% between 1995 and 1999, and 28.75% between 2000 and 2004). Finally, 3,040 companies (82.45% of sample) are still active as independent entities at the end of 2008. Of the 647 companies which are not any longer active as independent , 243 (6.59%) have been acquired, 370 (10.04%) have been liquidated and 34 (i.e. 0.92%) are inactive (e.g. in a restructuring process, waiting for a liquidation process to be executed, temporary out of business…).

[Table 1 about here]

Out of the 3,687 companies in our sample 261 (7.08%) are IVC-backed and 99 (2.69%) are CVC-backed; 53 companies (1.44% of the sample, 19.85% of IVC-backed companies and 53.54% of CVC-backed companies) are financed by both IVC and CVC along their lives (i.e. companies which are financed by either IVC or CVC are 313). The distribution of IVC and CVC backed companies broadly follows that of the whole sample with, however, some exceptions which are worth mentioning. First, both IVC and CVC backed companies appear to be more active in Internet &TLC services and Biotech & Pharmaceutics. In Internet &TLC services we find 13.34% of the whole sample against 21.07% of IVC-backed companies and 34.34% of CVC-backed companies. Biotech & Pharmaceutics constitute 8.38% of the whole sample against 15.33 of the IVC-backed and 12.12% of CVC-backed. On the contrary, Software represents 47.84% of the whole sample but only 38.31% of IVC-backed companies and 31.31% of CVC-backed companies. This confirms the well known attitude VC investors to specialize in some industries (IT in the mid and late 1990s and Biotech between the early and mid 2000s). We also find that a larger proportion of VC-backed (81.61% and 83.63% of respectively IVC-backed and CVC-backed) companies have been founded since 1995: this confirms that VC activity in Europe has been limited, especially in NTBFs, in the 1980s and early 1990s. While the percentage of IVC-backed companies declines slightly since the burst of the Internet bubble, the fraction of CVC-backed companies rises, suggesting that this latter investor gained increasing importance in Europe. Finally, it is also interesting that a significant difference can be found in the distribution of companies according to their current status. IVC-backed and CVC-backed companies are respectively 1.9 and 2.6 time more likely to be acquired than non-VC-backed companies. This is easily explained by considering that acquisitions (in form of trade-sales) are, especially in Europe, a very common way out for VC investors.

4 - Methodology

4.1 TFP estimation

We use TFP to measure NTBF's innovation performance. TFP is estimated through a semi-parametric procedure originally proposed by Olley and Pakes (1996), which allows

for firm-specific productivity differences exhibiting idiosyncratic changes over time.[6] This semi-parametric approach, increasingly used in empirical industrial organization literature (e.g. Pavcnik, 2003; Cingano and Schivardi, 2004; Blalock and Gertler, 2007), presents several advantages compared with other methods in dealing effectively with the typical simultaneity problem in the choice of inputs. More in detail, to obtain consistent estimates of production function parameters (and thus a consistent measure of TFP), we have to address two estimation problems: a selection problem generated by the relationship between the unobserved productivity variable and firm's shutdown decision, and a simultaneity problem generated by the relationship between productivity and input factors.

Specifically, the Olley and Pakes methodology assumes that at the beginning of every period an incumbent firm has to decide whether to exit or continue in operation. If it continues, it chooses variable factors (labor) and the level of investments, which together with the current capital value determine the capital stock at the beginning of the next period.[7] Starting from a standard Cobb-Douglas production function:

$$y_{it} = \alpha + \beta_a a_{it} + \beta_l l_{it} + \beta_k k_{it} + \omega_{it} + \varepsilon_{it}, \quad (1)$$

where y_{it}, a_{it}, l_{it}, and k_{it} denote the logarithm of production output, firm age, the logarithm of labor and the logarithm of capital, respectively; subscripts *i* and *t* stand for the cross-section dimension and time; ω_{it} represents a productivity difference known to the firm but unobservable to the econometrician; and ε_{it} denotes other sources of i.i.d error. Consistent estimates of the coefficients of the input factors in (1) are prevented by an endogeneity problem. In fact, firms choose the input knowing their own level of productivity, leading to correlation between regressors and error terms if (a proxy of) ω_{it} is not specified. To deal with this problem, it is assumed that labor is a variable input while capital is a fixed factor affected only by the distribution of ω conditional on information in *t-1* and past values of ω (i.e. a first-order Markov process). The level of investments depends on the capital stock, on firm age, and on the firm's unobserved productivity: $i_{it}=(\omega_{it}, a_{it}, kit)$. In turn, if monotonic properties are satisfied, the unobserved productivity ω_{it} can be expressed as a function of observable investments and k_{it}: $\omega_{it}=(i_{it}, a_{it}, kit)$. In the first step, we consistently estimate β_l. The coefficient β_k is similarly obtained in a second step by exploiting the assumption that the stock of capital does not immediately respond to productivity shocks. This procedure is run separately for each industry.

4.2 Impact of VC investors

In assessing the treatment effect of VC financing on firm's TFP according to investor typology, we face two obstacles. First, a positive association between TFP and the presence of a VC investor may simply be a consequence of reverse causality, with higher TFP firms being more likely to receive external financing. Second, there may be unobserved factors (e.g. a smart management team) that explain both firms' economic performance and VC backing. To account for possible unobserved heterogeneity that, if correlated with regressors, may lead to biased estimates of the parameters of interest, we use within-group estimator (WG).

As explained above, we use TFP as a measure of NTBFs economic performance. To investigate whether VC financing has an impact on TFP, the following econometric model is specified:

[6] For a survey of the various estimation techniques of TFP and a more detailed description of Olley and Pakes's methodology, see Levinsohn and Petrin (2003) and Van Biesebrock (2007).

[7] As customary in this context, investments are calculated as the book value of tangible and intangible assets at time *t* minus the book value of tangible and intangible assets at time *t-1* plus depreciation at time *t*.

$$\ln TFP_{it} = \alpha + \beta' VC_{it} + \lambda Age_{it} + \delta' Z_{it} + \eta_i + \varepsilon_{it}, \quad (2)$$

where $lnTFP_{it}$ is a measure of TFP (described in detail in Section4.1); VC_{it} is a vector of covariates that captures the different typologies of VC investors, namely IVC and CVC investors; Age_{it} denotes the age of NTBFs; Z_{it} are a series of control variables that include the ratio of debt to total assets *DTAit* (Becchetti and Trovato, 2002), the cash flow to sales ratio *CFSit* (Brush et al., 2000), a series of controls about industry, country, and a complete set of time dummies (to control for macroeconomic effects). Fixed effects, η_i, capture unobserved firm-specific heterogeneity; and ε_{it} are usual independent disturbance terms.

5 - Results

Table 2 shows the results of the estimation of equation (1) through Olley and Pakes methodology. The coefficient β_l, which measures the elasticity of output with respect to Labor, exhibits a relatively low variation across industries going from 0.403 in Internet & TLC services to 0.624 in Biotech & Pharmaceutical. The coefficient β_k is instead less leveled and ranges between 0.061 (Non-ICT manufacturing) and 0.236 (Internet & TLC services). Firm's age is instead never significant at conventional confidence levels.

[Table 2 about here]

Before moving to a full-fledged econometric approach it is useful to compare the level and evolution of TFP computed with the Olley & Pakes method. **Figure 1** compares the level of log(TFP) across industries and age between VC-backed and non VC-backed companies.

[**Figure 1** about here]

The broken line in **Figure 1** represents median log(TFP) of non VC-backed companies. The evolution of log(TFP) is, as expected, increasing over time and concave in all industries. The solid line in **Figure 1** is instead the median log(TFP) for companies after receiving VC financing (either VC or CVC). The median log(TFP) is significantly higher than that for the control group, which confirms that VC-backed companies are on average more efficient than non VC-backed ones controlling for age and industry. This preliminary evidence is of course compatible with both productivity enhancement by VC investors and ex-ante superior productivity by companies which eventually become VC-backed. To disentangle between the two we estimate model (2) using WG (the OLS estimator is added for comparison purposes only). Results are reported in Table 3.

[Table 3 about here]

In the first two columns in Table 3, we insert a VC variable which does not distinguish whether VC comes from IVC and/or CVC. As regards the control variables, estimates confirm the intuition in **Figure 1** that age has a positive significant impact on TFP. Relatively more mature firms have had more time than very young ones to properly organize their production and sales activity. DTA_{it} and CFS_{it} show negative and positive coefficients, respectively, even though the coefficient of CFS_{it} is statistically significant only in OLS estimation. Quite reasonably, having higher liquidity positively influences firm investments and, consequently, productivity. More interestingly for the purpose of this paper, VC financing has a dramatic positive impact on the TFP of NTBFs. The coefficients

of the VC variable is positive and significant at 99% in both OLS and WG regressions. Standard errors of these coefficients are very small and we can reject the hypothesis that VC financing does not affect TFP. Our results thus confirm that VC financing improves firm efficiency. Comparing the estimated WG coefficients of firm's age and VC financing, we can estimate that once VC- backed, companies exhibit a TFP which, if non VC-backed, they would have attained only some 8 years later.

In this paper we are particularly interested in assessing the different impact of IVC and CVC investors. Again, before commenting the results in Table 3, it is useful to graphically assess the dynamics of TFP for IVC and CVC backed companies. The solid and broken lines in **Figure 2** represent log(TFP) for respectively IVC-backed and CVC-backed companies in a period ranging between 3 years before and 3 years after receiving VC. After investment median log(TFP) of IVC- and CVC-backed companies grows steadily but no significant difference seems to emerge between the two investors.

[**Figure 2** about here]

Results of econometric analyses confirm this intuition. In columns (3) and (4) we distinguish VC according to its nature, namely IVC or CVC. The results relating to control variables are similar to those discussed above and do not deserve any further comments. The coefficients of the IVC and CVC variables are statistically significant both estimations at conventional confidence levels.[8] The estimates show however that, quite surprisingly, the effect of VC financing on firm TFP indeed does not differ significantly between IVC and CVC. Wald tests on the coefficients of IVC and CVC never reject the null hypothesis that they are equal. Our results indicate though that the differences between these two types of investors in terms of objectives, investment period, skills and sectoral experience as reported in Section 2.2 do not reflect in different patterns of TFP increase.

Finally, we control for one aspect which appears to be rather important in our sample: the simultaneous presence of IVC and CVC in VC-backed companies. As we mentioned in Section 3, more than half CVC-backed companies (53.54%) are also, at some point of their live, IVC-backed. This allows us to indirectly test whether IVC and CVC bring different forms, rather than extent, of productivity enhancement. Suppose, for instance, that IVC and CVC had not only approximately the same level of productivity enhancement, but also that this was obtained by the same means (e.g. process innovation). We would expect that the joint effect of IVC and CVC would not differ significantly from the effect of IVC or CVC when investing alone. If, instead, the means by which IVC and CVC enhance productivity are different (e.g. IVC fostering product innovation and CVC helping process innovation) we would expect their joint effect to be the combination of those they have when investing on their own. Columns (5) and (6) show that the joint effect is negative but not statistically significant, and with a magnitude which is substantially less than the positive effect of both IVC and CVC. This suggests that while CVC and IVC yield approximately the same extent of productivity enhancement, this is achieved by different means and, consequently, their joint effect is only marginally less than the sum of their separate effects. Translating, again, the effect in terms of years, IVC and CVC accelerate the growth of TFP by respectively 7.8 and 9.2 years and their joint effect is of 14.5 years (i.e. companies which receive IVC and CVC would have reached, other things being equal, the same level of TFP only 14.5 years later without IVC and CVC).

We are quite confident that the econometric results that have been illustrated above are robust. In particular, the rather long longitudinal dimension of our dataset allowed us to

[8] In OLS estimation confidence levels for the coefficients of IVC and CVC are 1% and 10%, respectively.

use WG techniques that effectively control for the allegedly unobserved heterogeneity that may affect (positively or negatively) both firm performance and the likelihood for a firm to be backed by a VC investor.

To sum up, the results of our estimates clearly support the view that VC financing has a beneficial effect on firm's TFP, but we do not detect a difference in the extent by which TFP is increased. However we find indirect evidence that the means by which TFP is increased differs between IVC and CVC.

6 - Conclusions

The aim of this paper was to analyze empirically whether VC financing affects the productivity of European NTBFs. The extant literature emphasizes the beneficial effects that VC financing allegedly has on portfolio firms, due to the scouting, monitoring and coaching role performed by these investors, and the certification effect of their endorsement to uninformed third parties. Nevertheless, the empirical evidence on this issue is fairly limited and not unanimous. In addition, a small but growing literature suggests that VC investors are an heterogeneous category. Accordingly, the effect of VC financing on the performance of portfolio firms may depend on the identity of the investor.

In order to detect the positive impact on TFP that could unambiguously be attributed to VC financing and differences relating to the type of investor, we have considered here a unique hand-collected longitudinal dataset that includes 3,687 European NTBFs that operate in high-tech manufacturing and service sectors and are observed over the period 1994-2008. As most sample firms are privately held, this dataset does not suffer from the selection bias that affects samples exclusively composed of IPO firms. Moreover it is not subject to survivorship bias as it includes both surviving and non-surviving (i.e. inactive, bankrupt and acquired) companies.

Our results clearly support the view that VC financing fuels firm's TFP. The difference in TFP levels with respect to that of otherwise similar non VC-backed firms is statistically significant. We do not find any significant difference between IVC and CVC in the extent by which they improve efficiency of European NTBFs. A company backed by IVC or CVC exhibits a TFP which would have attained, without VC, only around 8 years after. We find indirect evidence, however, that IVC and CVC achieve this productivity boost differently. In fact their joint effect is only slightly less than the individual marginal effects of IVC and CVC, and a company which receives both IVC and CVC accelerates its productivity path by 14.5 years.

We think that these results offer new interesting insights into the role of VC financing in improving the efficiency of high-tech start-ups. Quite interestingly, VC financing has a dramatic positive influence on NTBF productivity. This evidence has important policy implications. In Europe the VC sector is far less developed than in the USA or in Israel. While an analysis of the determinants of this situation lies beyond the scope of the present work,[9] the findings illustrated here support the view that the development of the demand for and supply of VC financing should figure prominently in the innovation policy agenda of European governments.

[9] See Da Rin *et al.* (2006) for an econometric study of country-specific and industry-specific factors that stimulate VC investments. For an analysis of the development of the Israel VC industry and the role of public policy see Avnimelech and Teubal (2004).

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8 - Table 1

Table 1 – Sample composition

	All sample		IVC-backed		CVC-backed	
	Number	Percent of sample	Number	Percent in category	Number	Percent in category
Country						
Belgium	542	14.70	39	14.94	18	18.18
Finland	677	18.36	41	15.71	10	10.10
France	721	19.56	52	19.92	5	5.05
Italy	982	26.63	47	18.01	37	37.37
Spain	190	5.15	35	13.41	10	10.10
United Kingdom	575	15.60	47	18.01	19	19.19
Total	3,687	100	261	100	99	100
Industry						
Internet & TLC services	492	13.34	55	21.07	34	34.34
Software	1,764	47.84	100	38.31	31	31.31
ICT manufacturing	783	21.24	54	20.69	16	16.16
Biotech & Pharmaceuticals	309	8.38	40	15.33	12	12.12
Non-ICT manufacturing	243	6.59	7	2.68	5	5.05
Other R&D	96	2.60	5	1.92	1	1.01
Total	3,687	100	261	100	99	100
Status						
Active	3,040	82.45	191	73.18	67	67.68
Acquired	243	6.59	32	12.26	17	17.17
Liquidated	370	10.04	33	12.64	14	14.14
Other inactive	34	0.92	5	1.92	1	1.01
Total	3,687	100	261	100	99	100
Foundation						
1984-1989	648	17.58	6	2.30	5	5.05
1990-1994	811	22.00	42	16.09	11	11.11
1995-1999	1,168	31.68	115	44.06	40	40.40
2000-2004	1,060	28.75	98	37.55	43	43.43
Total	3,687	100	261	100	99	100

9 - Table 2

Table 2 - Olley & Pakes stage

	Internet & TLC		Software		ICT-manufacturing		Biotech & Pharma		Non ICT manufacturing		Other R&D	
β_k	0.236	***	0.111	***	0.181	***	0.210	***	0.061		0.182	**
	(0.059)		(0.022)		(0.049)		(0.070)		(0.086)		(0.073)	
β_l	0.403	***	0.523	***	0.612	***	0.583	***	0.624	***	0.557	***
	(0.027)		(0.015)		(0.026)		(0.055)		(0.053)		(0.044)	
$Age_{i,t}$	-0.004		0.168		-0.014		0.018		-0.134		-0.091	
	(4.899)		(5.508)		(1.607)		(2.098)		(1.419)		(23.654)	
Observations	3,269		11,832		5,970		2,196		1,878		1,800	

Note: estimates in table are obtained by using Olley & Pakes methodology on Equation (1) as described in Section **Errore. L'origine riferimento non è stata trovata.**. Dependent variable is firm's log(Sales). Significance levels: * p<0.10, ** p<0.05, *** p<0.01

10 - Table 3

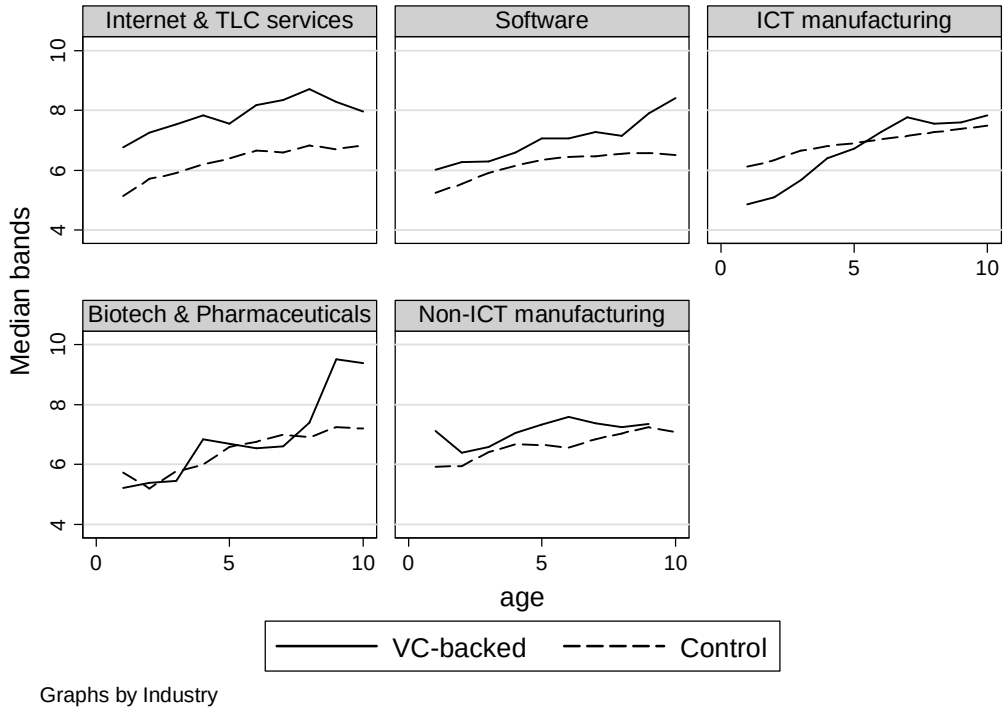
Table 3 - The effects of VC on TFP

	Pooled VC				IVC vs CVC				IVC and CVC			
	OLS		WG		OLS		WG		OLS		WG	
IVC or CVC	0.511	***	0.748	***								
	(0.108)		(0.118)									
IVC					0.464	***	0.684	***	0.500	***	0.698	***
					(0.123)		(0.130)		(0.067)		(0.104)	
CVC					0.346	*	0.710	***	0.463	***	0.817	***
					(0.184)		(0.255)		(0.104)		(0.329)	
IVC and CVC									-0.320		-0.229	
									(0.195)		(0.491)	
Age_{it}	0.097	***	0.089	***	0.097	***	0.089	***	0.097	***	0.089	***
	(0.006)		(0.029)		(0.006)		(0.029)		(0.003)		(0.029)	
CFS_{it}	0.005	*	0.003		0.005	*	0.003		0.005	*	0.003	
	(0.003)		(0.002)		(0.003)		(0.002)		(0.003)		(0.002)	
DTA_{it}	-0.202	***	-0.048	*	-0.203	***	-0.048	*	-0.209	***	-0.061	***
	(0.033)		(0.026)		(0.033)		(0.026)		(0.030)		(0.021)	
Constant	6.130	***	6.095	***	6.135	***	6.093	***	5.504	***		
	(0.360)		(0.391)		(0.360)		(0.391)		(0.308)			
Time dummies	Yes		Yes		Yes		Yes		Yes		Yes	
Country dummies	Yes		No		Yes		No		Yes		No	
Industry dummies	Yes		No		Yes		No		Yes		No	
N. obs.	18,054		18,054		18,054		18,054		18,054		18,054	
N. groups			3,687				3,687				3,687	
R^2	0.273		0.183		0.273		0.184		0.273		0.184	
F(IVC = CVC)					0.238	(1)	0.007	(1)	0.09	(1)	0.11	(1)
P-value IVC = CVC					0.626		0.931		0.760		0.735	

In OLS estimations standard errors are clustered at the firm level, in WG estimations robust standard errors are reported. Country and Industry dummies are included in OLS regression. Time dummies are included in all regressions. *CFS* is firm's cash flow to sales ratio. *DTA* is firm's debt to assets ratio. *IVC* and *CVC* are dummy variables which take value 1 since the year in which a firm receives the first round of IVC and CVC respectively. *IVC or CVC* and *IVC and CVC* are respectively the logic or and the logic and of variables *IVC* and *CVC*. Significance levels: * p<0.10, ** p<0.05, *** p<0.01

11 - Figure 1

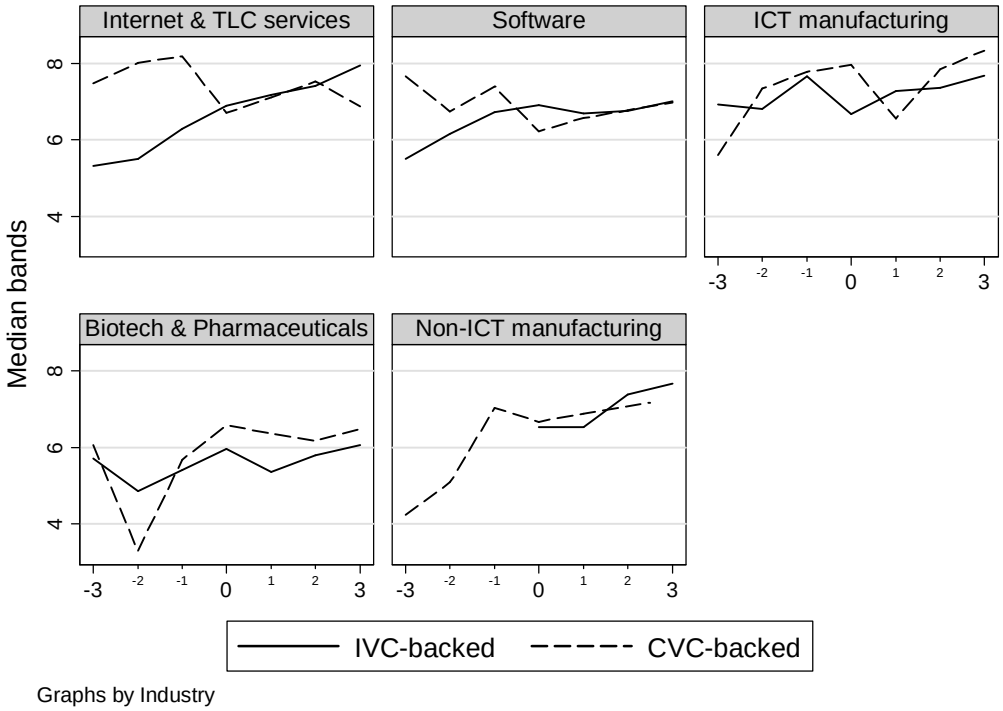
Figure 1: Evolution of firm's productivity: VC-backed vs. non VC-backed



Note: Figure reports median log(TFP) estimated by Olley & Pakes (see section **Errore. L'origine riferimento non è stata trovata.** for details) for VC-backed (solid line) and non VC-backed (broken line) firms. The horizontal axis is firm's age.

12 - Figure 2

Figure 2: Dynamics of TFP across time of investment



Note: Figure reports median log(TFP) estimated by Olley & Pakes (see section **Errore. L'origine riferimento non è stata trovata.** for details) for IVC-backed (solid line) and CVC-backed (broken line) firms. The horizontal axis is centered on, and ranges between 3 years before and 3 years after, the first round of investment.