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The ecology of European Venture Capital

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SUMMARY

My thesis, structured as a collection of three papers, tackles different aspects of the ecology of European venture capital. Venture capital is considered by policy makers as a key ingredient to develop an economy based on knowledge and innovation (European Commission 2010, p. 23), because it is the most suitable financing mode for high tech entrepreneurial ventures. These firms are important drivers of the innovation and employment growth of the countries in which they operate (Audretsch & Thurik, 2001; Audretsch, 1995; Stam & Garnsey, 2008; Westhead & Cowling, 1995). Unfortunately, the information asymmetries and agency problems typical of these firms make them financially constrained and force them to abandon some of their profitable projects (Hall, 2002; Stiglitz & Weiss, 1981; Stiglitz, 1985). Scrutinizing firms before providing capital (Chan, 1983) and monitoring them afterwards (Lerner 1995), venture capital investors alleviate information asymmetries and agency problems in the capital markets and relax portfolio firms' financial constraints. However, there is still a huge number of high-potential firms that are financially constrained, especially in Europe (Rosa & Raade, 2006). European policy makers are trying to follow the USA example to develop an efficient European venture capital market. As a matter of fact, the governmental interventions in Europe are much more important than in the USA. However, despite the efforts of policy makers, European venture capital market is smaller than USA one (Kelly, 2011).

The venture capital markets are typically not homogeneous. Independent venture capital investors and venture capital affiliated to firms and to banks co-exist in the same ecosystem. Moreover, the government itself designed its own venture capital programs. Interestingly, European venture capital ecosystem is characterized by a wider heterogeneity of actors with respect to USA. In Europe, the importance of captive venture capital investors, i.e. non-independent investors, is much more important (Bottazzi, Da Rin, & Hellmann, 2004, 2008).

As the general introduction reported in **Chapter 1** explains, the aim of this thesis is to analyze some of the characteristics of European venture capital ecosystem. In particular, we aim at studying the VC ecology, i.e. the roles of the different venture capital investor types in venture capital ecosystem, and the relationships between them. The research questions that this work aims at answering are *1) Does each venture capital investor type has its role in the European venture capital ecology?* and *2) How do different venture capital investor types play their roles in Europe?* The research is conducted on a sample of venture capital investments in European firms. This kind

of study can shed new light on the criticalities of European venture capital market and provide recommendations on appropriate governmental interventions to address them.

Chapter 2 investigates whether each venture capital investor type has its role in the European venture capital ecology, by *studying the investment patterns* of independent venture capital investors, corporate venture capital investors, bank-affiliated venture capital investors and governmental venture capital investors. I and my co-authors analyze the relative investment specializations of each investor type along several dimensions that characterize investments (e.g., syndication, duration and exit mode) and investee companies (e.g., industry of operation, age, size, development stage, location and distance from investor's premises at the time of the investment). Our findings indicate that venture capital types in Europe differ markedly in their patterns of investment specialization, especially governmental venture capital on the one side and private venture capital on the other. We compare our findings with evidence from the USA and find some interesting differences, notably regarding independent and governmental venture capital investors.

The second part of the thesis aims at studying *how* different venture capital investor types pursue their respective roles, and in particular *how they contribute to firm success*. Since the most sticking differences in the European investing patterns emerge between private venture capital and governmental venture capital, the third and fourth chapters of this thesis focus on each of these investor types.

In **Chapter 3**, I and my co-author study the most typical and traditional form of private venture capital: the independent venture capital. This investor type aims at realizing firm potential and have a capital gain from its investments. A strong contribution of independent venture capital investors to the success of their portfolio firms is the relaxation of financial constraints. In particular, we investigate how independent venture capital affects the sensitivity of young high-tech firms' employment policies to the availability of internal capital, by alleviating their financial constraints. We find that the sign of the employment cash flow sensitivity (ECFS) depends on the ability of the firm to generate internal capital. Moreover, we observe that ECFS is stronger for smaller firms. Independent venture capital investors prove to be able to relax firm's ECFS only when firms produce positive cash flows. Independent venture capital investors also improve the ability of high tech entrepreneurial ventures to attract high-skilled labor, especially when ECFS is most pronounced.

In **Chapter 4** we study how governmental venture capital pursues its role and contributes to firm success. Literature suggests that the direct impact of governmental venture capital on firms' performance is often poor. However, governmental venture capital can have an indirect impact on firms' performance and increase firms' probability of receiving other forms of financing. Governmental venture capital's role is therefore fostering private venture capital investments in the most risky segments of the industry. In particular, we evaluate governmental venture capital effectiveness in certifying high tech entrepreneurial ventures to private venture capital investors, which encompass independent, corporate and bank-affiliated venture capital investors. Using a sample of governmental venture capital-backed high-tech entrepreneurial ventures and a matched sample of non governmental venture capital-backed firms, we estimate the probability of receiving a first round of private venture capital. Furthermore, we evaluate whether private venture capital investments originated by governmental venture capital certification are at least as successful as other private venture capital investments, by estimating firms' probability of receiving a second round of private venture capital and of achieving a successful of exit (IPO or M&A). Results show that firms certified by of governmental venture capital are more likely to receive a first round of private venture capital than the matched sample. Moreover, after the first round of private venture capital, firms invested by governmental venture capital are more likely to receive a second round of private venture capital financing and to achieve a successful exit than other private venture capital - backed firms. These results support the view that governmental venture capital positively influences the development of the private venture capital market in Europe, by increasing the number of successful private venture capital investments in high-tech entrepreneurial ventures.

In **Chapter 5** I summarize the results of the thesis and the implications of my work, presenting also some directions for future research. Lastly, in **Appendix A**, I describe more in details the database used in this thesis, the VICO database.

ACKNOWLEDGEMENTS

The thesis is a collection of papers. As such, some of the work presented here has been done in collaboration with other researchers. The work in Chapter 2 is co-authored with Prof. Massimo G. Colombo (Politecnico di Milano) and Prof. Fabio Bertoni (EMLYON Business School). The work in Chapter 3 is co-authored with Prof. Fabio Bertoni and Ing. Annalisa Croce (Politecnico di Milano). Lastly, Chapter 4 is co-authored with Ing. Massimiliano Guerini (Università di Pisa). To my co-authors, and in particular to my supervisor Prof. Fabio Bertoni and my tutor Prof. Massimo G. Colombo, I address all my gratitude.

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All the errors and omissions are mine.

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1. General Introduction

1.1. HIGH TECH ENTREPRENEURIAL VENTURES, FINANCIAL CONSTRAINTS AND VENTURE CAPITAL

High tech entrepreneurial ventures are the key ingredient of modern knowledge-based economies. They are responsible for more innovation and are potentially more likely to create employment than similar firms in the general population (Audretsch & Thurik, 2001; Audretsch, 1995; Stam & Garnsey, 2008; Westhead & Cowling, 1995).

This is why policy makers are interested in the survival and growth of these firms (European Commission, 1998). Unfortunately, the success of high tech entrepreneurial ventures is hampered by the presence of acute financial constraints, i.e. by the relatively high cost of external sources of finance.

The origins of financial constraints are theoretically explained by financial economics literature. Modigliani and Miller (1958) demonstrate that, under the assumption of perfect capital markets, the source of financing (internal or external capital) is irrelevant in firm's investment choices and every privately profitable investment should be made. Unfortunately, capital markets are not perfect. In their seminal contribution, Jensen & Meckling (1976) show how the *hidden action* of managers generates agency conflicts between managers and investors, affecting the willingness of both debt and equity holders to provide capital. *Hidden information* problems are also important in financial markets. The typical "lemons" problem (Akerlof, 1970) is present in equity markets (Myers & Majluf, 1984) as well as in debt markets (Stiglitz & Weiss, 1981). In presence of hidden action and hidden information problems, the cost of external capital increases and firms are forced to use almost exclusively internal sources of finance for their investments, and are therefore financially constrained (Fazzari, Hubbard, & Petersen, 1988). This condition as strong negative consequences on firms growth and innovation (Hajivassiliou & Savignac, 2008; Savignac, 2008; Schulman, Cooper, & Brophy, 1993)

Financial constraints are particularly strong for young high tech entrepreneurial ventures. On the one hand, because of the technology-intensive nature of their activity and the lack of a track record, these firms face even more severe hidden action and hidden information problems (Hall, 2002). On the other hand, most of their assets are firm-specific or intangible and hence cannot be pledged as collateral (Berger and Udell 1998). These features lead to an increase in the cost of external capital and have a strong negative consequences on firm growth and survival (Carpenter & Petersen, 2002a; Hall, 2002).

However, when traditional financial intermediaries, like banks, fail in providing high tech entrepreneurial ventures with the capital they need to invest, survive, and grow, venture capital (VC) can be a viable alternative. There is quite unanimous agreement that specialized financial intermediaries, such as VC, can address the information asymmetries affecting high tech entrepreneurial ventures. The entrepreneurial finance literature has extensively analyzed the mechanisms that VC investors have developed to overcome information asymmetries. First, their industry specialization allows VC firms to better screen innovative projects (Amit, Brander, & Zott, 1998; Chan, 1983), thus reducing the hidden information problem. Second, VC investors have evolved contractual agreements and operational procedures in order to prevent hidden action problems once that capital is invested in the portfolio company, such as the extensive use of convertible securities (Casamatta, 2003; Kaplan & Stromberg, 2003; Repullo & Suarez, 2004); taking seats on the portfolio firm's board of directors (Lerner, 1995); meting out financing in discrete stages over time (Gompers, 1995) and syndicating investments with other VC firms (Brander, Amit, & Antweiler, 2002; Lerner, 1994a). Furthermore, VC investors complement the financial resources with a complex bundle of value-adding activities such as financial, administrative, marketing, strategic and managerial support (Gorman & Sahlman, 1989; Sahlman, 1990).

Empirical literature confirms that VC provide a fundamental contribution to high tech entrepreneurial ventures success (Colombo & Grilli, 2010; Denis, 2004; Gompers & Lerner, 2001a; Hellmann & Puri, 2002; Kortum & Lerner, 2000) with important positive repercussions on the innovation, employment and growth at macro level (Hirukawa & Ueda, 2011; Kortum & Lerner, 2000; Samila & Sorenson, 2011).

1.2. EUROPEAN VENTURE CAPITAL MARKET

VC in the USA has been extremely beneficial to the creation and development of a number of entrepreneurial ventures that in few years grew and employed thousands of people (Apple, Genentech, Microsoft and Intel are some of the most illustrative examples). In Europe, high tech entrepreneurial ventures still finance new investments by relying primarily on internal funds (Revest & Sapio, 2010). While an exhaustive discussion of the reasons why European VC market is lagging behind the USA VC market is beyond the scope of this thesis, I will list in the following some important differences between the two markets.

First, European VC market is smaller than the USA one: according to Kelly (2011), Europe's investment as a share of GDP in 2009 was only 25% of that of the USA.

Second, European VC investors are more risk averse than USA ones. In particular, there is wide evidence that private VCs tend to avoid investing in very early stage companies, which have high levels of risks and significant information asymmetries (Kelly, 2011; Lockett, Murray, & Wright, 2002; Mason & Harrison, 1997; Murray & Lott, 1995). Therefore, it is likely that a great number of European entrepreneurial ventures remain financially constrained, generating a "market failure".

Third, the European Commission aims at "making an efficient European venture capital market a reality" in order to make financing available for high tech entrepreneurial ventures (European Commission 2010, p. 23). Therefore, a number of government interventions have tried to foster the European VC market. Kelly (2011) shows that the role of government agencies as sources of VC funds in 2009 in Europe was 3 times bigger than in the USA.

Fourth, European VC market is characterized by a wider heterogeneity of VCs than USA one (e.g., Bottazzi, Da Rin & Hellmann, 2004; Bottazzi et al., 2008). The VC types differ for their structure, with important consequences in terms of investor objectives. In particular, in the USA the typical organization of a VC is the Independent VC (IVC), organized as limited partnership between a management company (general partner) and the investors (limited partners) (Sahlman, 1990). IVC investors (IVCs) must periodically completely recapitalize themselves by raising a new limited partnership; otherwise they would be forced to cease operations. IVCs' objective is the realization of capital gain from the investments, to be distributed to the general partners. In this process, the establishment of a good reputation among general partners is extremely important for IVCs (Gompers & Lerner, 1999; Gompers, 1996). As a consequence, they are highly committed to realize portfolio firms' potential as soon as possible, making firms growth quickly and eventually listing or selling them to other firms.

A considerable fraction of European VC activity is performed by non-independent, or captive, VC investors, structured as investment vehicles or business units of a parent company. The parent company can be either non financial (corporate VC, CVC) or financial (bank-affiliated VC, BVC). In the case of governmental VC (GVC), the parent company is a governmental body. Captive venture capital investors do not need to raise funds from third parties (Wright & Robbie, 1998), but the amount they allocate for investment purposes reflects the overall strategy of the parent institution. Besides financial objectives, CVC investors (CVCs) are aimed at opening a "technology window" on the development of promising new technologies by their investee firms (Dushnitsky &

Lenox, 2005a; Siegel, Siegel, & MacMillan, 1988). BVC investors (BVCs) on the contrary aim at establishing profitable bank relationships with investee firms rather than to realize large capital gains (Hellmann et al., 2008). Lastly, the aim of GVC investors (GVCs) is to support the development of high-tech entrepreneurial firms, by fostering PVC investments (Lerner, 1999; Lerner, 2002).

1.3. ECOLOGY OF EUROPEAN VENTURE CAPITAL

The VC market encompasses organizations that have different structures and objectives, but that basically are all oriented to linking potential investors with young entrepreneurial ventures (Dimov & Gedajlovic, 2010). It is therefore important to understand how the actors can coexist in the same environment and what the relationships between them are. In particular, the goal of this thesis is to shed light on the *role that each VC investor type plays in the ecology of VC financing.*

The first research aim is to evaluate whether *each VC investor type has a defined role in the European VC ecology.* The very few papers that have dealt with this issue in the literature have mainly focused on the USA case, while evidence on Europe is still preliminary (e.g., Bottazzi et al., 2004; Dimov & Gedajlovic, 2010). In **Chapter 2**, I and my co-authors provide a global picture of the European VC market in terms of investment patterns of the VC investor types. Using a transformed Balassa index, we analyze the investment specialization of IVCs, CVCs, BVCs and GVCs along several dimensions that characterize investments and investee companies. The analysis is based on a dataset including 1,663 VC first investments made by 846 investors in 737 young high-tech ventures located in seven European countries between 1994 and 2004. Results indicate that VC types in Europe differ markedly in their patterns of investment specialization, consistently with the idea that each VC type plays a different role in European VC ecosystem. As literature suggests that the investment patterns of VC investor types may be affected by institutional characteristics (Mayer, Schoors, & Yafeh, 2005), in the second part of Chapter 2 we compare our findings with evidence from the USA. We find some interesting differences in the investment patterns in the two geographic areas, notably regarding IVCs and GVCs.

The second research aim of the thesis is to study *how different VC investor types play their roles in the European VC ecosystem.* In particular, I look at the mechanisms used by different VC investor type to contribute to firms success. I conduct an analysis on European IVC and GVC investor types, as Chapter 2 suggests that they have opposite roles in VC ecosystems (as a consequence of their different objectives, skills and complementary assets).

IVC investors are moved by the aim of obtaining high capital gains from their investments (Hsu, 2004). Moreover, they have the skills and resources necessary to directly invest in the target firm, remove their financial constraints, and realize firm's potential (Hall et al., 2009). The effects of financial constraints on firms investment policies have received a lot of attention in the literature, to the point that the financial constraints have been often measured as the sensitivity of firms' investment to the availability of internal capital, the "investment-cash flow sensitivity" (e.g. Fazzari et al., 1988; Kaplan & Zingales, 1997). The moderating role of VC in this relationship is as well an established concept in financial literature (Bertoni et al., 2010). However, few studies have considered the consequences of financial constraints on firms employment policies (Cantor, 1990), and, to the best of our knowledge, none have evaluated VC impact in this case. In **Chapter 3** I and my co-authors investigate how IVC affects the sensitivity of young high-tech firms' employment policies to the availability of internal capital, by alleviating their financial constraints. The study is based on a sample of 4,681 companies in 6 European countries. Building on a model developed to study firm's investment cash flow sensitivity, we find that the sign of the employment cash flow sensitivity (ECFS) depends on the ability of the firm to generate internal capital. Moreover, ECFS is stronger for small firms. IVC proves to be able to relax firm's ECFS only when firms produce positive cash flows. Finally, IVC improves the ability of high tech entrepreneurial ventures to attract high-skilled labor, especially when ECFS is most pronounced.

Chapter 4 is about how GVC contributes to firms' success in Europe. The aim of GVC is not to realize a capital gain but to reduce the equity gap in the market by fostering PVC investments. Moreover, due to the low skills of GVC managers (Leleux & Surlemont, 2003), GVC are not able to provide the managerial support to the target firm. The literature has indeed emphasized that the direct effect of GVC investors on firm performance is limited (Luukkonen, Deschryvere, Bertoni, & Nikulainen, 2011). We therefore focus on the indirect effect of GVC. The chapter investigates whether obtaining GVC facilitates high-tech entrepreneurial ventures' subsequent access to private VC (PVC, i.e. IVC, CVC and BVC) as a consequence of a certification effect. While this effect has been documented for other forms of policy interventions (Lerner, 2002; Meuleman & De Maeseneire, 2012), the is only partial evidence on the certification effect of GVC. Using a unique longitudinal database of 189 European GVC-backed high-tech entrepreneurial ventures and a matched sample of 797 comparable firms, which have not received GVC, we estimate the probability of receiving a first round of PVC, depending on whether the firm is GVC-backed or not.

Furthermore, we evaluate whether PVC investments in GVC-backed firms are at least as successful as other private VC investments (i.e. in non GVC-backed firms), by estimating the probability of receiving a second round of private VC and of achieving a successful exit (IPO or M&A). Results show that PVC investors are more likely to invest in firms backed by GVC. We also find that private VC-backed firms previously backed by GVC have a higher probability of receiving a second round of private VC financing and of achieving a successful private VC exit than other PVC backed firms. These results, robust to different model specifications and to alternative explanations, support the view that GVC positively influences the development of PVC market in Europe, by increasing the number of *successful* private VC investments in high-tech entrepreneurial ventures.

In **Chapter 5** I summarize the results of the thesis and the implications of my work, presenting also some directions for future research. Lastly, in **Appendix A**, I describe more in details the database used in this thesis, the VICO database.

2. Patterns of venture capital investments in Europe

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2.1. INTRODUCTION

Scholars and policymakers agree that venture capital investors (VCs) are fundamental for the development of high-potential innovative entrepreneurial ventures and for economic growth in general (e.g. Gompers & Lerner, 2001b; Samila & Sorenson, 2011). However, the literature has long recognized that VCs are heterogeneous and differ along several dimensions, one of the most important being the type of governance and ownership (Da Rin, Hellmann, & Puri, 2011). In its most familiar form, a VC manages several pools of capital provided by institutional and individual investors. Each pool is organized as a legally separate limited partnership, with a management company serving as a general partner and the investors serving as limited partners (Sahlman, 1990). This is the most common type of VC (independent VC, IVC), but there are also others. Non-independent, or captive, VCs are structured as investment vehicles or business units of a parent company. The parent company may be a nonfinancial company, in the case of corporate VC (CVC), a financial intermediary, in the case of bank-affiliated VC (BVC), or a governmental body, in the case of governmental VC (GVC). Regardless of its nature, the parent company of a captive VC provides capital and has substantial influence on the selection and management of investments (Dimov & Gedajlovic, 2010; Dushnitsky, 2012; Gompers, 2002; Hellmann, Lindsey, & Puri, 2008; Leleux & Surlemont, 2003).

The differences in ownership and governance between independent and captive VCs, and among different types of captive VCs, supposedly influence the objectives and outcomes of their investment activities. However, most of our understanding on how different types of VCs operate is based on evidence from the USA.[1] A limited number of studies have analyzed different VC types outside the USA and, with few exceptions (Bottazzi et al., 2008; Brander, Du, & Hellmann, 2010; Mayer et al., 2005; Sapienza, Manigart, & Vermeir, 1996), have mostly focused on specific countries (e.g., Audretsch & Lehmann, 2004, and Tykvovà, 2006 on Germany; Bertoni, Colombo, & Croce, 2010, and Bertoni, Colombo, & Grilli, 2012 on Italy; Cumming, 2006 and Brander, Egan, & Hellmann, 2010 on Canada; Cumming, 2007 on Australia).

Therefore, our overall understanding of this issue is still partial. In particular, no large-scale analysis has thus far been conducted on the *investment strategies* pursued by different types of VCs outside the USA and on their differences from (or similarities to) the investment strategies of their American counterparts. This is an important gap in the literature because the findings of the studies

[1] For a survey of this literature see Da Rin et al. (2011) and Dushnitsky (2012). See Dimov and Gedajlovic (2010) for a comprehensive analysis of the investment strategies of IVC, CVC and BVC in the USA over the period 1962-2004.

mentioned above suggest that there are substantial differences in the ways in which different types of VCs operate in different investment environments.

The present chapter aims to contribute to filling this gap in the VC literature. For this purpose, we provide a systematic analysis of the investment strategies of different types of VCs in Europe, taking advantage of a new database, the *VICO database*, created by the 7th Framework Programme VICO research project promoted by the European Commission (see www.vicoproject.org). We use information on 1,663 VC first investments made between 1994 and 2004 by 846 VCs in 737 entrepreneurial ventures that were located in seven European countries (i.e., Belgium, Finland, France, Germany, Italy, Spain and the United Kingdom), were less than 10 years old at the time of the VC investment, and operated in the high-tech manufacturing and service industries. We compare the patterns of investment specialization of IVCs, CVCs, BVCs and GVCs along a series of dimensions relating to both investee company characteristics (i.e., industry of operations, age, size, stage of development, localization and distance of investee companies from the investor at the time of the investment) and investment characteristics (i.e., syndication, duration and exit mode). We then compare the evidence from European VCs obtained through the VICO database with similar evidence provided by Thomson One (previously, VentureXpert) on VCs in the USA.

The chapter proceeds as follows. In section 2.2, we describe the methodology used to examine the investment specialization patterns of the different types of VCs. In section 2.3, we present the dataset. The results on the patterns of investment specialization of different European VC types are reported in section 2.4. Section 2.5 is devoted to comparing our results with the available evidence relating to the USA. Finally, section 2.6 highlights the contribution of this work to the VC literature and policy implications conclude the chapter.

2.2. METHODOLOGY

We employ specialization indexes to compare the investment patterns of the different types of VCs in Europe. Specialization indexes were originally used to compare trade flows and evaluate the revealed comparative advantages of different countries (Hoover, 1937; Liesner, 1958). Due to their easy construction and interpretability, they attracted substantial interest in the fields of innovation research and science studies. They were applied to phenomena such as employment and patents (e.g., Hall & Soskice, 2001; Kim, 1995). In this work, we used these indexes to measure the divergence in the investment strategies of the different VC types from those of the “average VC”.

We analyzed specialization along several dimensions relating to investee companies and investment characteristics (see the following section for details).

The most widely used family of specialization indexes is derived from a measure that was initially proposed by Balassa (1965). For each dimension *k* characterizing investee companies and investments, we identified a number of mutually exclusive categories. Let $N_{i,j}^{k}$ be the number of investments made by investor type *i* that belong to category *j* of dimension *k*. The Balassa Index (BI) is defined as follows:

$$BI_{i,j}^{k} = \frac{N_{i,j}^{k}}{\sum_{j} N_{i,j}^{k}} \cdot \left(\frac{\sum_{i} N_{i,j}^{k}}{\sum_{i,j} N_{i,j}^{k}} \right)^{-1}$$

The first term measures the share of the investments made by investor type *i* in category *j* of dimension *k* over the total number of investments made by investor type *i.* The second term is the inverse of the share of the investments made by any VC type in category *j* of dimension *k* over the total number of VC investments. In other words, BI measures the ratio of the share of the investments made by a given type of VC in a given category of a given dimension to the share of total VC investments in that category.[2]

The BI is easy to compute and has an intuitive definition but also some serious shortcomings (Bowen, 1983; De Benedictis & Tamberi, 2002; Laursen, 1998; Yeats, 1985). A major problem with BI arises in our study due to the substantially different numerosity of investments by different VC types. The problem arises because sampling and measurement errors have a larger impact on VC categories for which the number of investments is smaller.[3] Moreover, when there are few investments, BI tends to have a more asymmetric and skewed distribution (Laursen, 1998). To

[2] For example, the specialization of *i*=IVC in the *j=biotechnology and pharmaceutical* category of the *k=industry of operation of investee companies* dimension is measured as the share of IVC investments accounted for by the biotechnology and pharmaceutical industry divided by the share of that industry out of the investments made by all VC investors.

[3] For instance, in our sample, the number of IVC investments is larger than the number of CVC investments by a factor of approximately 5.6 (918 vs. 165, respectively). Assume that we only want to compare the sectorial specialization of these two investor types. Suppose that the underlying data generation process is such that IVC and CVC have the same specialization in industry category *j*. Each of their BIs should then be equal to 1. Sampling and measurement errors, however, have a very asymmetric impact on the BI of the two types of VC investors. If, due to sampling or measurement errors, we move 1 single observation in category *j* from the IVC investor type group to the CVC investor type group, we will obtain a decrease in the specialization of IVC investors in category *j* that is approximately 5.6 times smaller than the increase in specialization in category *j* observed for CVC investors.

alleviate these problems, we computed a symmetric version of BI by applying the following transformation (Dalum, Laursen, & Villumsen, 1998):

$$TBI_{i,j}^{k} = \frac{BI_{i,j}^{k} - 1}{\left(BI_{i,j}^{k} + 1\right)}$$

TBI ranges from [−1, 1], and its neutral value is 0. Negative (positive) values of TBI indicate that investor type i is less (more) specialized in category j of dimension k than other VC investor types. Like BI, TBI not only distinguishes between the investor types that are specialized in a certain category from those that are not, but it also quantifies the degree of specialization (Ballance, Forstner, & Murray, 1987). More importantly, this transformation is shown to have two main advantages. First, it attributes the same weight to changes below the neutral value as to changes above the neutral value. Second, the assumption of normality is more acceptable for TBI than for the original Balassa Index BI (Dalum et al., 1998). It is therefore possible to derive a hypothesis test to determine whether the observed specialization is statistically significant. Under a set of assumptions, TBI is asymptotically normal and its variance can be consistently estimated from the data (Schubert & Grupp, 2011). We can then use this asymptotic distribution to test the null hypothesis that, for a given VC type in a given category of a given dimension, the value of TBI is equal to 0. Rejection of the null hypothesis then gives statistical support to the argument that the TBI is unlikely to be the mere result of measurement or sampling errors.[4]

2.3. DATA AND DESCRIPTIVE STATISTICS

Our sample of VC investments is drawn from the VICO database built by the VICO project. A full description of the database is provided in the appendix of this thesis. The database provides detailed information on a large sample of European high tech entrepreneurial ventures.

In this study, we focus on the sub-sample of 737 VC-backed ventures that received their first round of VC between 1994 and 2004, were less than 10 years old at that time, and for whom we know the nature of the VC investor.

[4] The transformation that we adopted to compute TBI is common in the literature, but other transformations are also possible (for a review, see De Benedictis & Tamberi, 2002). In particular, the original Balassa Index can be subjected to a log-transformation (Vollrath, 1991) or a symmetrifying transformation (Grupp, 1994). We replicated our analyses using these alternative transformation methods. The TBI that was used is correlated at 99% with both the Grupp (1994) and the Vollrath (1991) specifications and the obtained results are virtually the same.

The VICO database provides detailed information about investee company-, investor-, and investment-specific characteristics that can be used to highlight the investment specialization patterns of different types of VCs in Europe. In particular, the characteristics of investee companies include the following dimensions: industry of operation, age, size, stage of development, localization and distance of the investee company from the premises of the VC at the time of the investment. The dimensions that characterize investments are: syndication, duration and exit mode.

VCs are identified and classified according to their type. The classification is driven by the ownership and governance of the management company. An investor characterized by an independent management company is classified as IVC. Captive investors are classified depending on the identity of the entity that controls their management processes. We classify those investors whose parent companies are nonfinancial companies as CVCs and those investors whose parent companies are financial intermediaries as BVCs. If the parent is a governmental body, we classify the investor as a GVC.[5] It should be noted that the ownership and governance of a VC firm, and thus its type, may change over time. An interesting example is provided by the Belgian GIMV, a VC firm established by the Flemish government in 1980, which changed from GVC to IVC after being listed on the stock market in 1997.

Because we are interested in analyzing the investment strategies of VC types, our unit of analysis is the first investment that a VC made in a specific company. We consider only the rounds in which a particular VC firm invests in a particular company for the first time, and exclude all follow-on rounds from the analysis (see Dimov & Gedajlovic, 2010, for a similar approach). The rationale for this is that when an investor first invests in a company, it reveals the structure of its investment preferences. The same is not necessarily true for follow-on rounds. The inclusion of follow-on rounds would result in a relative overrepresentation of cases in which VC investment is split over several rounds in the computation of specialization indexes. Including all investment rounds, not just the first investment, would thus give us very limited additional information about the structure of investors' preferences and expose us to measurement biases. It is worth highlighting that when two VCs co-invest in the same company, these investments are recorded as two first investments in our analysis. Again, the logic behind this is that a co-investment is informative about the preferences of each of the investors taking part in it.

[5] There is generally a close correspondence between the type of VC investor and the origin of the funds it invests. IVC firms invest on behalf of institutional investors and wealthy individuals even though they may receive a portion of the funds they invest from public bodies (like the European Investment Fund). Captive investors generally invest funds obtained by their parent companies (CVC and BVC) or public sources (GVC). See Mayer et al. (2005).

The distributions of VC investments according to investee companies and investment characteristics are reported in Table 2.1. The sample includes a total of 1,663 VC investments, the majority of which are made by IVC firms (55.2%). The second largest category is GVC, representing 19.5% of the sample, followed by BVC, accounting for 15.4%. CVC is the smallest category, with 9.9% of the investments. The distribution of investments across industries highlights the interest of European VCs in software (34.2%) and biotechnology and pharmaceuticals (24.4%). Companies operating in internet and telecommunication (TLC) services and ICT manufacturing,[6] accounting for 20.6% and 17.1% of investments, respectively, are also important targets of VC investments. Investments in the remaining sectors are quite rare. Sample companies are typically very young at the time of the investment: only 15.7% of the investments are in companies older than 5 years, while 22.7% of the investments are in newly funded companies (less than 1 year old). The sample companies are also rather small: 38.7% of the investments are in micro companies with fewer than 10 employees, 48.6% are in small companies (i.e., having between 10 and 49 employees), and only 12.8% are in companies with 50 or more employees. Similarly, the majority of VC investments are made in early stages: 24.2% of them occur during the seed stage, 37.0% during the start-up stage and 38.8% during the expansion stage. These data are in line with the evidence reported by Bottazzi et al. (2004), who found that more than half of the first VC investments in Europe were at the seed or start-up stages.

Another variable that has attracted the interest of VC scholars is the geographic distance between the investee company and the investor. In 29.0% of investments, the VC is located less than 10 km away from the investee company and in 19.6% of investments, the distance is between 10 and 50 km. The distance is more than 300 km only for 22.6% of investments. The vast majority (77.5%) of the investments in our sample are domestic. These data confirm the local bias of VCs and their limited internationalization as highlighted by previous studies.[7]

[6] ICT manufacturing includes the following industries: electronic components, computers, telecommunications equipment, and electronic, medical and optical instruments.

[7] For instance, Schertler and Tykvovà (2011) found that approximately two thirds of global VC deals between 2000 and 2008 included only domestic investors.

Table 2.1. Distribution of the first VC investments included in the sample

	N	%		N	%
Investor type					
Independent VC (IVC)	918	55.2%			
Corporate VC (CVC)	165	9.9%			
Bank-affiliated VC (BVC)	256	15.4%			
Public VC (GVC)	324	19.5%			
Total	1,663	100.0%			
Investee company characteristics					
Industry of operation			*Age at the time of the investment*		
ICT manufacturing[a]	284	17.1%	<1 year	378	22.7%
Biotech and pharmaceutics	405	24.4%	1-2 years	560	33.7%
Other high-tech manufacturing[b]	34	2.0%	3-5 years	464	27.9%
Software	568	34.2%	>5 years	261	15.7%
Internet and TLC services	343	20.6%			
R&D and engineering services	29	1.7%			
Total	1,663	100.0%	Total	1,663	100.0%
Size at the time of the investment			*Development stage at the time of the investment*		
<10 employees	430	38.7%	Seed	312	24.2%
10-24 employees	339	30.5%	Start up	476	37.0%
25-49 employees	201	18.1%	Expansion[c]	499	38.8%
>49 employees	142	12.8%			
Total	1,112	100.0%	Total	1,287	100.0%
Distance between investor and investee company			*Localization*		
<10 km	407	29.0%	Same country as the investor	1,288	77.5%
10-50 km	275	19.6%	Different country from the investor	375	22.5%
50-300 km	318	22.6%			
>300 km	404	28.8%			
Total	1,404	100.0%	Total	1,663	100.0%
Investment characteristics					
Syndication			*Exit mode*		
Syndicated investments	1,093	65.7%	IPO	189	19.2%
Non-syndicated investments	570	34.3%	Trade Sale	435	44.3%
			Buyback	58	5.9%
			Write-off or liquidation	301	30.6%
Total	1,663	100.0%	Total	983	100.0%
Duration[d]					
<2 years	101	8.0%			
2-4 years	367	29.2%			
5-7 years	467	37.1%			
>8 years	323	25.7%			
Total	1,258	100.0%			

Legend: [a] Electronic components, computers, telecommunication equipment, electronic, medical and optical instruments. [b] Robotics and automation equipment, aerospace. [c] This category also comprehends few (17) investments in buyouts or other later stages. [d] Years between first investment and year of exit or, if no exit occurred until the end of the observation period (2010), between first investment and 2010.

Regarding the investment characteristics, most VC investments (65.7%) are syndicated (see Hopp & Rieder, 2011 for similar evidence on German VCs). We have information on the exit type for 983 investments. Some 30.6% of the investments terminate with write-offs or the liquidation of the investee companies. Trade sales account for 44.3% of investments, and IPOs account for 19.2%. Buy-back by founders is less frequent (5.9%). For investments where exit occurred, we measured investment duration as the number of years between the first round and exit. When exit did not occur, we had a right-censoring problem and computed investment duration as the time between the first round and 2010 (i.e., the year when exit information was collected; results are unaffected if we omit these cases from the analysis). Only 8% of investments last for less than 2 years. The most common durations are between 5 and 7 years (37.1%) and between 2 and 4 years (29.2%). A non-negligible share (25.7%) of investments is longer than 8 years in duration.

2.4. RESULTS

The investment specialization patterns of different VC types

Tables 2.2 and 2.3 show the TBIs of different types of VCs. Let us first focus on investee company characteristics (Table 2.2). With respect to other types of VC, IVCs are more inclined to invest in internet and TLC services (TBI=0.052, p-value<1%) and less in R&D and engineering services (TBI=-0.280, p-value<5%) and other high tech manufacturing (TBI=-0.182, p-value<10%). CVCs show an even greater specialization in internet and TLC services (TBI=0.150, p-value<1%), are also specialized in the other high-tech manufacturing sector (TBI=0.280, p-value<10%), but abstain from investing in biotech and pharmaceuticals (TBI=-0.179, p-value<5%). BVCs exhibit a less distinct pattern of industry specialization and none of their TBIs is significantly different from 0 at customary confidence levels. Conversely, GVCs have a very distinct pattern of industry specialization. Their TBIs are negative, of large magnitude, and significant in internet and TLC services (TBI=-0.366, p-value<1) and positive, of large magnitude, and significant in the R&D and engineering services (TBI=0.321, p-value<1%) and other high-tech manufacturing (TBI=0.325, p-value<1%). They are also specialized in biotechnology and pharmaceuticals (TBI=0.093, p-value<5%).

Figures relating to age and size of investee companies indicate that IVCs are specialized in relatively young companies (i.e., companies ranging from 3 to 5 years of age, TBI=0.046, p-value<1%), but not in newly founded companies (TBI=-0.042, p-value<10%). Moreover, the TBIs of IVCs increase monotonically with the size of investee companies: they are negative and significant for companies with fewer than 10 employees (TBI=-0.042, p-value<5%) and positive and significant for companies with between 25 and 49 employees (TBI=0.046, p-value<10%). The investment specialization pattern of BVCs according to company size is similar to that of IVCs but is even more marked. BVCs abstain from investing in companies with fewer than 10 employees (TBI=-0.151, p-value<1%) but are attracted to companies with 50 or more employees (TBI=0.187, p-value<1%). Similarly, with regard to company age, BVCs exhibit a clear aversion for newly created companies (TBI=-0.197, p-value<1%) and a preference for older companies (more than 5 years old, TBI=0.138, p-value<5%). CVCs do not exhibit any specific pattern of investment specialization with regard to the ages or sizes of investee companies. Their TBIs are quite low in absolute value and not significant at customary confidence levels. Again, GVCs show a very different investment specialization pattern from other investor types. In terms of the age of investee companies, GVCs are specialized in companies that are at the foundation stage (i.e., are less than 1 year old, TBI=0.185, p-value<1%) and are averse to 3- to 5-years-old companies (TBI=-0.186, p-value<1%). The TBIs of GVCs decrease monotonically with investee company size: they are large and positive for companies with fewer than 10 employees (TBI=0.189, p-value<1%) and large and negative for companies with 25 to 49 employees (TBI=-0.152, p-value<10%) and more than 49 employees (TBI=-0.575, p-value<1%).

With regard to the company's stage of development at the time of the VC investment, the results are consistent with the evidence presented above. IVCs, CVCs and BVCs exhibit increasing TBI values along company lifecycles. However, only the negative value of the TBI of IVCs for companies at the seed stage (TBI=-0.051, p-value<5%) and the positive value for companies at the expansion stage (TBI=0.037, p-value<1%) are significant. Again, the investment specialization patterns of GVCs are the opposite of those of other investor types. GVCs specialize in companies that are in the seed stage (TBI=0.180, p-value<1%) and neglect companies that are in the expansion stage (TBI=-0.207, p-value<1%).

Table 2.2. TBI relating to investee company characteristics.

	IVC		CVC		BVC		GVC	
Industry of operation								
ICT manufacturing[a]	0.019		-0.123		-0.020		0.015	
	(0.023)		(0.094)		(0.065)		(0.054)	
Biotech and pharmaceutics	-0.013		-0.179	**	0.013		0.093	**
	(0.020)		(0.080)		(0.050)		(0.038)	
Other high-tech manufacturing[b]	-0.182	*	0.280	*	-0.447		0.325	***
	(0.104)		(0.168)		(0.273)		(0.096)	
Software	-0.014		0.023		-0.003		0.028	
	(0.016)		(0.049)		(0.040)		(0.033)	
Internet and TLC services	0.052	***	0.150	***	0.029		-0.366	***
	(0.019)		(0.057)		(0.054)		(0.070)	
R&D and engineering services	-0.280	**	0.163		0.057		0.321	***
	(0.127)		(0.223)		(0.201)		(0.105)	
Age at the time of the investment								
< 1 year	-0.042	*	0.032		-0.197	***	0.185	***
	(0.022)		(0.065)		(0.067)		(0.033)	
1-2 years	0.001		0.030		-0.007		-0.014	
	(0.015)		(0.049)		(0.041)		(0.036)	
3-5 years	0.046	***	-0.046		0.050		-0.186	***
	(0.016)		(0.063)		(0.043)		(0.051)	
> 5 years	-0.033		-0.038		0.138	**	-0.019	
	(0.027)		(0.090)		(0.054)		(0.059)	
Size at the time of the investment								
< 10 employees	-0.042	**	0.024		-0.151	***	0.189	***
	(0.019)		(0.054)		(0.051)		(0.027)	
10-24 employees	0.002		0.058		0.026		-0.068	
	(0.021)		(0.062)		(0.047)		(0.053)	
25-49 employees	0.046	*	-0.178		0.068		-0.152	*
	(0.026)		(0.116)		(0.063)		(0.081)	
> 49 employees	0.048		-0.006		0.187	***	-0.575	***
	(0.032)		(0.118)		(0.063)		(0.121)	
Development stage at the time of the investment								
Seed	-0.051	**	-0.062		-0.080		0.180	***
	(0.024)		(0.086)		(0.067)		(0.036)	
Start up	-0.008		-0.005		-0.015		0.034	
	(0.016)		(0.059)		(0.046)		(0.034)	
Expansion	0.037	***	0.040		0.057		-0.207	***
	(0.014)		(0.053)		(0.039)		(0.047)	

Table 2.2. TBI relating to investee company characteristics (cont.)

	IVC		CVC		BVC		GVC	
Distance between investor and investee company								
< 10 km	-0.053	***	-0.143	*	-0.013		0.165	***
	(0.020)		(0.084)		(0.050)		(0.030)	
10-50 km	-0.069	**	-0.035		0.181	***	0.024	
	(0.027)		(0.095)		(0.047)		(0.051)	
50-300 km	0.063	***	-0.107		-0.209	***	-0.016	
	(0.019)		(0.094)		(0.074)		(0.050)	
> 300 km	0.040	**	0.184	***	-0.001		-0.255	***
	(0.017)		(0.051)		(0.049)		(0.056)	
Localization								
Same country of the investor	-0.009		-0.127	***	-0.001		0.077	***
	(0.006)		(0.029)		(0.016)		(0.009)	
Different country from the investor	0.030		0.279	***	0.002		-0.404	***
	(0.019)		(0.041)		(0.053)		(0.068)	

Legend. The table shows the TBI for each investor in each category of invested firms. Standard deviations are in parentheses. *p<10%; **p<5%; ***p<1%. [a] Electronic components, computers, telecommunication equipment, electronic, medical and optical instruments. [b] Robotics and automation equipment, aerospace.

Regarding the distance between the investee company and the VC firm, GVCs are the most strongly oriented to local investments. Their TBI is positive and significant for investments in companies located closer than 10 km from their premises (TBI=0.165, p-value<1%), decreases with distance, and is negative and significant for investments farther than 300 km away (TBI=-0.255, p-value<1%). The specialization pattern of BVCs also highlights a preference for local investments. These investors are attracted to companies that are located between 10 and 50 km from them (TBI=0.181, p-value<1%) and abstain from investing in companies that are located farther away (in the “50-300 km” category, the TBI of BVCs is -0.209, p-value<1%). IVCs and CVCs exhibit an opposite pattern of investment specialization, being the most prone to select distant companies. The TBIs of IVCs are negative and significant at conventional confidence levels in the first two distance categories (TBI=-0.053, p-value<1% and TBI=-0.069, p-value<5%), but are positive and significant in the remaining two (TBI=0.063, p-value<1%, and TBI=0.040, p-value<5%). The specialization pattern of CVCs is even more marked: CVCs are specialized in companies located farther than 300 km from their premises (TBI=0.184, p-value<1%), and abstain from investing in local companies (in the less than 10 km category, the TBI is equal to -0.143, p-value<10%). We find similar results relating to cross-border investments. CVCs are more specialized in cross-border investments than the average VC (TBI=0.279, p-value<1%), while GVCs are particularly attracted by national companies (TBI=0.077, p-value<1%). BVCs and IVCs do not show any significant specialization either in national or cross-border investments.[8]

Let us now consider the investment specialization patterns of different types of VCs relating to investment characteristics (Table 2.3). BVC is the investor type that exhibits the highest specialization in syndicated investments (TBI=0.089, p-value<1%), whereas GVC is the investor type with the lowest tendency to syndicate (TBI=-0.089, p-value<1%). This is consistent with the evidence reported above, showing that GVCs have an investment pattern that is substantially different from that of other investor types, making syndication more difficult.

Some significant differences also emerge regarding exit modes. In comparison with other VCs, BVCs more often exit through the IPO of the company (TBI=0.106, p-value<10%) and more rarely through the buyback of the shares (TBI=-0.425, p-value<5%). In contrast, GVCs exhibit large positive values for the TBI corresponding to the buyback exit mode (TBI=0.243, p-value<5%).The specialization indexes of IVC and CVCs relating to exit mode are not significant.

In terms of the duration of the investment, the TBIs of IVCs and CVCs again do not significantly differ from 0. BVCs are specialized in the investments up to 4 years in duration (TBI=0.177, p-value<5% and TBI=0.128, p-value<1% for investments shorter than 2 years and between 2 and 4 years, respectively) and abstain from very long investments (TBI=-0.237 in the "More than 8 years" category, p-value<1%). Conversely, GVCs appear to be much more patient. For GVC, TBI values increase monotonically with the duration of investments, with the shorter durations being especially unlikely (TBI=-0.335, p-value<5% and TBI=-0.140, p-value<1%, for durations of less than 2 years and between 2 and 4 years, respectively). A specialization is present in investments whose duration is longer than 8 years (TBI=0.178, p-value<1%).

[8] That the TBI of CVC investors is positive for cross-border investments does not mean that CVC investors are more likely to invest abroad than locally. It means that they are more likely to invest abroad than the "average investor" (and GVC and BVC in particular). Cross-border investments indeed represent only 39.9% of CVC investments, but this value is substantially higher than the overall mean (22.5%).

Table 2.3. TBI relating to investment characteristics.

	IVC		CVC		BVC		GVC	
Syndication								
Syndicated investments	-0.001		0.016		0.089	***	-0.089	***
	(0.008)		(0.025)		(0.016)		(0.022)	
Non-syndicated investments	0.002		-0.032		-0.229	***	0.136	***
	(0.015)		(0.054)		(0.053)		(0.027)	
Exit Mode								
IPO	0.002		-0.097		0.106	*	-0.080	
	(0.029)		(0.108)		(0.061)		(0.081)	
Trade Sale	0.004		0.025		0.018		-0.050	
	(0.016)		(0.050)		(0.038)		(0.044)	
Buy-back	-0.006		0.003		-0.425	**	0.243	**
	(0.057)		(0.187)		(0.195)		(0.096)	
Write-off or liquidation	-0.006		0.017		-0.045		0.051	
	(0.022)		(0.069)		(0.057)		(0.049)	
Duration[a]								
< 2 years	0.027		0.030		0.177	**	-0.335	**
	(0.040)		(0.136)		(0.089)		(0.130)	
2-4 years	-0.013		0.089		0.128	***	-0.140	***
	(0.020)		(0.056)		(0.043)		(0.053)	
5-7 years	0.015		-0.042		-0.030		0.001	
	(0.016)		(0.058)		(0.047)		(0.037)	
> 8 years	-0.016		-0.066		-0.237	***	0.178	***
	(0.022)		(0.077)		(0.076)		(0.035)	

Legend. The table shows the TBI for each investor in each category of investment style. Standard deviations are in parentheses. *p<10%; **p<5%; ***p<1%. Standard deviations are in parentheses. [a] Years between first investment and year of exit or, if no exit occurred until the end of the observation period (2010), between first investment and 2010.

To gain further insights into the similarities and differences between the investment specialization patterns of different VC types, we computed the correlation between their TBIs. Each VC type i, i=IVC, CVC, BVC, GVC, is characterized by a vector $TBI_{i,j}^{k}$ of specializations along dimensions (k) and categories (j). We examined the similarity of these vectors by computing their correlations. Because the number of available observations is rather small (it equals 33, i.e., the total number of categories considered along all the dimensions), in addition to the parametric Pearson correlation, we also computed the non-parametric Spearman's rank correlation and Kendall's tau rank correlation.

The results are reported in Table 2.4. The correlation between the investment specialization patterns of private investors (i.e., IVC, CVC and BVC) are generally not significant, with the partial exception of the one between CVC and IVCs, whose Pearson's correlation of TBIs is -0.31 and is significant at 10%. The pattern of investment specialization of GVCs is remarkably different from those of all the other VC types. This is documented by the large negative values of the correlation indexes, significant at the 1% confidence level, with the exception of those relating to the correlation with CVC.

Table 2.4. Correlation for transformed Balassa indexes

	IVC	CVC	BVC	GVC
Pearson				
IVC	1.00			
CVC	-0.31 *	1.00		
BVC	0.22	-0.15	1.00	
GVC	-0.68 ***	-0.16	-0.63 ***	1.00
Spearman				
IVC	1.00			
CVC	-0.01	1.00		
BVC	0.23	0.05	1.00	
GVC	-0.79 ***	-0.17	-0.68 ***	1.00
Kendall [a]				
IVC	1.00			
CVC	0.00	1.00		
BVC	0.16	0.03	1.00	
GVC	-0.58 ***	-0.13	-0.50 ***	1.00

Legend. *p<10%; **p<5%; ***p<1%. Number of observations: 33. [a] We report Tau-a statistic.

Lastly, we used the TBIs to check the stability of the investment specialization patterns of the different VC types over time. This is particularly important because the internet bubble in the late 1990s is thought by scholars and practitioners alike to have altered the investment patterns of VCs (e.g., Green, 2004). To check whether a structural break occurred in the specialization of the different VC types, we computed the TBIs by splitting the sample in two periods: before the burst of the internet bubble (1994-2001) and after the burst of the internet bubble (2002-2004). We then computed the Pearson's, Spearman's and Kendall's correlation indexes of the value of the $TBI_{i,j}^{k}$ relating to each investor type between the two periods. The higher the correlation, the more persistent the investment specialization pattern of the VC type is.

Table 2.5. Correlation for the transformed Balassa indexes before and after the internet bubble

Type of VC	Number of observations	Pearson		Spearman		Kendall[a]	
Overall	132	0.34	***	0.52	***	0.38	***
IVC	33	0.69	***	0.49	***	0.34	***
CVC	33	-0.23		0.16		0.14	
BVC	33	0.36	**	0.62	***	0.44	***
GVC	33	0.70	***	0.74	***	0.57	***

Legend. *p<10%; **p<5%; ***p<1%. [a] We report Tau-a statistic.

The results are reported in Table 2.5. The overall correlation, computed on 132 observations, ranges from 0.34 to 0.52, depending on the correlation index. All these correlations are significant at the 1% confidence level, indicating that the pattern of investment specialization of the VC types is quite stable over time. GVC, IVC and BVCs indeed exhibit high positive correlation values (the correlation ranges from 0.57 to 0.74 for GVCs, from 0.34 to 0.69 for IVCs, and from 0.36 to 0.62 for BVCs; with only one exception, these values are significant at 1% or 5%). Conversely, the TBIs of CVCs before and after the burst of the internet bubble are not significantly correlated. This is consistent with previous findings pointing to changes in investment patterns of CVCs over time (e.g., Dushnitsky, 2012, p. 167-168).

Investment specialization patterns of different VC types: A synthesis

The results illustrated in the previous section highlight significant differences across the investment specialization patterns of different types of VCs. In comparison with other investor types, IVCs quite surprisingly tend to select relatively older (but not too old) and larger companies in their expansion stages. This pattern of investment specialization is stable over time. If anything, it has been reinforced in the post-internet bubble period.[9] This evidence suggests that European IVCs abstain from the most risky investments. Note also that IVCs care less than other VCs about geographic distance, selecting companies located relatively far away from their premises. The popular Silicon Valley "20 minutes rule", according to which start-up companies located further

[9] We compared the TBIs of IVC investors in the pre- and post-internet bubble periods, and tested for the existence of significant differences (results are available from the authors upon request). The only significant difference relates to the "1-2 years" category of the age dimension and indicates a lower inclination to invest in this type of company in the latter period.

then a 20-minute drive from the VC firm will not be funded[10], is not confirmed by our data (see Fritsch & Schilder, 2008 for similar evidence).

Previous studies argued that CVC investments are an important element of parent companies' "open innovation" strategies (e.g., Dushnitsky, 2012, p. 164) and, in addition to, or even in substitution of, financial objectives, they are driven by the wish to open a "technology window" on the development of promising new technologies by entrepreneurial ventures (see e.g., Dushnitsky & Lenox, 2005a; Siegel, Siegel, & MacMillan, 1988). In accordance with this view, Dushnitsky & Lenox (2005b) found that CVCs are particularly attracted by companies operating in industries with high technological ferment. They are also more active in industries with weak intellectual property protection in which other mechanisms to obtain access to promising new technologies (e.g., licenses) are ineffective. This evidence is confirmed by our findings. CVCs were indeed found to specialize in internet and TLC services and abstain from investing in biotechnology and pharmaceuticals. The former industry is characterized by a weak appropriability regime (Coriat, Malerba, & Montobbio, 2004; Malerba, 2004) and high technological turbulence in the observation period (Montobbio, 2004). Conversely, IPRs provide efficient protection of proprietary technologies in biotechnology and pharmaceuticals (see e.g., Levin et al., 1987). Previous studies, based on North American data, also indicated that CVCs are less likely to invest in early-stage companies than IVCs (see Cumming, 2006 on Canada; Katila, Rosenberger, & Eisenhardt, 2008 and Dushnitsky & Shapira, 2010 on the USA). Our data relating to Europe do not support this claim, most likely as a consequence of the previously mentioned limited preference of European IVCs for this type of investment. We also do not find any evidence that CVCs are more likely to syndicate than average investors. Conversely, CVCs adopt a more global investment strategy than the other investor types and are more prone to select companies located far away from their premises (for similar evidence, see Gupta & Sapienza, 1992; Mayer et al., 2005). Hence, our data confirm the view that CVC is often used by parent companies "to access foreign technologies or learn about and enter geographically distant markets" (Dushnitsky, 2006, p. 397).

Let us now turn our attention to BVCs. Previous studies argued that the main objective of this type of VC is to support the establishment of profitable bank relationships with investee companies rather than to realize large capital gains (Hellmann et al., 2008). In accordance with this view, we found that BVCs, compared to IVC and CVCs, are more likely to invest locally, where they could exploit their superior ability to gather soft information (Coval & Moskowitz, 2001; Fritsch &

[10] "It's not the people you know. It's where you are." The New York Times, 10/22/2006.

Schilder, 2008; Hellmann et al., 2008; Mayer et al., 2005). Moreover, our results clearly documented that BVCs employ more passive strategies than other VC types and are more inclined to invest in older and larger companies that, being in a later stage of development, are closer to an IPO. In fact, we find that BVCs are relatively more likely to exit through an IPO than other investor types and are specialized in investments of shorter durations. In addition, they more frequently employ syndication as a means of reducing investment risk.[11]

Finally, GVCs exhibit a pattern of investment specialization that differs from that of all other investor types. Previous studies argued that the rationale for the creation of GVCs is to fill the funding gap that is left by private investors (Lerner, 1999; Lerner, 2002).[12] In accordance with this argument, we found that GVCs are specialized in investments that are not attractive to other investor types. Because of the information asymmetries surrounding young, small high-tech companies and their high risks of failure, these companies find it difficult to attract private funding, especially at the seed stage (Carpenter & Petersen, 2002b; Hall, 2002). These difficulties are magnified in industries, such as biotechnology, in which there are long lead times and substantial resources are needed for new product development. Our data show that these are precisely the categories in which GVCs are specialized. The duration of the investments of GVCs is also longer than for all other investor types. Moreover, in line with previous studies (e.g., Gupta & Sapienza, 1992; Mayer et al., 2005; Fritsch & Schilder, 2008), we found that GVCs more frequently select local investment targets, which is consistent with the fact that GVC programs in Europe have often been created to implement regional development objectives (Leleux & Surlemont, 2003). Finally, that the investment strategies and specific policy-related objectives of GVCs differ from those of other investor types explains why they rarely take part in syndicated investments and are forced to invest on a stand-alone basis.

[11] Hellmann et al. (2008) claim that BVC investors “let others do more of the origination work rather than themselves” (p. 521) and “avoid early-stage investments” (p. 536). On this latter issue, see also Tykvovà, (2004), Mayer et al. (2005), and Cumming (2006).

[12] This objective is generally shared by public policy measures in support of high-tech entrepreneurial firms. For instance, Audretsch (2003) claimed that, in the USA, the “SBIR awards provide a source of funding for scientists to launch start-up companies that otherwise would not have had access to alternative sources of funding” (p. 133) and that “the emphasis on SBIR and most public funds is on early stage finance, which is generally ignored by private venture capital” (p. 133).

2.5. PATTERNS OF VC INVESTMENT SPECIALIZATION IN EUROPE AND USA

Our results are based on a sample of VC investments in companies located in Europe. It is therefore interesting to explore the extent to which they are specific to the European institutional context or whether they represent a general characterization of VCs. In the previous section, we have shown that some of our results resemble those obtained by prior studies, most of which relate to the USA, while others do not. The aim of this section is to more systematically compare the investment specialization patterns that we found in our study with similar evidence on VC investments in the USA. For this purpose, we employed the Thomson One database (previously VentureXpert, retrieved on 12/23/2011), which has been extensively used in the VC literature. According to this database, between 1994 and 2004, 3,457 investors belonging to the four types of investors considered in this chapter were responsible for 24,242 first VC investments in 9,024 companies with fewer than 10 years of age, operating in high tech sectors and located in the USA. The distributions of these investments according to the type of investor, industry of operations, age of investee companies at the time of the investment, and syndication are reported in Table 2.6.[13]

Table 2.6. Distribution of the first VC investments in the USA.

	N	%		N	%
Investor type					
Independent VC (IVC)	16,478	68.0%			
Corporate VC (CVC)	4,207	17.4%			
Bank affiliated VC (BVC)	2,955	12.2%			
Public VC (GVC)	602	2.5%			
Total	24,242	100.0%			
Industry of operation of investee company			***Age of investee company at the time of the investment***		
ICT manufacturing	3,751	15.5%	<1 year	5,646	23.5%
Biotech and pharmaceutics	2,283	9.4%	1-2 years	9,601	40.0%
Other high-tech manufacturing	311	1.3%	3-5 years	6,447	26.9%
Software	9,243	38.1%	>5 years	2,282	9.5%
Internet and TLC services	7,428	30.6%			
R&D and engineering services	1,226	5.1%			
Total	24,242	100.0%	Total	23,976	100.0%
Syndication					
Syndicated investments	19,452	80.2%			
Non-syndicated investments	4,790	19.8%			
Total	24,242	100.0%			

Source: Elaboration of Thomson One data. Data refer to first VC investments in the USA between January 1, 1994 and December 31, 2004.

[13] We do not consider the stage of development of investee companies at the time of the VC investment because the classification, being to some extent subjective, is not entirely comparable across the two datasets.

Of these investments, 68.0% were made by IVCs, 17.4% by CVCs, 12.2% by BVCs and the remaining 2.5% by GVCs. A χ^2 test shows that this distribution is significantly different from that observed in Europe (p-value<1%). In particular, the importance of IVCs is much lower in Europe than in the USA and CVC investments are relatively more frequent in the USA than in Europe, whereas BVC and, more remarkably, GVC investments are more frequent in Europe. There are also significant differences across the USA and Europe relating to the distribution of VC investments by industry of operations and age of investee companies. Moreover, USA investments are syndicated more often.

Similarly to what was performed in the previous sections, we computed TBIs for each VC type in the USA for the three dimensions for which a meaningful comparison was possible and tested their significance. We then computed the Pearson's, Spearman's and Kendall's correlation indexes of the TBIs of the VC types in the USA and Europe. Table 2.7 reports the correlation indexes, and Table 2.8 presents the TBIs for the VC types in the USA.

Table 2.7. Correlation between the TBI of European and USA VCs

	Number of observations	Pearson		Spearman		Kendall[a]
Overall	60	0.24		0.20		0.15
Industry of operation of investee company	24	0.14		0.17		0.15
Age of investee company at the time of the investment	16	0.09		-0.17		-0.12
Syndication	8	0.75	**	0.71	**	0.50

Source: Elaboration of Thomson One data and VICO data. Details on the industry reclassification are available from the authors upon request. **p<5%. [a] We report Tau-a statistics.

The results indicate that the specialization patterns of the VC types in the USA and Europe differ quite substantially. The overall correlation indexes reported in Table 2.7 are low and not significant at customary confidence levels. We also computed the correlation indexes for each dimension of the TBIs. We found that the patterns of investment specialization of VC types in the USA and Europe are not correlated along the industry dimension. Table 2.8 shows that the only industries in which the investment specialization patterns of VC types are similar are biotech and pharmaceuticals and internet and TLC services. In both Europe and the USA, GVCs are specialized in the former industry and abstain from investing in the latter, whereas the opposite is true for CVCs.

Table 2.8. TBI relating to investee company and investment characteristics in the USA

	IVC		CVC		BVC		GVC	
Industry of operation of investee company								
ICT manufacturing	-0.002		0.041	***	-0.041	*	-0.034	
	(0.005)		(0.015)		(0.021)		(0.049)	
Biotech and pharmaceutics	-0.015	**	-0.063	***	0.082	***	0.276	***
	(0.007)		(0.023)		(0.024)		(0.041)	
Other high-tech manufacturing	-0.011		-0.125	*	0.138	**	0.217	
	(0.020)		(0.070)		(0.063)		(0.134)	
Software	0.006	**	-0.009		-0.011		-0.047	*
	(0.003)		(0.009)		(0.011)		(0.028)	
Internet and TLC services	-0.002		0.019	*	-0.001		-0.077	**
	(0.003)		(0.010)		(0.013)		(0.034)	
R&D and engineering services	0.008		-0.046		0.002		0.084	
	(0.009)		(0.032)		(0.037)		(0.079)	
Age of investee company at the time of the investment								
<1 year	0.052	***	-0.143	***	-0.141	***	-0.016	
	(0.003)		(0.015)		(0.018)		(0.039)	
1-2 years	-0.014	***	0.036	***	0.031	***	-0.043	
	(0.003)		(0.008)		(0.010)		(0.028)	
3-5 years	-0.027	***	0.054	***	0.043	***	0.085	***
	(0.004)		(0.011)		(0.013)		(0.031)	
>5 years	-0.004		-0.009		0.042	*	-0.054	
	(0.007)		(0.022)		(0.025)		(0.070)	
Syndication								
Syndicated investments	-0.025	***	0.049	***	0.061	***	-0.009	
	(0.001)		(0.003)		(0.003)		(0.010)	
Non-syndicated investments	0.091	***	-0.267	***	-0.360	***	0.037	
	(0.003)		(0.019)		(0.024)		(0.039)	

Legend: The table shows the TBI for each investor in each category of investment style. Standard deviations are in parentheses. *p<10%; **p<5%; ***p<1%. [a] "Early stage" in Thomson One. Source: Elaboration of Thomson One data. Details on the industry reclassification are available from the authors upon request.

Table 2.7 also shows that the investment specialization patterns in the USA and Europe are not correlated along the age dimension (the Spearman's and Kendall's correlation indexes are negative, though not significant). The most striking difference is the inverted role of IVC and GVC in the two institutional contexts. In the USA, IVCs are specialized in very young companies and abstain from investing in 3- to 5-year-old companies, whereas GVCs specialize in this type of company (Table 2.8). This evidence confirms that IVCs in Europe are less attracted to risky investments than those in the USA (see e.g., Kaiser, Lauterbach, & Schweizer, 2007).

Finally, the investment specialization patterns of VCs in the USA and Europe are very similar in terms of syndication. The Pearson and Spearman correlations are equal to 75% and 71%, respectively, and both are significant at 95% confidence level; the Kendall correlation, though not significant, is quite high (50%).

2.6. CONCLUSIONS

In this study, we have analyzed the investment specialization patterns of four different types of VCs (IVCs, CVCs, BVCs and GVCs) between 1994 and 2004 in Europe and in USA. As to Europe, we have shown that the different VC types tend to select European companies with different characteristics relating to their industry of operation, age, size, stage of development, localization and distance from the premise of the VC at the time of the investment. The four types of VCs also differ in their propensity to syndicate and in the duration and type of exit of their investments. In addition, we have documented that the investment specialization patterns of different types of VCs are quite stable over time, with few exceptions. This evidence confirms the view proposed by previous studies (e.g., Dimov & Gedajlovic, 2010) that IVC, CVC, BVC and GVC play different roles in the VC ecosystem and often do not compete with each other for the same types of deals. Moreover, we have shown that there are similarities but also remarkable differences between the investment specialization patterns of VC investments in Europe and those observed in the USA in the same period. In this respect, the most striking difference is that, in Europe, IVCs refrain from investing in very young, small, seed-stage companies. This investment gap is filled by GVCs, which in Europe account for a sizable share of total VC investments, contrary to the situation in the USA.

This study offers two original contributions to the VC literature. First, the VC literature has long recognized that the ownership and governance of VC firms is an important source of heterogeneity in VC markets. In particular, previous studies have shown that the investment strategies and practices of IVCs differ from those of captive VCs and that the private or governmental ownership of captive VCs also makes a considerable difference (Cumming & MacIntosh, 2006; Dimov & Gedajlovic, 2010; Dushnitsky & Shaver, 2009; Gompers, 2002; Hellmann et al., 2008; Katila et al., 2008). Moreover, previous studies have documented that there is considerable variation across different geographical areas in the presence of different VC types (Mayer et al., 2005). Hence, the differences detected in the functioning of the VC market in different geographical areas may simply be a consequence of a "composition" effect (e.g., Sapienza et al., 1996). Our study makes further progress in the understanding of the sources of these differences by showing that the composition effect provides only a partial explanation. Whereas the investment strategies of private captive VCs in Europe broadly resemble those used in the USA, the investment strategies of IVCs differ quite remarkably across the two geographical areas. A possible explanation lies in the need to "grandstand" – i.e., to take actions that signal investment capabilities – of European IVCs (Gompers, 1996), who are supposedly less experienced and reputable than their American counterparts and struggle to rapidly achieve good results to be able to raise new capital. Nonetheless, we do not observe any evidence that the specialization of IVCs in risky investments increases over time. Therefore, it is unlikely that the pattern of investment specialization of this type of investor is simply a consequence of the immaturity of the European VC market, the limited experience and reputation of VCs, which presumably increase over time, and the supposed more limited diffusion of the investment practices that are popular in the USA (e.g., stage financing, carried interest). Instead, as suggested by Bruton, Fried & Manigart (2005), this pattern is possibly the result of the institutional environment in which investors operate (see also Li & Zahra, 2012). From this perspective, regulatory factors (such as the level of protection of minority shareholders, which influences the propensity of investors to invest in younger, early-stage, riskier companies), and cognitive factors (such as the status of entrepreneurs, which influences the birth rate of entrepreneurial ventures), are likely to play an important role. Although the analysis of this issue lies beyond the scope of the present work – and would require an enlargement of the VICO dataset to allow for country-level analysis – it is clearly an interesting direction for future research.

Second, this study offers an original contribution to the debate about governmental intervention in the VC market. In the past two decades, governments around the world, notably in Europe, have paid increasing attention and committed considerable resources to the development of an active VC market. In particular, GVC firms (and other government-supported VC firms) have been created in several countries (Brander, Du, et al., 2010), and in some of them, such as Canada and South Korea, they have become the dominant VC type. Although there is a lack of large-scale comprehensive empirical studies on the effects of GVCs on the performance of investee companies, the available evidence suggests that these effects have been less positive on average than those of private VC investments along a series of dimensions including company investments (Bertoni, Croce, & Guerini, 2012; Brander, Du, et al., 2010) and growth (Grilli & Murtinu, 2012).[14] Some studies have

[14] A possible reason is that GVC investors provide limited value-enhancing services to investee companies (Luukkonen et al., 2011). In accordance with this view, the effects seem to be more positive when GVC investors syndicate with private VC investors. For instance, while analyzing a large sample of VC-backed companies in 25 countries, Brander, Du, et al. (2010) documented that these syndicated investments have outperformed other types of VC investments in terms of the total amount of investment obtained by

even suggested that GVCs may "crowd out" private VCs: by raising cheap capital, they may attract the best deals and out-bid offers by private VCs (see Cumming & MacIntosh, 2006 and Brander et al., 2010b for evidence consistent with this argument relating to Canada; see Armour & Cumming, 2006 for international evidence; see Leleux and Surlemont 2003 for evidence supporting the view that in Europe, GVCs did not crowd out private VCs). In sum, VC scholars are quite skeptical about the effectiveness of policy intervention in this domain (see e.g., Lerner, 2009). This study has provided a systematic illustration of the investment strategies of GVCs in Europe in a period during which European governments have been very active to foster VCs' activity. Our data document that GVCs have specialized in industries (biotech and pharmaceuticals) and types of companies (young, small, seed-stage companies) that have proved quite unattractive for private VCs in Europe, thereby filling the entrepreneurial financing gap left by private VCs.

This study also has important implications for European policymakers, indicating some guidelines for improving policy intervention. First, European policymakers have been trying since well before the Lisbon Agenda (e.g., European Commission, 1998) to create an EU-wide VC market for early-stage high-potential companies. Our results are in line with the view that, despite these efforts, the European VC market remains quite fragmented. In particular, IVCs in Europe do not exhibit any pronounced propensity for cross-border investments. Recently, this aspect has been the object of specific measures by European policymakers aimed at regulatory simplification and harmonization. In particular, in a series of recent Acts (most notably the Small Business Act and the Single Market Act), the European Commission has committed itself to promoting cross-border VC investments through the adoption of new rules ensuring that, by 2012, VC funds established in any Member State can invest freely throughout the EU (the so-called pan-European passport for VCs). While this is clearly a positive initiative for IVCs, a parallel mechanism leading to a more immediate increase of the internationalization and reduction of the fragmentation of the European VC market would be to increase CVC investments, which are relatively less numerous in Europe than in the USA. Indeed, we have shown that this type of VC has a natural propensity to invest at long distances and across national borders.

Second, as previously mentioned, IVCs in Europe are not attracted to early stage deals. This gap has been filled by GVCs. However, our findings point to some serious weaknesses of this policy that

companies and the likelihood of successful exit (i.e., through IPOs and third-party acquisitions). Bertoni and Tykvova (2012) found similar results with regard to the patenting activity of young European biotech and pharmaceutical companies. In Europe, however, GVC investors are quite unlikely to form a syndicate, as has been documented in the present study, probably due to the divergence of their objectives with those of private investors.

are not mentioned in previous studies. On the one hand, GVC investments are highly localized. GVCs are the most prone to investing in companies located closer than 10 km and the least likely to invest abroad. This is most likely the consequence of the local natures of their mandates because they have often been established by regional authorities with local development objectives.[15] The local bias of GVCs creates two types of problems. First, it exacerbates the fragmentation of the European VC market. Second, it exposes GVCs to the risk of regulatory capture (Lerner, 2002), thereby jeopardizing their investment selection abilities. Our findings argue in favor of the removal of the regulatory constraints that lead to this local bias. On the other hand, GVCs are the least inclined to syndicate, possibly as a consequence of their unique investment specialization pattern. The VC literature has long recognized the benefits of syndication in terms of reduction of risk exposure and better monitoring of investee companies (Brander et al., 2002). These benefits are likely to be especially important for GVCs, who generally lack the high-powered incentives and investment expertise of their independent private peers (Lerner, 2002). Indeed, the (scarce) available evidence points towards the effectiveness of syndicates that involve GVCs (see footnote 15). Therefore, GVCs should abandon a "go it alone" investment strategy and use syndication with private investors in combination with suitable incentive schemes (e.g., based on asymmetric capital gain sharing arrangements) to attract smart money to the sectors of the European entrepreneurial economy where it is more needed.

While this chapter offers preliminary evidence on how GVC pursue its role in the European VC ecosystem, Chapter 4 goes more into details, and explicitly tests whether GVC-backed companies are able to attract private VC investments in their portfolio companies.

[15] Investment vehicles founded by a regional or national government are often statutorily prevented or otherwise discouraged from investing outside regional or national borders. The quite obvious reason for this is that policymakers would find it difficult to explain to taxpayers in one region or country why their money is being used to support companies in another region or country. SITRA, a Finnish GVC, provides an interesting counter example. SITRA invests a portion of VC funds outside Finland, claiming that the objective of these cross-border investments is to create a window to the international VC market and learn about new investment practices. At the end of 2010, the international portion of the assets managed by SITRA had a book value of 42 million Euro, corresponding to 6% of total assets (SITRA, 2011).

3. VENTURE CAPITAL AND THE EMPLOYMENT POLICY OF HIGH-TECH ENTREPRENEURIAL VENTURES

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3.1. INTRODUCTION

The ability of high-tech entrepreneurial ventures to create innovation and employment, which make them so important in modern knowledge-based economies (Audretsch, 1995; Westhead & Cowling, 1995), is often hampered by financial constraints (Carpenter & Petersen, 2002a; Hall, 2002). The investment opportunities of high-tech entrepreneurial ventures often exceed both their revenues and the amount of capital available to founders, and debt capital is normally an ineffective form of external financing for these companies (Berger & Udell, 1998). VC are considered as the most suitable form of financing for high-tech entrepreneurial ventures (Carpenter & Petersen 2002b). This is particularly true for the most traditional form of VC, Independent VC (IVC). IVC provides skills and reputation besides a significant injection of financial resources (Cumming, Fleming, & Suchard, 2005). It is then perhaps not surprising that, once IVC is received by a young high-tech company, employment growth accelerates (Bertoni, Colombo, & Grilli, 2011; Davila, Foster, & Gupta, 2003).

In this chapter we show that IVC's impact of on firms' employment policies is more complex than just a boost to firm's growth, as the effect of financial constraints on these policies is actually the composition of different effects.

First, financial constraints make firm's employment policy unstable. The literature has shown that, due to financial constraints, firm employment policy is affected by current cash flows (Cantor, 1990). A closely related phenomenon is observed in connection with firm's capital investments (Fazzari et al., 1988; Kaplan & Zingales, 2000). In both cases, the phenomenon originates from the importance of internal financing for financially constrained companies. Financial constraints determine a gap between the cost of internal and external financing (Myers & Majluf, 1984). A shock in cash flows affects the level of available internal financing, the marginal cost of capital, and the probability of default, all of which have an effect on the optimal level of labor and capital in any given period. This, ultimately, gives rise to a sensitivity of investments and labor policies to current cash flows. While the investment cash flow sensitivity (ICFS) has been thoughtfully studied, also in relationship with its change after VC investments (Bertoni et al., 2010; Engel, Stiebale, & Frederiksberg, 2009), employment cash flow sensitivity (ECFS) in high tech entrepreneurial ventures has received more limited attention. A first objective of this chapter is to fill this gap. In doing so, we explicitly take into account, and empirically verify, the non-monotonic nature of the employment curve (i.e. the relationship between firm's employment and cash flow). Intuitively, one would expect ECFS to be positive: a positive shock in cash flows should be associated to an increased growth in employment. This assumption is normally made by the literature (e.g., Cantor 1990; Benmelech et al. 2011). However, especially when studying high tech entrepreneurial ventures, the assumption that ECFS is always positive might be too restrictive. Cleary et al. (2007) were the first to highlight, within the ICFS literature, that when cash flows are very low ICFS can become negative: higher cash flows translate in lower capital investments, determining a U-shape for the investment curve. As we will argue later in this work, the same mechanism that determines the U-shape of the investment curve is also likely to operate when the employment curve is considered.

Second, financial constraints make it harder for young high-tech firms to hire and retain high-skilled labor. ECFS, whichever its sign, determines the impossibility for high tech entrepreneurial ventures to follow their optimal employment growth path. Deviations from this path generate additional labor turnover which has an expected cost both for the company (e.g., recruitment, training, and loss of competences) and for its workers (e.g., earning loss after displacement). What is perhaps most interesting, however, is that both firm's and worker's costs of labor turnover are higher for high-skilled than for unskilled labor (Carrington & Zaman, 1994; Del Boca & Rota, 1998; Jacobson, LaLonde, & Sullivan, 1993). Accordingly, the stronger is the ECFS, the more difficult it becomes to hire and retain high-skilled labor for the firm. This problem is particularly critical for entrepreneurial ventures, as "at a time of unparalleled technological development, it is the human resources that paradoxically spell success or failure for all firms, and especially entrepreneurial ones" (Katz et al. 2000, p.7). Analyzing this issue is an additional objective of our work.

The literature has shown that IVC relaxes the financial constraints of its portfolio companies (Engel & Stiebale 2009; Bertoni et al. 2010; Bertoni et al. 2012). If we want to understand deeply IVC effect on the employment policies of firms, due to the relaxation of their financial constraints, we have to consider two effects. First, we expect to observe a reduction in the magnitude of ECFS in IVC-backed firms. With respect to their peers, IVC-backed firms should exhibit lower, or no, dependence of employment from current cash flows (whichever its direction). Second, the weakening in ECFS should reduce the costs of high-skilled labor and, accordingly, it should determine an increase in the average quality of firm's workforce.

We conduct our empirical analysis on a panel of 4,681 high tech entrepreneurial ventures in 6 European countries (Belgium, Finland, France, Italy, Spain, and the United Kingdom). The sample is extracted from the VICO database. All firms in the dataset operate in high-tech sectors and were independent at foundation. In order to test whether financial market imperfections have a significant impact on employment decisions of young high-tech firms, and whether and how IVC investors influence this relationship, we resort to an augmented version of Benmelech et al. (2011)'s model, in which we allow ECFS to be U-shaped. The model specification allows us to estimate the impact of IVC on firm's ability to hire and retain high-skilled employees. The estimation is conducted by a GLS robust random effect model. Moreover, we implement two different controls for the endogeneity of IVC.

Our main findings are the following. First, our empirical analysis confirms that the employment curve of high tech entrepreneurial ventures is U-shaped. ECFS is positive when cash flows are positive and negative when cash flows are negative. Moreover, if we split the sample in two subsamples, depending on firm size, we observe a stronger ECFS in the subsample of small companies. This is consistent with the expectation that these companies are most exposed to asymmetries in information and capital market imperfections.

Second, we find that IVC is successful in reducing the magnitude of ECFS only in the upward sloped region of the employment curve. Firms that generate positive cash flows see their ECFS go from positive and significant to non-significant, after they receive IVC. However, the ECFS of firms with negative cash flows is negative both before and after IVC is received. We interpret this result as the outcome of the impact of IVC on the expected loss in case of firm's liquidation (which is a fundamental factor in determining the negative sign of ECFS). Our findings would be compatible with the hypothesis that IVC increases firm's expected cost of liquidation, because of an increase in the risk profile of the investments or because of their higher intangibility.

Third, we find that IVC improves the ability of high tech entrepreneurial ventures to attract and retain high-skilled labor, especially when ECFS is most pronounced (i.e., for small firms). This finding is consistent with the idea that ECFS does not only imply a higher costs of labor turnover; but that it also has a potentially more critical negative impact on the firm, reducing its ability to hire and retain high-skilled labor.

The rest of the work is organized as follows. In section 3.2 we summarize the relevant literature and formalize our research hypotheses. In Section 3.3 we outline the empirical methodology. We describe the sample used in this study in Section 3.4. The empirical results are reported in Section 3.5. The implications of our results and some concluding remarks are discussed in Section 3.6.

3.2. THEORETICAL FRAMEWORK AND RESEARCH HYPOTHESIS

Financial constraints and employment cash flow sensitivity

The high uncertainty, the absence of a track record of past performance, and the intangibility and specificity of their assets, make high tech entrepreneurial ventures particularly prone to capital market imperfections (Carpenter & Petersen, 2002a; Denis, 2004). For high tech entrepreneurial ventures the gap between the cost of internal and external capital (Myers, 1984) is particularly high, and financial constraints interfere significantly with their investment and employment policy. Firms' investment and employment policies are contingent to the availability of financial resources generated internally, i.e. to firms' cash flow.

ICFS and its removal have received significant attention in the literature (Hall, 2002). The extent to which ICFS is proportional to financial constraints has been the subject of a significant scientific debate. On the one hand, Fazzari et al. (1988, 2000) showed that firms most exposed to financial constraints exhibited the highest ICFS. On the other hand, Kaplan and Zingales (1997, 2000) critiqued this assumption, both on the theoretical and on the empirical ground, showing that firms that are extremely financially constrained show a lower, not higher, ICFS than firms that are less financially constrained. Cleary et al. (2007) have demonstrated that the investment curve is non monotonic. The non-monotonicity of the investment curve derives from the way in which cash flows affect both the marginal cost of capital and the probability of bankruptcy. First, if a company is financially constrained (i.e., if its investment opportunities exceed its internal capital), a negative shock in available internal capital determines an increase in the marginal cost of capital, since more, costlier, external capital is needed to fund the investments. Second, the survivorship of a firm that generates negative operating cash flows is possible only if the returns from its investments are sufficiently high. A negative shock in cash flows, in these circumstances, may then determine an increase in the level of investment to keep the firm alive. When available cash flows are sufficiently high, the first effect dominates, and ICFS is positive (i.e., a decrease in cash flows determines a decrease in the optimal level of investment). When available cash flows are low, ICFS is negative (i.e., a negative shock in cash flows determines an increase in investment). The threshold level of cash flow where the curve changes its slope is empirically very close to zero (Cleary et al. 2007). Finally, Cleary et al. (2007) show that the investment curve is steeper (in both its positive and negative portion) the more asymmetries in information are high.

Benmelech et al. (2011) argue that some results obtained by the literature on the relationship between financial constraints and capital investments can be generalized to employment decisions.

It is particularly likely to be so for high tech entrepreneurial ventures. Labor, just like capital, has significant adjustment costs, especially in high-tech sectors (Del Boca & Rota, 1998). To some extent, employment is likely to suffer for financial constraints even more than capital investments. While capital investments constitute, at least in part, assets that can be pledged by creditors in case of default, the value created by employees (e.g., through tacit knowledge) is non collateralizable. Accordingly, the same mechanism that generates ICFS, is also likely to give rise to a sizeable ECFS in high tech entrepreneurial ventures.

While the idea that there is a link between employment and internal financing is well established at macro level (Greenwald & Stiglitz, 1987), the empirical work at micro level on ECFS is limited. Cantor (1990) was the first to mention and test the presence of ECFS using micro data. In his work, based on a sample of 586 Compustat firms, both employment and capital investments are found to be sensitive to cash flows, especially in high-levered companies. Benmelech et al. (2011), utilizing three quasi-experiments used previously to study ICFS and firm's growth, document the presence of ECFS. They also test a mediation effect for investments in a labor equation and show that the ECFS is not an indirect effect of ICFS, but is indeed a genuinely independent phenomenon. Pagano and Pica (2012), in an analysis at country level, give an indirect proof of the ECFS by showing that the financial development of a country, by increasing the fraction of unconstrained firms, decreases ECFS.

The literature, however, has so far ignored the possibility that ECFS, like ICFS, may be negative when cash flows are low. Theoretically, the model developed by Cleary et al. (2007) can be easily applied to labor, as well as investment, decisions. The model assumes that external funds are costly, that their cost is endogenous, that investment is scalable and that the company has a non-transferable continuation value in excess of its liquidation value. If the production function modeled by Cleary et al. (2007) is augmented to include labor, besides capital, a U-shaped ECFS would emerge naturally. This is particularly relevant for companies, like young innovative companies, that are likely to operate very close to the region where cash flow is so low that ECFS turns negative. Accordingly, our first research hypothesis is the following:

Hypothesis 1: A U-shaped relationship between employment and cash flow exists in young high-tech entrepreneurial companies.

Not all high tech entrepreneurial ventures are, however, equally exposed to financial constraints. There are different theoretical arguments according to which small high-tech ventures face a higher cost of capital than their larger peers. Small firms face the liability of smallness and often lack of the necessary resources to grow (Stinchcombe, 1965). Small firms are typically less well-known, are often unable to provide audited financial statements and have lower collateral relative to their liabilities (Bernanke, Gertler, & Gilchrist, 1996). Because of the fixed costs associated with screening, contracting, monitoring and servicing loans, bank capture scale economies in dealing with larger firms, making debt capital more costly for smaller lenders (Avery, Bostic, & Samolyk, 1998). In addition, small firms also have a more difficult access to stock markets (Hall, 2002; Harhoff, 1998). Therefore, small high tech entrepreneurial ventures are expected to face tougher financial constraints and higher cost of external capital. The empirical evidence confirms this view. Using data on firms in the United Kingdom, Canepa and Stoneman (2008) find that the cost and availability of finance matters for innovation, especially for the smaller firms in their sample. Magri (2009) finds that the investment of innovative firms is more sensitive to cash flow when they are small. Hao and Jaffe (1993) show that small companies are financially constrained, while large companies are not (see, for similar results, Harhoff, 1998, on German firms and Colombo et al., 2012, on Italian firms). In a study that explicitly takes into account the non-linearity of ICFS, Guariglia (2008) finds that the ICFS is monotonically decreasing with firm's size. To the extent to which we are correct in expecting that the model by Cleary et al. (2007) can be extended to employment decisions, we should then expect the following:

Hypothesis 2: The employment cash flow sensitivity is stronger in small young high-tech entrepreneurial companies.

Independent Venture Capital and employment cash flow sensitivity

IVC is the ideal candidate to alleviate the financial constraints of high tech entrepreneurial ventures (Carpenter & Petersen 2002b). First, because of their superior scouting and monitoring capabilities, IVC investors are able to effectively address the information asymmetries in young high-tech firms (Kaplan & Stromberg, 2001). In addition, the governance structure of IVC investors gives them explicit (Sahlman, 1990) and implicit (Gompers, 1996) incentives to boost the performance of their portfolio firms, allowing them to succeed as quickly as possible. Moreover, IVC conveys a signal to other, uninformed, parties, certifying the firm's quality (P. M. Lee & Wahal, 2004; Megginson & Weiss, 1991; Stuart, Hoang, & Hybels, 1999) and facilitating its access to additional finance in the form of financial debt, operational debt, or external equity (Vanacker, Seghers, & Manigart, 2011).

Once they become IVC-backed, firms should then be less exposed to financial constraints. To the extent to which ECFS is the result of financial constraints, we should then expect IVC to reduce the ECFS of its portfolio companies. To the best of our knowledge, this phenomenon has not been studied by the literature.[16] There is, however, some empirical evidence that IVC financing relaxes firms' ICFS (Engel & Stiebale 2009; Bertoni et al. 2010; Bertoni et al. 2012). Accordingly, we formulate the following hypothesis:

Hypothesis 3: IVC reduces the employment cash flow sensitivity of young high-tech entrepreneurial companies.

Employment cash flow sensitivity and high-skilled labor

The asymmetries in information that affect the access of high tech entrepreneurial ventures to external finance also influence their access to labor markets: potential employees may find it difficult to acquire information about the firm, uncertainties on its potential make skilled employees wary to select it as employer-of-choice, and the lack of formal human resource policies and compensation practices typical of new and small firms make uncertainty even stronger (Barber, Wesson, Roberson, & Taylor, 1999; Williamson, Cable, & Aldrich, 2002; Williamson, 2000).

Different theoretical contributions and empirical evidence suggest that IVC may improve substantially the ability of portfolio firms to hire and retain high-skilled employees. First, IVC investors share with their portfolio companies a vast network of contacts with experienced professionals and infrastructure providers (such as accounting firms, law firms, and executive search firms) (Hochberg, Ljungqvist, & Lu, 2007). These contacts reduce the cost of acquiring information about the company for high-skilled workers. Second, IVC conveys a signal about company's quality (Megginson & Weiss, 1991; Stuart et al., 1999) that reduces uncertainty and improves legitimacy as employer (Davila et al., 2003). Third, IVC increases and accelerates the professionalization of start-up companies by setting up human resource and compensation policies (Colombo & Grilli, 2013)(Balkin & Gomez-Mejia, 1987; Hellmann & Puri, 2002; Kaplan & Stromberg, 2003). Accordingly we formulate the following hypothesis:

Hypothesis 4: IVC improves the ability of young high-tech entrepreneurial ventures to hire and retain high-skilled employees

Finally and more importantly, given the objectives of this work, the ability to hire and retain high-skilled employees may be deteriorated even further by ECFS. Financial constraints destabilize the employment policy of the firm, which is subject to the availability of internal financing. If internal financing is abundant, the firm will be able to afford the cost of hiring new employees, while a lack

[16] There is a sound literature, however, on the positive impact of VC on the level of employment e.g., Lerner 1999; Davila et al. 2003; Bertoni et al. 2011; Puri and Zarutskie, 2012).

of internal financing may push the firm to lay off workers. Labor turnover has a cost for the firm and for the employee. Hiring and firing costs can be extremely significant for the company (Del Boca & Rota, 1998), and displaced workers lose their firm-specific skills as well as earnings before they find a new job or when they accept a lower-paid employment (Carrington & Zaman, 1994; Jacobson et al., 1993). Costs on both firm and employee's side are higher for high-skilled labor (Carrington & Zaman, 1994; Del Boca & Rota, 1998; Jacobson et al., 1993). High skilled employees, interested in a long-term relationship and not willing to face search and transfer costs, may be particularly attracted by firms whose employment policy is not driven by their contingent availability of cash. Accordingly, we expect the difficulty faced by young high-tech entrepreneurial companies in hiring and retaining high-skilled labor to be more severe when ECFS is more pronounced, which, according to Hypothesis 2, is the case for small companies. We thus formulate the following hypothesis:

Hypothesis 5: The improvement in the ability of attracting and retaining high-skilled labor after IVC investment is higher the smaller the firm.

3.3. METHODOLOGY

Model specification

EMPLOYMENT-CASH FLOW SENSITIVITY

In order to test whether financial market imperfections have a significant impact on employment decisions of high-tech firms and whether and how IVC investors influence this relationship (hypothesis 1, 2 and 3), we develop a model of firm's ECFS. Our baseline model is an augmented version of Benmelech et al. (2011)'s model, in which we allow ECFS to be U-shaped. The baseline model is the following:

$$\%\Delta labor_{it} = \beta_1 + \sum_{\gamma\in\Theta}\beta_{2,\gamma} CF_{it}\, d_{it}^{\gamma} + \lambda\, X_{it-1} + \theta\, y_t + \psi\, Ind_i + \omega\, Cou_i + \eta_i + \varepsilon_{it} \qquad [1]$$

The dependent variable, $\%\Delta labor_{it}$, is the annual percentage change in the amount of labor costs in year t.[17] CF_{it} is the cash flows ratio (i.e., the ratio between cash flows and total fixed assets) of firm i in year t. X_{it-1} is a vector of firm specific control variables including: the lagged values of firm's

[17] It is important to observe that we resort to a monetary measure of the human resources (i.e., annual percentage change in the amount of payroll expenses) instead of headcount growth. In fact, using headcount does not consider the heterogeneity in the skill level of the employees, which is reflected by the different wages earned (Almus & Nerlinger, 1999), and therefore is a partial measure of the total investment in human resources.

internal liquidity ratio $Liquidity_{it-1}$ (i.e., the ratio between firm cash and cash equivalents and total assets), the logarithm of the book value of total assets $Size_{it-1}$, the leverage ratio $Leverage_{it-1}$ (i.e., the ratio between total financial debt and total assets), and asset maturity $AssetMaturity_{it-1}$ (i.e., the ratio between total fixed assets and total depreciation). Investment opportunities, that in the specification used by Benmelech et al. (2011) are summarized by firm's market-to-book ratio (not suitable for our sample of non-listed companies), are captured by the intangible ratio $Intangibles_{it-1}$ (i.e., the ratio between intangible assets and total fixed assets). We also include firm's age (Age_{it}) among regressors to control for changes in employment policies throughout firm's life. Finally, all models include year, industry and country fixed-effects (y_t, Ind_i and Cou_i respectively) and a firm-level randomly distributed effect η_i. The most significant novelty that distinguishes equation [1] from Benmelech et al. (2011)'s model is that ECFS is allowed to take different values when cash flow is positive or negative, thanks to the inclusion of the interaction between cash flow and a dummy variable (d_{it}^{γ}) that indicates whether its sign is positive or negative ($\gamma \in \Theta = \{+,-\}$). This specification for the employment curve reflects the expectation that the sign of the ECFS will be positive when cash flows are positive (i.e., $\beta_{2,+} > 0$) and negative when cash flows are negative (i.e., $\beta_{2,-} < 0$), indicating a U-shaped relationship between employment and cash flows (Hypothesis 1).

We test Hypothesis 2 using two different procedures. First, we re-estimate model [1] on two subsamples obtained by splitting firm-year observations below and above the median size. According to Hypothesis 2, smaller values (in absolute terms) are expected for $\beta_{2,+}$ and $\beta_{2,-}$ in the subsample of large firms than in the subsample of small firms. Moreover, as additional check, we augment equation [1] by interacting size and cash flow as follows:

$$\%\Delta labor_{it} = \beta_1 + \Sigma_{\gamma\in\Theta} (\beta_{2,\gamma}\, CF_{it}\, d_{it}^{\gamma} + \beta_{3,\gamma}\, CF_{it}\, d_{it}^{\gamma}\, Size_{it-1}) + \lambda\, X_{it-1} + \theta\, y_t + \psi\, Ind_i + \omega\, Cou_i + \eta_i + \varepsilon_{it} \quad [2]$$

where $\beta_{3,\gamma}$, is expected to have opposite sign of $\beta_{2,\gamma}$, this indicating that financial constraints are less severe the larger the company. To the extent to which ECFS to be U-shaped (i.e., $\beta_{2,+} > 0$ and $\beta_{2,-} < 0$) we then expect $\beta_{3,+} < 0$ and $\beta_{3,+} > 0$.

To study the effect of IVC financing on firms' ECFS (Hypothesis 3), we add to equation [1] the variables related to the presence of IVC investors as follows:

$$\%\Delta labor_{it} = \delta_1 + \delta_2\, IVC_{it} + \delta_3\, A_{it} + \Sigma_{\gamma\in\Theta} (\delta_{4,\gamma}\, CF_{it}\, d_{it}^{\gamma} + \delta_{5,\gamma}\, CF_{it}\, d_{it}^{\gamma}\, IVC_{it}) + \lambda\, X_{it-1} + \theta\, y_t + \psi\, Ind_i + \omega\, Cou_i + \eta_i + \varepsilon_{it} \quad [3]$$

where IVC_{it} is a dummy variable equal to one if IVC invested in company *i* in year *t* or before. We also include the amount of the capital injection received by firm *i* in each financing round, A_{it} (i.e., the ratio between the amount of IVC financing and firms' total assets). A capital injection A_{it} increases firm's availability of internal capital and this could affect its employment decision, leading to a horizontal shift in the employment curve. The moderating role of IVC on firm's employment decisions is captured by δ_2, δ_3 and $\delta_{5,\gamma}$. In particular, $\delta_{5,\gamma}$ captures the impact of IVC on the ECFS: to the extent to which a IVC investor reduces firm's ECFS we should expect $\delta_{5,+} < 0$ and $\delta_{5,-} > 0$. Moreover, if the ECFS is not only reduced but completely removed, we should obtain that: $\delta_{4,\gamma} + \delta_{5,\gamma} = 0$ for both positive and the negative values of cash flows. Parameter δ_3 denotes a possible increase in employment rate related to financial effect of IVC (i.e., to the amount of capital received by IVC investor), while δ_2 represents instead the average increase in employment change rate observed after a firm becomes IVC-backed, net of the financial effect engendered by the amount of capital received by IVCs.

FIRM'S ABILITY TO HIRE AND RETAIN HIGH SKILLED EMPLOYEES

In order to study the impact of IVC on firm's ability to hire and retain high-skilled employees and test Hypotheses 4 and 5, we estimate the following model:

$$wage_{it} = \mu_1 + \mu_2\, IVC_{it} + \mu_3\, IVC_{it}\, Size_{it-1} + \mu_4\, A_{it} + \lambda\, Y_{it-1} + \theta\, y_t + \psi\, Ind_i + \omega\, Cou_i + \eta_i + \varepsilon_{it} \qquad [4]$$

where $wage_{it}$ is the logarithm of payroll expenses per employee registered by the firm in year t used, as customary in human capital theory, as a proxy for the fraction of high-skilled employees working for the company (Becker 1964). Control variables (represented by the vector Y_{it-1}) include firm size ($Size_{it}$), age (Age_{it}) and the intangible ratio ($Intangibles_{it}$). Moreover, the model includes year, industry, and country fixed effects as well as the cross-products of the industry and country dummies. In order to estimate the effect of IVC on the ability of firms to hire and retain high-skilled workers (Hypothesis 4) we look at μ_2: a positive and significant value would imply a positive effect of IVC on firm's ability to hire and retain skilled employees. It is worth noticing that μ_2 is net of the financial effect engendered by the capital injection by IVC, captured by the coefficient μ_4. As to the higher effect of IVC on firm's ability to hire and retain high skilled employees for small firms (Hypothesis 5), we expect the coefficient μ_3 to be negative and significant.

Lastly, we want to make sure that the effect of IVC on the ability to hire and retain high skilled employees of small firms is not only due to networking and certification, but that it is the result of the relaxation of financial constraints. In order to do so, we need to control for IVC networking and certification ability. We thus include, in an augmented version of equation [4], two variables capturing the experience of IVC investors, IVC_exp_{it}, indicating the cumulative number of investments in companies before the IVC invested in the firm *i;* and, for the industry specialization of IVC investors, IVC_spec_{it}, given by the ratio between the cumulative number of investments in companies in the same sector as firm *i* and the total cumulative number of investments of the IVC firm, before it invested in the company *i* (source: VentureXpert).

Estimation methodology

To take advantage of the panel structure of our data, we estimate Equations [1]-[4], using a GLS robust random effect estimation. To minimize the risk of misspecification, Equations [1]-[2] (aiming to test that the ECFS is U-shaped in young high-tech entrepreneurial ventures, especially the small ones), are estimated on a sample composed of all firm-year observations in which IVC is not involved (i.e., all observations of non IVC-backed firms and all years before the IVC investment for IVC-backed firms). Equations [3]-[4] (aiming to test the impact of IVC on the ECFS of invested firms and on their ability to hire and retain high skilled human capital) are estimated on all available firm-year observations.

Endogeneity is an obvious issue in this context, since IVC-backed and non-IVC-backed firms may be characterized by unobservable differences that the random effect estimation fails to control. We address this issue in two ways. First, we implement a direct test to check the presence of sorting in the spirit of Wooldridge (1995) and Semykina and Wooldridge (2010). The procedure, essentially, requires the estimation of a selection equation for IVC financing. In particular, we estimate a probit model in which the dependent variable is the probability of receiving IVC and independent variables include firms characteristics in the year before as age, size, number of granted patents ($Patents_{it}$), intangibles ratio and cash flow ratio. Other controls at macro-level are included such as country and industry dummies, the average wage by country and industry for non-IVC-backed firms and an additional variable, $IVC\_fundraising_{it}$, which reflects the fundraising of IVC funds in year *t* in Europe (source: VentureXpert). An inverse Mills ratio is computed from this selection equation for each firm-year observation (IMR_{it}). This time-varying ratio is then inserted as an additional covariate in our models, which are estimated via GLS robust random effects. A significant coefficient of IMR_{it} variable would indicate that unobservable firm characteristics affect firm growth and the likelihood that a firm receives IVC financing, requiring then to control for endogeneity.

Second, we explicitly control for the endogeneity of IVC by implementing a Hausman and Taylor (1981) estimation. This approach is an extension of a random-effects estimator in which some of the covariates are allowed to be correlated with the unobserved individual-level random effect η in equations [3]-[4]. In particular we instrument all the variables related to the presence of IVC (and their interactions).

Finally, as is customary in this type of analysis, some transformations have to be performed for the accounting ratio before a meaningful parametric model can be estimated. All of the variables included in the Equations [1]-[4] are normalized by the beginning-of-period-t stock of total assets. Because firms in our sample are relatively young and small, this value is sometimes close to zero, producing extremely skewed and leptokurtic distributions of the variables. The presence of these outliers could severely bias our results. To avoid this problem, we winsorize all of the variables with a 1% cut-off for each tail (Dixon, 1960). In other words, for each variable we calculated the values corresponding to the 1st and 99th percentiles of the variable's distribution and assigned these values to all of the observations that fall beyond them. This approach is useful because it reduces the impact of outliers, without the loss of observations than would occur if outliers were deleted. Furthermore, it has been extensively in the literature on ICFS (Bertoni et al., 2010; Cleary, 1999, 2006).

3.4. SAMPLE AND DESCRIPTIVE STATISTICS

Sample characteristics and distribution

In this work we rely upon a sample of European high-tech companies extracted from the VICO database.[18]

We extract our sample from the VICO database following a series of exclusion rules. First, we include only VC-backed companies invested by an independent VC or a syndicate led by an independent VC, thus excluding firms backed by captive VC investors (e.g., bank-affiliated VC, corporate VC, and governmental VC). The rationale for excluding these firms is that we want to investigate the role of VC in its most significant form (i.e., independent VC), without having to deal

[18] See again the Appendix.

with the heterogeneity of different types of VC investor. The differences between independent and captive VC investors, which are likely to be significant, are outside the scope of the present work. Second, we exclude all companies that do not have a complete record of information for being included in this study.[19]

Restricting the VICO dataset according to these criteria we obtain a sample of 4,681 companies, 233 of which are VC-backed, for a total of 27,476 firm-year observations. Table 3.1 reports the distribution of sample firms across countries, industries, and foundation periods.

Table 3.1. Sample distribution by country, industry and foundation year

	Total		***VC-backed***		***Non-VC-backed***	
	N	***%***	***N***	***%***	***N***	***%***
Country						
Belgium	693	14.80%	34	14.59%	659	14.82%
Finland	537	11.47%	33	14.16%	504	11.33%
France	1313	28.05%	36	15.45%	1277	28.71%
Italy	657	14.04%	32	13.73%	625	14.05%
Spain	622	13.29%	32	13.73%	590	13.26%
UK	859	18.35%	66	28.33%	793	17.83%
Total	*4,681*	*100.00%*	*233*	*100.00%*	*4,448*	*100.00%*
Industry						
Internet	556	11.88%	46	19.74%	510	11.47%
TLC services	249	5.32%	14	6.01%	235	5.28%
Software	2028	43.32%	88	37.77%	1940	43.62%
ICT manufacturing	869	18.56%	46	19.74%	823	18.50%
Biotech and Pharmaceutical	379	8.10%	30	12.88%	349	7.85%
Other high-tech manufacturing	317	6.77%	4	1.72%	313	7.04%
Other high-tech services	283	6.05%	5	2.15%	278	6.25%
Total	*4,681*	*100.00%*	*233*	*100.00%*	*4,448*	*100.00%*
Foundation period						
Before 1995	1758	37.56%	48	20.60%	1710	38.44%
1995-1999	1477	31.55%	113	48.50%	1364	30.67%
2000-2004	1446	30.89%	72	30.90%	1374	30.89%
Total	*4,681*	*100.00%*	*233*	*100.00%*	*4,448*	*100.00%*

[19] This determines the exclusion of all German companies from the sample since in Germany only large companies are mandated to deposit detailed accounts at Chambers of Commerce.

Descriptive statistics

Some interesting insights on the characteristics of VC investments in our sample can be gained by looking at descriptive statistics in Table 3.2.

Table 3.2. Descriptive statistics of the variables included in regression models

	Whole sample				*IVC backed*	*Non-IVC backed*	*Diff.* *IVC vs non IVC backed*	
Variable	*Obs.*	*Mean*	*Median*	*Std.dev.*	*Mean*	*Mean*	*Mean*	
$\%\Delta labor_{it}$	27,476	0.227	0.062	0.856	0.362	0.221	0.141	***
CF_{it}	27,476	1.181	0.457	6.727	-1.897	1.323	-3.220	***
$Liquidity_{it-1}$	27,476	0.194	0.122	0.204	0.231	0.193	0.038	***
$Leverage_{it-1}$	27,476	0.178	0.070	0.290	0.277	0.173	0.104	***
$AssetMaturity_{it-1}$	27,476	5.743	3.067	8.640	4.936	5.780	-0.844	***
$Intangibles_{it-1}$	27,476	0.311	0.116	0.362	0.441	0.305	0.136	***
$wage_{it}$	22,719	3.765	3.791	0.584	3.944	3.750	0.194	***
$Size_{it-1}$	27,476	7.053	6.895	1.845	8.008	7.009	0.999	***
Age_{it}	27,476	9.663	9.000	5.432	7.659	9.756	-2.096	***
IVC_exp_{it}	375	3.212	2.772	1.947	3.212	-		
IVC_spec_{it}	375	0.164	0,074	0.221	0.164	-		
A_{it}	239	1.185	0.515	2.161	1.185	-		

Note: Mean values of the variables included in equations [1]- [4]. The variables definition is reported in Section 3.1. The variables are winsorized at the 1% threshold. All monetary amounts are deflated using the country-level Consumer Price Index. Statistics on IVC_exp_{it} and IVC_spec_{it} only refer to VC-backed firms. Statistics on A_{it} only refer to the observations corresponding to IVC financing rounds on invested firms.

As expected, companies in our sample are fast-growing, with mean employment growth rate, $\%\Delta labor_{it}$, of 22.7% (median 6.2%). As a matter of comparison, mean employment growth is reported by Benmelech et al. (2011) to be 6.0% in a sample of Compustat firms (median 1.7%). The mean cash flow rate is 1.181 (median 0.457), which is in line with what observed in studies about ICFS in samples of high tech entrepreneurial ventures. For instance, Bertoni et al. (2010) report, on a sample of Italian high tech entrepreneurial ventures, a mean cash flow rate of 1.231 (median 0.465).

It is also interesting to observe how employment growth and cash flows differ between IVC-backed and non-IVC-backed firms. Employment in non-IVC-backed firms in our sample grows at 22.1%, which is still substantial but significantly lower than the 36.19% rate growth observed in IVC-backed firms. This is consistent with evidence in the literature about IVC-backed firms outperforming non-IVC-backed ones in terms of growth (Bertoni et al., 2011; Davila et al., 2003). This superior growth is not associated to a superior ability to generate internal financing: the cash flow ratio in IVC-backed firms is significantly lower than in non-IVC-backed firms (-1.89 vs. 1.32). IVC-backed companies invest more in human capital, but this is not because they have an easier access to internal financing.

It is useful, here, to give some preliminary descriptions of the shape of the employment curve. In Table 3.3, corresponding to each decile of cash flow rate, we compute the average employment growth. The employment growth rate reaches a minimum when cash flows are closest to zero (third decile). When cash flows are negative, the investment rate appears to increase the lower cash flows are. When cash flows are positive, investment increases with cash flows. Accordingly, this preliminary evidence seems to support Hypothesis 1, in showing that the employment curve is indeed U-shaped.

Table 3.3. Descriptive evidence on the U-shape of the employment strategies curve

CF decile	*Mean CF*	*Mean %Δlabor*
1	-8.171	42.34%
2	-0.465	16.45%
3	0.066	11.63%
4	0.220	14.61%
5	0.369	16.47%
6	0.567	18.45%
7	0.870	22.27%
8	1.443	24.15%
9	2.975	28.25%
10	13.944	32.19%
Total	*1.181*	*22.68%*

3.5. RESULTS

The first column of Table 3.4 reports the estimates of equation [1] performed on a sample including non-IVC-backed firms and IVC-backed firms that have not yet received IVC (i.e. excluding IVC-backed firms after they receive IVC). The results we obtain with respect to control variables, closely mirror those obtained by Benmelech et al. (2011). Employment growth is positively related to investment opportunities (captured by the intangible ratio) and asset maturity, and negatively related to firm size. Moreover, we find that growth is influenced positively by liquidity and negatively by leverage.

Table 3.4. Estimates of employment cash flow sensitivity in high tech entrepreneurial ventures

		Equation [1]		***Equation [2]***		***Equation [1] Small firms only***		***Equation [1] Large firms only***	
β_1	Const.	0.855	***	0.769	***	1.043	***	0.621	***
		(0.064)		(0.065)		(0.119)		(0.088)	
$\beta_{2,+}$	$CF_{it}\, d_{it}^{+}$	0.012	***	0.028	***	0.015	***	0.006	***
		(0.002)		(0.007)		(0.003)		(0.001)	
$\beta_{2,-}$	$CF_{it}\, d_{it}^{-}$	-0.021	***	-0.047	***	-0.024	***	-0.017	***
		(0.003)		(0.012)		(0.006)		(0.003)	
$\beta_{3,+}$	$CF_{it}\, d_{it}^{+} size_{it}$			-0.003	***				
				(0.001)					
$\beta_{3,-}$	$CF_{it}\, d_{it}^{+} size_{it}$			0.003	***				
				(0.001)					
λ_1	$Liquidity_{it-1}$	0.258	***	0.259	***	0.299	***	0.199	***
		(0.047)		(0.047)		(0.073)		(0.052)	
λ_2	$Leverage_{it-1}$	-0.175	***	-0.181	***	-0.184	***	-0.162	***
		(0.034)		(0.035)		(0.054)		(0.032)	
λ_3	$AssetMaturity_{it-1}$	0.016	***	0.016	***	0.015	***	0.015	***
		(0.001)		(0.001)		(0.002)		(0.002)	
λ_4	$Intangibles_{it-1}$	0.083	***	0.084	***	0.149	***	0.035	
		(0.024)		(0.024)		(0.041)		(0.024)	
λ_5	$Size_{it-1}$	-0.074	***	-0.064	***	-0.141	***	-0.043	***
		(0.006)		(0.006)		(0.018)		(0.008)	
λ_6	Age_{it}	-0.032	***	-0.033	***	-0.042	***	-0.023	***
		(0.001)		(0.001)		(0.002)		(0.002)	
	N° observations	26,266		26,266		13,133		13,133	
	N° firms	4,503		4,503		3,040		2,391	
	χ^2	930.24 (21)	***	937.02 (23)	***	497.67 (21)	***	481.67 (21)	***

Legend: * p<0.1; ** p<0.5; *** p<0.01. Robust standard errors in parentheses. Year, industry and country dummies are included in the estimates but not reported in the table.

Moving to cash flows, we find robust confirmation about the U-shape of the employment rate curve. For non-IVC-backed firms, the coefficient associated with cash flow is negative and significant when the firm has negative cash flows and positive and significant when the firm has positive cash flows. The magnitude of the coefficient implies that, other things being equal, a one standard deviation increase in internal funds is associated with a -14.1% change in employment in the region with negative cash flows. Conversely, ECFS is positive in the region with positive cash flow: other things being equal, a one standard deviation increase in internal funds is associated with an 8.1% increase in employment. The U-shape of the employment curve confirms that the theoretical framework developed by Cleary et al. (2007) with respect to ICFS, is valid also when analyzing ECFS. Accordingly, Hypothesis 1 is supported.

Table 3.4 also reports estimates to empirically test Hypothesis 2. Estimates of equation [2], performed on the same sample used for equation [1], are reported in the second column of Table 3.4. Results confirm that ECFS is stronger for smaller firms. The coefficients of the interaction of size and cash flows in the two regions ($\delta_{5,\gamma}$ in equation [2]), have opposite signs to that of the corresponding coefficient of cash flow ($\delta_{4,\gamma}$ in equation [2]). In other words, the larger the firm the less steep is its U-shaped employment curve. This result is confirmed when we estimate equation [1] in the two subsamples of small and large firms (results are reported in columns III and IV of Table 3.4, respectively): the magnitude of the coefficients of cash flow ratio in small firms is higher than those found for large firms. A shock in cash flows still translates in an increase in employment when cash flows are positive and in a decrease in employment when cash flows are negative, but the ECFS is weaker for large firms both when cash flows are positive and when they are negative. Accordingly, we may conclude that Hypothesis 2 is supported.

The validation of Hypotheses 1 and 2 supports the theoretical model that underpins our empirical strategy. We may then proceed to estimate equation [3] on the full sample to test whether IVC is indeed effective in reducing ECFS (Hypothesis 3). Table 3.5 reports results of equation [3] obtained using different estimation procedures. The first column reports estimates of a random effects model, in which no control for endogeneity is included. We test and control for endogeneity in the second and third columns by augmenting the specification by including an IMR and using a Haussmann-Taylor procedure, respectively. Again, the coefficients of all control variables in Table 3.5 (liquidity, leverage, asset maturity, intangible assets, age, and size) have the expected signs, are statistically significant, and exhibit a remarkably consistent magnitude across estimates.

Table 3.5. The impact of idependent venture capital on employment cash flow sensitivity

Panel A: Estimate results

		Equation [3] Random effects		Equation [3] Random effects & IMR		Equation [3] Haussmann-Taylor	
δ_1	*Const.*	0.828	***	0.665	***	1.101	***
		(0.062)		(0.066)		(0.076)	
δ_2	IVC_{it}	0.030		0.081		-0.155	*
		(0.055)		(0.058)		(0.082)	
δ_3	A_{it}	0.103	*	0.090		0.107	***
		(0.061)		(0.062)		(0.023)	
$\delta_{4,+}$	$CF_{it}\, d_{it}^{+}$	0.012	***	0.012	***	0.012	***
		(0.002)		(0.002)		(0.001)	
$\delta_{4,-}$	$CF_{it}\, d_{it}^{-}$	-0.021	***	-0.027	***	-0.021	***
		(0.003)		(0.004)		(0.002)	
$\delta_{5,+}$	$CF_{it}\, d_{it}^{+}\, IVC_{it}$	-0.011	**	-0.008	*	-0.010	
		(0.005)		(0.007)		(0.007)	
$\delta_{5,-.}$	$CF_{it}\, d_{it}^{-}\, IVC_{it}$	-0.001		-0.007		-0.007	
		(0.008)		(0.009)		(0.005)	
δ_6	*IMR*			-0.867	***		
				(0.059)			
λ_1	$Liquidity_{it-1}$	0.302	***	0.289	***	0.289	***
		(0.046)		(0.048)		(0.034)	
λ_2	$Leverage_{it-1}$	-0.176	***	-0.156	***	-0.203	***
		(0.031)		(0.033)		(0.023)	
λ_3	$AssetMaturity_{it-1}$	0.017	***	0.017	***	0.017	***
		(0.001)		(0.002)		(0.001)	
λ_4	$Intangibles_{it-1}$	0.080	***	0.151	***	0.069	***
		(0.023)		(0.026)		(0.021)	
λ_5	$Size_{it-1}$	-0.075	***	-0.030	***	-0.099	***
		(0.006)		(0.007)		(0.006)	
λ_6	Age_{it}	-0.032	***	-0.041	***	-0.033	***
		(0.001)		(0.002)		(0.002)	
	N° observations	27,476		24,618		27,476	
	N° firms	4,681		4,613		4,681	
	χ^2	1,027.32 (25)	***	1,066.60 (26)	***	2,517.31 (27)	***

Legend: * p<0.1; ** p<0.5; *** p<0.01. Robust standard errors in parentheses. Year, industry and country dummies are included in the estimates but not reported in the table.

Table 3.5. The impact of venture capital on employment cash flow sensitivity (cont.)

Panel B. Employment cash flow sensitivity for VC-backed and non-VC-backed firms

	Equation [3] ***Random effects***		***Equation [3]*** ***Random effects & IMR***		***Equation [3]*** ***Haussmann-Taylor***	
Employment cash flow sensitivity in VC-backed firms						
H0: $\delta_{4,+} + \delta_{5,+} = 0$	0.001		0.004		0.002	
	(0.004)		(0.007)		(0.007)	
H0: $\delta_{4,-} + \delta_{5,-} = 0$	-0.021	***	-0.034	***	-0.028	***
	(0.008)		(0.008)		(0.005)	

Legend: * p<0.1; ** p<0.5; *** p<0.01. Robust standard errors in parentheses.

Coefficients connected to cash flows are once again positive when cash flows are positive and negative when cash flows are negative. The most interesting part of Table 3.5 lies in the variables added in the regression to control for the effect of IVC. To have a better understanding of the impact of IVC on ECFS we report in Panel B of Table 3.5 the linear combination of cash flows coefficients and their interaction with IVC in the two regions of the U-curve. Panel B shows that, for IVC-backed firms, ECFS disappears when cash flows are positive ($d_{it}^{+} = 1$), but not when cash flows are negative ($d_{it}^{-} = 1$). When firm experiences a shock in cash flows, no significant impact on employment is observed in a IVC-backed company if cash flows are positive. If cash flows are negative, however, the presence of IVC seems to make little difference for firm's ECFS. This result, that is consistent across the three estimation methods, gives only partial support to Hypothesis 3. In order to interpret this result, we have to go back to the origin of the negative slope of ECFS when cash flows are negative. Ultimately, the slope of the employment curve in that region is dominated by the minimization of the expected loss from bankruptcy, which is due to the loss in case of liquidation (equal to the wedge between the liquidation value of assets and their continuation value) and to the likelihood of bankruptcy. IVC could increase, on average, the expected cost of bankruptcy, for instance because it could favor more risky and intangible investments. This could explain why IVC fails to relieve firm's ECFS when cash flows are negative.

Turning now to the differences between the three estimation procedures in Table 3.5, we notice that the coefficient of IMR_{it} in the second column is statistically significant. This means that we can reject, at customary confidence levels, the assumption that the receipt of IVC is an exogenous event. The negative sign of IMR suggests that unobservable firm characteristics that positively affect firm growth, negatively affect the likelihood that the firm do not receive ("survive") IVC financing. Put differently, the firms that, due to unobservable characteristics, are the most likely to exhibit significant growth are also those that are most likely to obtain IVC financing. Controlling for IVC endogeneity, as we do in the third column, is then imperative. Consistently with the observed sign of IMR, once we control for endogeneity, the estimated impact of IVC on firm growth is substantially lower: the slope of the impact of the amount invested (A_{it}) is nearly unaltered, but the intercept (coefficient of IVC_{it}) is lower (from 0.03 in the first column to -0.155 in the third one). Interestingly, the control for endogeneity does not affect the results on the impact of IVC on ECFS, suggesting that our findings are robust.

Finally, let us turn our attention to the analysis of the impact of IVC on firm's ability to hire and retain high-skilled employees. Estimates of equation [4] are reported in Table 3.6. The first column of Table 3.6 reports random effect estimates without controls for endogeneity. The second and the third columns of Table 3.6 report estimates of equation [4] in which endogeneity is tested and controlled for by using an IMR and the Haussmann-Taylor procedure, respectively. Again, the significance of the coefficient of IMR_{it} variable can be interpreted as an indication of the endogeneity of IVC and the necessity to control for it. In the last column of Table 3.6, we report the estimates of an augmented version of equation [4] in which we add two different measures of IVC experience. Regardless of the model, results indicate a positive and significant effect of IVC on the ability to attract and retain high-skilled labor, as testified by the significant increase in the average wage of employees. This results support Hypothesis 4. Moreover, the interaction between IVC and firm size is negative, suggesting that the impact of IVC on firm's ability to hire and retain high-skilled employees is higher the smaller is the firm (i.e., the most pronounced is its ECFS). This gives support to Hypothesis 5. Finally, it is worth noticing that the coefficients of both IVC_exp_{it} and IVC_spec_{it} are positive and significant, suggesting that both IVC experience and specialization have a positive effect on the IVC impact of firm's ability to hire and retain high skilled employees. However, even after controlling for IVC experience, Hypothesis 5 is still confirmed: the higher effect of IVC on the ability of hiring high skilled employees of small firms is not due to higher abilities of IVC to certify the quality of small firm towards the labor market or to provide a network of knowledge (captured by IVC experience and industry specialization), but is a direct effect of the reduction of ECFS, that, as we showed, is higher for small firms.

As to control variables, larger firms with more tangible assets have a higher ability to attract and retain high-skilled workers.

Table 3.6. Estimates of the impact of independent venture capiutal on wage

		Equation [4] Random effects		***Equation [4] Random effects & IMR***		***Equation [4] Haussmann-Taylor***		***Equation [4] Control for IVC experience***	
μ_1	*Const.*	2.073	***	2.119	***	1.890	***	2.051	***
		(0.142)		(0.133)		(0.244)		(0.144)	
μ_2	IVC_{it}	0.463	***	0.379	**	0.540	***	0.510	**
		(0.146)		(0.162)		(0.113)		(0.235)	
μ_3	A_{it}	0.001		0.008		-0.004		0.044	***
		(0.008)		(0.008)		(0.012)		(0.014)	
μ_4	$IVC_{it}\, size_{it}$	-0.045	**	-0.036	*	-0.063	***	-0.057	**
		(0.018)		(0.020)		(0.013)		(0.025)	
μ_5	IMR_{it}			0.059	***				
				(0.027)					
μ_6	IVC_exp_{it}							0.044	*
								(0.024)	
μ_7	IVC_spec_{it}							0.322	**
								(0.149)	
λ_1	$Size_{it}$	0.154	***	0.153	***	0.152	***	0.155	***
		(0.006)		(0.006)		(0.003)		(0.006)	
λ_2	$Intangibles_{it-1}$	-0.045	***	-0.035	**	-0.048	***	-0.045	***
		(0.016)		(0.018)		(0.011)		(0.017)	
λ_3	Age_{it}	-0.002	*	-0.001		-0.003	*	-0.002	
		(0.001)		(0.002)		(0.002)		(0.001)	
	N° observations	31,126		27,079		31,126		30,003	
	N° firms	4,545		4,423		4,545		4,382	
	χ^2 (dof)	2,915.30 (64)	***	2,691.60 (62)	***	5,244.95 (64)	***	1,9742.9 (66)	***

Legend: * p<0.1; ** p<0.5; *** p<0.01. Robust standard errors in parentheses. Year, industry, country dummies and their interactions are included in the estimates but not reported in the table.

3.6. CONCLUSIONS

Financial constraints have been thoughtfully studied with respect to their impact on firm's investments, but their impact on the employment policies of high tech entrepreneurial ventures is still under-researched. We contribute with this work to fill this gap. First, we confirm previous findings that firm's employment is sensitive to cash flows. However, we highlight that ECFS is more subtle than normally assumed by the extant literature. Depending on firm's ability to generate internal financing, ECFS can be positive or negative. Second, we show that IVC may relax firm's ECFS, even though this only occurs for companies whose ECFS is positive. The companies for which liquidation concerns are material, still exhibit a negative ECFS after receiving IVC. This can be interpreted as the result of an increase in the risk profile or intangibility of firm's investments driven by the presence of IVC. Finally, we find that IVC does improve the ability of high tech entrepreneurial ventures to attract and retain high-skilled labor, especially when ECFS is strongest. This suggests that ECFS may be a factor that deters high-skilled employees from working for high tech entrepreneurial ventures.

Our findings may be relevant for several categories of stakeholders. First, to entrepreneurs who may appreciate how IVC can add value to their companies by stabilizing their employment growth path, saving labor turnover costs, and facilitating the attraction and retention of high-skilled workers. At the same time, these benefits seem to fully accrue only to companies that are able to generate positive cash flows. The employment policies of IVC-backed companies close to financial distress instead do not seem to be any more stable than that of non-VC-backed company. Our results can also be of interest for policymakers. With this work, we aim at contributing to the debate on the influence of financial distress on firm's operating decisions in real terms (Benmelech et al., 2011; Hristov, 2009; Pagano & Pica, 2012), which has strong policy implications, especially in the European context. In particular, Acemoglu (2001) argues that credit market frictions may be an important contributor to high unemployment in Europe. Wasmer and Weil (2004) demonstrate that credit and labor market restrictions can interact, explaining pronounced differences in the dynamics between of employment in Europe and the USA. By taking a microeconomic perspective and studying the relationship between financial constraints and firms' employment policies in Europe, we hope to contribute to this relevant debate. Moreover, we show that financial constraints make the creation of high-skilled labor particularly difficult for high tech entrepreneurial ventures. This is particularly relevant from the perspective of policymakers, since these companies are often seen as an important driver of "smart growth". Finally, our work stresses, once more, that IVC plays an important role in knowledge-based economies and, by stabilizing the employment policy of high tech entrepreneurial ventures, making their growth "smarter". However, the abovementioned limits of IVC to fulfill this task deserve attention by policymakers, suggesting the development of specific policy improving, for instance, the effectiveness of the regulation on liquidation and restructuring for small companies.

4. Does Governmental venture capital certify European high tech entrepreneurial ventures to private venture capital investors?

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4.1. INTRODUCTION

Venture capital in the USA has been extremely beneficial to the creation and development of a number of entrepreneurial ventures that in few years grew and employed thousands of people (Apple, Genentech, Microsoft and Intel are some of the most illustrative examples). Nevertheless, venture capitalists invest only in a tiny fraction of firms that apply for a funding. This holds especially true in Europe, where high-tech entrepreneurial ventures finance new investments by relying primarily on internal funds (for a recent review of the liteature see, e.g., Revest & Sapio, 2010). As the results of Chapter 2 confirm, the risk-averse mentality of European venture capital investors make them particularly likely to shy away from firms affected by stronger information asymmetries, such as the ones in their early stage of development or operating in high-risk industries (Aernoudt, 1999). It is thus not surprising that the European venture capital market is not well developed yet. According to Kelly (2011), Europe's investment as a share of GDP is only 25% of that of the US. Therefore, it is likely that a great number of European entrepreneurial ventures remain financially constrained, generating a market failure.

The creation of an active venture capital market has become a priority in the agenda of European policymakers (Da Rin, Nicodano, & Sembenelli, 2006; European Commission, 1998). To this aim, in recent years many governments in Europe have established Governmental Venture Capital (GVC) programs in order to energize Private Venture Capital (PVC) markets. According to the certification hypothesis (Lerner 2002), GVC investors can enhance high-tech entrepreneurial ventures' access to PVC financing by reducing the information asymmetries surrounding them.

In this chapter we investigate whether obtaining GVC facilitates high-tech entrepreneurial ventures' subsequent access to PVC, thanks to a certification effect. PVC encompasses independent VC (IVC) or VC affiliated to a private institution, such as a company (CVC) or a bank (BVC). [20] In particular, we discuss and offer empirical evidence on the following two research questions: *does the receipt of GVC increase the likelihood that a high-tech entrepreneurial venture attracts PVC, thanks to a certification effect? Are PVC investments in firms certified by GVC at least as successful as other PVC investments?* To answer the first research question, we evaluate whether GVC-backed firms have a higher probability of receiving a first round of PVC investment than a matched sample of non GVC-backed firms. To answer to the second research question, we assess whether PVC

[20] Considering whether the certification of GVC is more effective towards independent, corporate or bank affiliated venture capital is for sure interesting but goes beyond the scope of the present chapter. However, performing this kind of analysis is in our research agenda.

investments in firms certified by GVC are as least as successful as other PVC investments in terms of reaching the second PVC round of financing or ending with a successful exit (see Hochberg et al. 2007, for a similar approach).

The empirical analysis is conducted using a unique firm-level longitudinal sample of 986 high-tech entrepreneurial ventures, extracted from the VICO database. The VICO database has been developed within an international project, sponsored by the European Union under the 7° Framework Program. The sample is constructed using a propensity score matching technique, in which 189 European GVC-backed high-tech entrepreneurial ventures are matched with 797 firms that have not received GVC. Using a Cox proportional hazard model we estimate the firms' hazard rates of receiving a first PVC round, and, for PVC-backed firms, the hazard rates of receiving a second PVC round and of achieving a successful PVC exit.

We are confident that our work significantly advances our comprehension on the effectiveness of GVC programs in Europe. First, studies at the macro level have investigated whether governmental interventions have increased the aggregate pool of PVC investments or whether they crowded out PVC investors, finding mixed evidence (Armour & Cumming, 2006; Cumming & MacIntosh, 2006; del-Palacio, Zhang, & Sole, 2012; Jeng & Wells, 2000; Leleux & Surlemont, 2003). However, the macro level unit of analysis does not allow to properly assessing the mechanisms through which GVC affects the aggregate pool of PVC investments. By investigating whether the presence of GVC is associated with an increased likelihood of receiving PVC at the firm level, we therefore provide new empirical evidence on the micro foundations that could explain macro level dynamics. Second, at micro level a number of papers focused on the certification effect of government subsidies towards PVC (Feldman & Kelley, 2006; Lerner, 1999) or external financing in general (Meuleman & De Maeseneire, 2012). Some works provide evidence on the effectiveness of GVC using micro level data, (e.g. Cumming, 2007; Cumming & Johan, 2009). However, few studies have explicitly tested whether the receipt of GVC increases the likelihood of obtaining PVC (Brander, Du, et al., 2010; Brander, Egan, et al., 2010; Munari & Toschi, 2011). Moreover, these studies are based on samples composed exclusively of venture capital-backed firms. In evaluating the certification effect of GVC, we need to know instead whether the firm that received GVC (the "treatment") would have attracted PVC had it not received GVC (Lach, 2002). In our work, we use as a counterfactual a matched sample of non-GVC backed firms. This allows assessing the treatment effect of GVC certification on the probability of receiving PVC.

Our results show that receipt of GVC increases firms' likelihood of receiving a PVC investment. The effect does not depend on the financial resources provided by GVC to the firm. Second, GVC makes the window in which a firm is attractive to PVC longer. Third, PVC is more likely to invest in a second round of financing and to achieve a successful exit if the investment was originated by the GVC certification. Results are robust to alternative estimation methodologies and other possible explanations. These results support the view that GVC positively influences the development of PVC market in Europe, by increasing the number of successful PVC investments in high tech entrepreneurial ventures.

The structure of the chapter is as follows. In the next section, we review the literature on the role of government intervention in the venture capital market and the certification hypothesis. Sections 4.3 describe the research framework we use in order to evaluate the effectiveness of GVC in certifying high-tech entrepreneurial ventures to PVC investors. Section 4.4 describes the data and the methodology used. Section 4.5 reports the results of the econometric estimates, some robustness checks and some relevant additional evidence. Section 4.6 concludes the chapter.

4.2. GOVERNMENT INTERVENTION IN THE PVC MARKET AND THE CERTIFICATION HYPOTHESIS

Even though PVC investors should be more able to deal with information asymmetries with respect to traditional financial intermediaries (see, e.g. Gorman & Sahlman, 1989; Sahlman, 1990; Lerner, 1995; Denis, 2004; Gompers & Lerner, 2001a), they proved to be highly selective in providing financing. First, there is wide evidence that PVC investors tend to avoid investing in very early stage companies, which have high levels of risks and significant information asymmetries (Kelly, 2011; Lockett et al., 2002; Mason & Harrison, 1997; Murray & Lott, 1995). Second, Lerner (2002) stresses that PVC investors are affected by an “herding” attitude, typical of institutional investors (Devenow & Welch, 1996), and are concentrated on a few industries with the highest growth potential, such as ICT and healthcare. Chapter 2 of this thesis confirms this proposition in the case of Europe, finding that European PVC are specialized in industries such as Internet and TLC services and abstain from investing in R&D and engineering services (especially independent venture capital) and biotech and pharmaceutics (especially corporate venture capital). Third, there is a high degree of spatial concentration of venture capital activity, both in terms of firms and investments, in core regions at the expense of peripheral, economically lagging, regions (Harrison & Mason, 1992; Sunley, Klagge, Berndt, & Martin, 2005). As a result, it is likely that an “equity gap” still remains for a great number of European high potential high-tech entrepreneurial ventures in early stages of development and operating in unappealing industries or geographic areas. The existence of a “market failure” in the financing of high-tech entrepreneurial ventures is the main rationale for the government intervention in the PVC market.

Government intervention can solve the market failure in two ways. On the one hand, governments can stimulate PVC markets, since they define the legal and fiscal environment in which PVC investors operate. In particular, capital gains taxes are widely recognized as being one of the most important legal instruments for stimulating PVC markets (e.g. Keuschnigg and Nielsen 2004; La Porta et al. 1997; Keuschnigg and Nielsen 2001; Armour and Cumming 2006). On the other hand, governments may directly invest in high potential financially constrained firms, by funding and managing their own GVC funds (e.g. Lerner 1999; Cumming 2007). By investing in high potential firms not attractive to PVC investors, GVC investors may alleviate their financial constraints, and have a positive effect on their investments and growth.

However, the extent to which GVC alone could solve the equity gap problem is limited by the relative low amount of resources that usually is available to these programs (Lerner, 1999). Moreover, GVC managers are often governmental employees and lack of the experience and skills necessary to provide value-adding activities, beside the money, to the target firm. The value-adding activities, such as professionalization, networking and monitoring, are on the contrary typical of PVC investments (Gorman & Sahlman, 1989; Sahlman, 1990; Tyebjee & Bruno, 1984).[21]

Therefore, it is important for GVC investors to attract and partner with PVC investors, which can provide to the target firms the managing competence and experience that they need. The certification of high-potential financially constrained firms towards PVC investors is one of the rationales of government intervention in the PVC market. Lerner (2002, p. F77) theorizes on the *certification hypothesis* in the case of the SBIR programs, a form of governmental subsidy broadly used in the USA to finance the R&D of small businesses. According to the certification hypothesis, the government can put a *stamp of approval* on its portfolio high-tech entrepreneurial ventures and certify their potential to outside investors. If PVC investors believe in the credibility of the certifying body, they can rely on this *stamp of approval* to overcome the information asymmetries surrounding the firm, and confidently invest in it. The certification of governmental bodies can have positive effects in the PVC market in both the amount of funding raised privately, and in the

[21] Literature has indeed shown that, with respect to PVC, GVC investors provide less value-enhancing services to portfolio companies (Cumming & MacIntosh 2006; Schilder 2006; Schäfer & Schilder 2006; Tykvovà 2006; T. Luukkonen et al. 2011; Brander, Du, et al. 2010; see Cumming 2007 for an exception).

distribution of firms backed over industries and stages (Lerner, 1999; Lerner 2002, Cumming 2007). [22]

Nevertheless, the extant literature raised some doubts on the ability of GVC programs to correctly certify the quality of high-tech entrepreneurial ventures to outside investors. First, the public finance literature has emphasized that government officials may frequently correspond to political interests (e.g. foster relationships between several political parties) rather than general and social ones (Becker, 1983; Peltzman, 1976). For this reason, some distortions in the firm's selection process and in the management of the GVC fund may interfere with the certification of the target firm. For instance, GVC investors may be willing to invest in firms based on their likelihood of success, regardless of whether government funds are needed (Wallsten, 2000). In this case, thanks to the below-market cost of capital offered by GVC investors, they would have the possibility of choosing the firms with the best projects on the market, leaving to existing PVCs only the "lemons" and making the entry of new PVC investors more difficult (Gilson, 2002; Lerner, 2002). Lerner (1999, 2002), Cressy (2002), Leleux and Surlemont (2003) and Cumming and MacIntosh (2006, 2007), among others, discuss the appropriate role of governments in PVC markets and consistently argue that government programs ought to complement, and not compete with, PVC investments. Otherwise, direct state intervention would be counterproductive and not only would not help to fill the equity gap left by PVC (Engel & Heger, 2006), but would also "crowd out" PVC investors (Gilson, 2002; Leleux & Surlemont, 2003). Second, another necessary condition for the certification hypothesis to hold is that GVC has credibility as a certifying body. PVC investors will believe in the certification credibility of GVC only if they think that GVC is able to screen the market and select high potential firms. Nevertheless, GVC investments are addressed to firms operating in industries and stages of development that are not appealing for PVC investors. As these industries and stages are characterized by higher information asymmetries, "picking winner" is particular difficult (Baum & Silverman, 2004). Moreover, the GVC certification effect is based on the assumption that "government's assessments are independent, educated and technically sophisticated" (Meuleman & De Maeseneire 2012, p 581). This assumption is unlikely to hold for GVC managers, which typically do not have the necessary skills and investment experience and whose behavior is affected by incentives not directly linked with the investment performance (Armour & Cumming, 2006; Leleux & Surlemont, 2003).

[22] The certification of high-tech firms to outside investors is not the only rationale for the governmental intervention in the venture capital markets. For instance, GVC programs may encourage also technological spillovers (Lerner, 2002).

However, other authors assess that the assumption that GVC are able to screen the market at least as PVC investors are, and to select high potential firms in the more risky industries is “not implausible” (Lerner, 2002, p. F78). GVC investors can have special information sources, on the base of which they can make good investment decisions (Lerner 1999, p. 293). Cumming (2007) finds that the Australian IIF program better screens the market than other forms of venture capital. In Luukkonen et al. (2011) paper based on a survey of European venture capital investors, GVC investors claim that they use a considerable amount of time, namely the 31-45% of their working hours, for evaluating investment proposals, which is a necessary step in the screening process, while PVC investors devotes only 16-30 % of their working hours to this activity.

The empirical literature on GVC ability to certify investee firms to PVC investors is limited. Most of the literature on GVC focused instead on the effectiveness of GVC programs in stimulating the PVC market at the macro level. Specifically, some works have studied whether GVC investments have a positive or negative impact (i.e. crowding in versus crowding out) on the total amount raised by PVC investors in a country/region, finding mixed evidence. Armour and Cumming (2006) and Cumming and MacIntosh (2006) results are consistent with a crowding out effect of GVC investments in Europe, USA and Canada. Leleux and Surlemont (2003) shows that GVC are not able to develop the PVC markets in European countries in which it is less developed. On the contrary, the evidence of Jeng and Wells (2000) and del-Palacio et al. (2012) show that GVC have a positive effect on the development of the PVC market. Also in the literature at the micro level (firm or investment level), the issue of whether receipt of GVC certifies investee firms to PVC investors has received limited attention. Cumming (2007) analyzes the performance of the Innovation Investment Fund (IIF) governmental program using information on 845 Australian venture capital-backed entrepreneurial firms extracted from the Venture Economics database. Results show that firms backed by IIFs are more likely to have one extra syndicated partner (public or private) than other types of funds. Again on Australian Venture Economics data, Cumming & Johan (2009) focus on the performance of the Pre-Seed Fund program. They find that firms in the program do not syndicate more frequently than other types of venture capital funds. Using an international sample of firms that received venture capital funding in the 2000-2008 period, Brander, Du, & Hellmann (2010) find that a first investment round from a GVC increases the overall venture capital investment (both private and public) obtained by the firm. Prior GVC amounts also tend to increase future non GVC amounts, although the effects are not always significant. Brander, Egan, et Hellman (2010) find that Canadian firms backed by GVC are less likely to attract a US PVC financing than firms backed by Canadian PVC. Using UK data, Munari and Toschi (2011) find that

GVC-backed firms have a greater ability to attract partners in syndication, especially in high-tech regions, with respect to firms backed by other venture capital investors.

Conversely, few studies properly evaluate the certification role of different forms on governmental interventions to outside investors. Lerner (1999) show that firms awarded by the SBIR Program in the US are more likely to receive PVC financing with respect to a matched sample of firms that did not received the SBIR award. Using a Belgian dataset of 1107 approved requests and a control group of denied requests for a specific type of R&D grant, Meuleman & De Maeseneire (2012) examine the impact of R&D subsidies on small firms' access to external equity, short term and long term debt financing, finding that obtaining an R&D subsidy provides a positive signal about firm's quality and results in better access to long-term debt. In our opinion, there is a lack of evidence on the GVC certification role toward PVC in Europe. This is the gap that we aim at filling with this chapter.

4.3. EVALUATION OF THE CERTIFICATION EFFECT OF GVC PROGRAMS

To evaluate the effectiveness of GVC in certifying high-tech entrepreneurial ventures to PVC investors, we formulate two research questions. First, if a certification effect is at work, we should expect that PVC should be more inclined to provide a first round of financing to the high-tech entrepreneurial ventures that have previously received GVC, with respect to other entrepreneurial ventures with similar characteristics that have not received GVC. This is the rationale of our first research question: *does the receipt of GVC increase the likelihood that a high-tech entrepreneurial venture attracts PVC, thanks to a certification effect?*

Second, we explicitly evaluate the GVC screening abilities, i.e. the ability of selecting high-potential firms. This is the rationale of our second research question: *are PVC investments in firms certified by GVC at least as successful as other PVC investments?* If PVC investments originated by GVC certification are at least as successful as other PVC investments, then the ability of GVC to screen the market and find high-potential firms is proved. Otherwise, if may be that PVC investors invest in firms certified by GVC and then find out that it was not worth a first round of investment. The consequences would be waste of public and private money, i.e. the amount invested by GVC and by PVC in the first investment round. We consider two indicators of PVC investment success: the receipt of a second round of PVC and PVC successful exit. Reaching the second round of funding is considered by recent literature as an indicator of investment success, when the firm is still in a early stage and not ready to be listed or sold to another corporation (Hochberg et al., 2007).

Most PVC investments are "staged" in the sense that portfolio companies are periodically reevaluated and receive follow-on funding only if their prospects remain promising. Staging allows the PVC investors to acquire information on firm's quality and limit the impact of bad investment decisions, once that capital has been invested in the portfolio company (Bergemann & Hege, 1998; Gompers, 1995). If, after the initial round of PVC financing, negative information about firm's future returns is observed, a second round of PVC financing becomes less likely. . However, sometimes a second round of PVC investment is not needed, because PVC is ready to collect its capital gains from the investment in the firm. Hence, as a second indicator of investment success, we consider exit via IPO or sale to another company (M&A), as it is typically done in the venture capital literature (e.g. Gompers, 1996; Lerner, 1994a). To sum up, when PVCs invest in the firm certified by GVC, they acquire soft information on the potential value of the firm and can take an informed decision on follow on rounds of financing and investment exit. If PVC investors are not satisfied with the investment originated by the GVC certification, a second round of financing (and eventually an IPO or M&A) will not occur. Otherwise, if GVC is able to screen the market and the certification of GVC is valuable, PVC investments in firms certified by GVC will be at least as likely to reach the second round of PVC or to end with a successful exit of PVC as other PVC investments.

4.4. DATA AND METHOD

Data

The sample used in this chapter is extracted from the VICO database. For each firm, the database collects information on foundation year, industry of operation, country, longitudinal accounting data and patenting activity.[23] Approximately the 10% of the firms are backed by at least a venture capitalist. For these firms, the database collects information on the existence and nature of the parent company of the venture capital. It is therefore possible to single out GVC investors and PVC investors. The former are venture capital firms whose parent company is a governmental agency. The latter are either independent "US style" venture capital firms or venture capital firms whose parent companies are other corporations, both financial (such as banks) and non financial. Moreover, VICO database collects information on all the investment rounds that each venture capital-backed firm received from each venture capital investor in the database, such as the year and the amount invested. This allows us to track the investment history of all firms.

[23] See Appendix once again.

To construct the sample for our analysis, we follow Lerner (1999)'s approach and we match GVC-backed firms with a comparable non GVC-backed firms. We first extract from VICO database firms that received their first round of funding by a GVC. Using a propensity score matching, we then match every GVC-backed firm in the year of the GVC investment with 5 firm-year observations of the non GVC-backed group. We use as matching variables the industry of the firm, the country in which it operates, the age, the size in the previous year, measured as total asset, and GVC availability, measured as the number of firms invested by GVC in each country in each year (source: ThomsonOne). We then drop from the sample all the firms for which we could not match any yearly observation to the yearly observations of GVC-backed firms.

This procedure helps in reducing a possible *selection effect* that could bias our results when comparing GVC-backed and non GVC-backed entrepreneurial ventures. The firms' characteristics that affect the probability of being GVC-backed are likely to influence also the probabilities of receiving a first round of PVC and, for PVC-backed firms, the receipt of a second PVC round or a successful PVC exit. This would create some biases in our estimates. For instance, the degree of the similarity between PVC and GVC selection criteria may affect our estimates since GVC may select firms which meet PVC selection criteria and that sooner or later would receive a PVC investment, with or without GVC certification. Even if no certification is at work, we still may find that GVC has a positive effect on the probability of receiving a first round of PVC. In this case, the selection effect would create an upward bias when estimating the impact of GVC on the likelihood of receiving a first PVC round. The matching procedure used in this work allows to properly control for the selection effect due to observable variables that are used as matching regressors.[24]

The matching technique leaves us with a sample of 189 GVC-backed firms and a matched sample of 797 non-GVC backed firms.[25] Out of the 986 firms, 220 are PVC-backed. These firms are observed from their inception to 2010 (or to their liquidation). Table 4.1 shows the distribution of GVC-backed firms and the matched sample, according to firm's industry, country and foundation period. As a consequence of the matching procedure, the distribution of GVC-backed firms is not significantly different from the one of the entire sample (chi-square tests on the differences in the distribution for industry, country and age classes are $\chi^2(5)=0.62$, $\chi^2(6)=2.12$ and $\chi^2(2)=1.74$, respectively).

[24] As a robustness check, we also control for selection based on unobservable variables. The procedure is described in section 4.6.

[25] We tested the balancing of the covariates before and after the matching. Some t-test show that after the matching the GVC-backed firms and the matched sample do not show significant differences for all the variables used in the matching procedure.

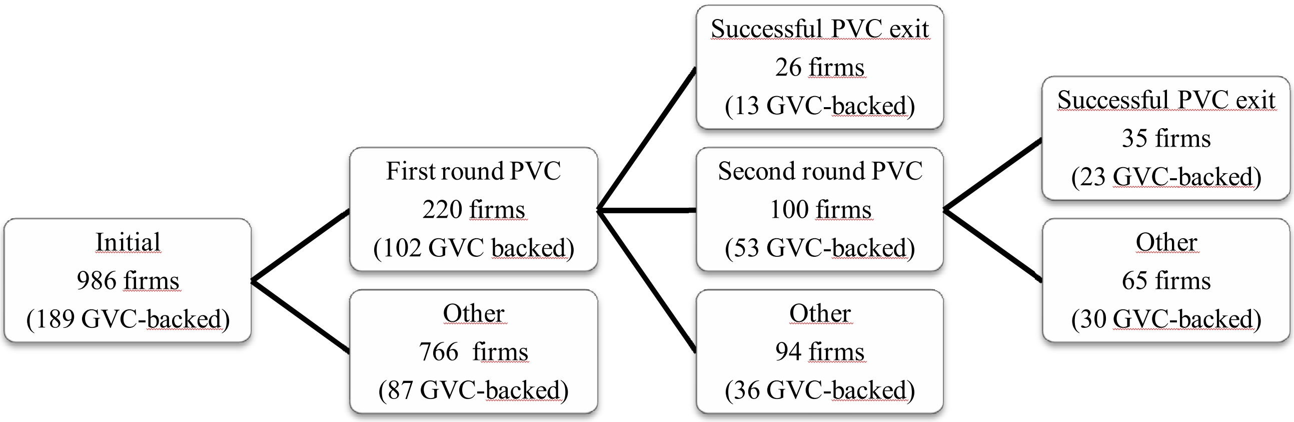
Table 4.1. Distribution of sample companies by industry, country and foundation period

	GVC backed companies		Matched companies	
	No	%	No	%
Industry				
Internet	15	7.94	72	9.03
TLC	8	4.23	28	3.51
Software	70	37.04	276	34.63
ICT manufacturing	32	16.93	147	18.44
Biotech and pharmaceuticals	49	25.93	207	25.97
Other high tech industries	15	7.94	67	8.41
Total	*189*	*100.00*	*797*	*100.00*
Country				
Belgium	25	13.23	119	14.93
Finland	28	14.81	119	14.93
France	39	20.63	166	20.83
Germany	31	16.40	97	12.17
Italy	13	6.88	60	7.53
Spain	34	17.99	138	17.31
United Kingdom	19	10.05	98	12.30
Total	*189*	*100.00*	*797*	*100.00*
Foundation period				
Founded before 1999	95	50.26	435	54.58
Founded in 1999 or 2000	54	28.57	198	24.84
Founded after 2000	40	21.16	164	20.58
Total	*189*	*100.00*	*797*	*100.00*

Figure 4.1 shows the event flow of our sample of high-tech entrepreneurial ventures. It tracks the number of firms that were interested by one of the following events: first round of PVC, second round of PVC, successful PVC exit (IPO or M&A). Out of 986 firms in our sample, 220 firms (102 of which are GVC-backed) receive a first PVC round. The remaining 766 firms do not receive PVC. After the first PVC round 100 firms receive a second round of PVC[26] (53 of which GVC-backed). The successful exits of PVC are 61: 26 firms (13 of which GVC-backed) are acquired or listed after the first round of PVC, and other 35 (23 of which GVC-backed) after the second round of PVC.

[26] It is worth pointing out that we consider as a second round of PVC the investment round provided by both the same PVC investor of the first round and other PVC investors.

Figure 4.1. Event flow of sample firms



Model specification

Our empirical analysis is articulated in two steps. In a first step, we focus on the 986 firms (GVC-backed firms and the matched sample) and we estimate their probability of receiving a first round of PVC. In the second step of the analysis, we restrict the analysis to the 220 firms that received a first round of PVC and analyze for them the probability of receiving a second round of PVC and the probability of a successful PVC exit (IPO and M&A). In both steps, we are interested in assessing GVC certification impact on these probabilities.

To estimate these probabilities, we resort to a semi-parametric Cox survival type model (Cox, 1972) that has been extensively used in the venture capital context (see e.g. Chang 2004, and Giot and Schwienbacher 2007). While probit or logit models allow us to predict whether the event will occur, survival models give also an indication on when the event will occur, as they estimate hazard rates, i.e. probabilities that an event take place at a certain time. In a Cox model, the hazard rates are estimated from the following hazard function:

$$\lambda(\tau)=\lambda_o(\tau)e^{Xi\,\beta}$$

Where τ is exposure time, X_i are the model's covariates for firm i and λ_0 is the baseline hazard rate, i.e. the hazard rate corresponding to $X_i = 0$. The Cox model does not require the distribution of time dependence of the hazards to be specified and is therefore very flexible. However, it is based on a set of assumptions that need attention. First, the standard Cox model assumes that time is continuous. The times at which events occur are not relevant, but the order of the events is relevant. For this reason, multiple events at the same time cause the order of the events to be unclear. Subject with the same events time are referred to as "tied". Since we use a discrete measure of time (the year), multiple subjects can have the same event time. We introduce the Breslow (1974) correction for ties.[27] Second, the Cox model is based on the assumption of proportional hazards. All the dependent variables of the model have an impact on the dependent variable which is proportional at each time τ. We test this assumption using the Schoenfeld residuals (Schoenfeld, 1982).[28]

Variables

In the first step we estimate the likelihood of the focal firm of obtaining the first round of PVC after τ years from foundation, conditional on not obtaining such financing up to τ (i.e. the hazard rate of receiving a first PVC round). The exposure time τ is represented by the years since firm's foundation, and therefore is equal to firm's age. Some firms are liquidated before receiving any PVC financing, while others are acquired or listed. We exclude from the analysis the firm-year observations after a liquidation, an IPO or an M&A take place, because in these cases the firm is not more at risk of receiving a PVC financing round (see Bertoni et al. 2011 for a similar approach).

In the second step, we have two different models: we estimate the likelihood of PVC-backed firms of receiving a second round of PVC, computed τ years after the first round of PVC, conditional on not receiving it up to τ (hazard of receiving a second round of PVC) and the likelihood of achieving a PVC successful exit, computed τ years after the first round of PVC, conditional on being listed or acquired up to τ (hazard of a PVC successful exit). Both models are defined only for those firms which received a first round of PVC. We exclude from the analysis the firm-year observations following a liquidation event.

Our main independent variable is $GVC_{i,t-1}$, a dummy variable that switches from 0 to 1 one year after the receipt of GVC.

We include a set of control variables in all our models. We control for the amount of financial resources brought about by GVC investor to the firm. On the one hand, the higher the amount invested by GVC, the higher the probability that the firm started to invest in new projects or to professionalize its management. These firms are therefore closer to an IPO or M&A event, and are more attractive to PVC investors moved by a "window-dressing" behavior (Lerner, 1994b). Higher

[27] As a robustness check, we also used Efron (1977) correction method for ties. Results are unchanged and available from the authors upon request.
[28] We also analyze the Marginale residuals to identify the most suitable functional form of the covariates, check for outliers and model fit (see Box-Steffensmeier and Jones, 2004, for details on the residual processes for Cox models). Lastly, we identify the subjects with a disproportionate influence on the estimated parameters using the DFBETA method (Belsley, Kuh, & Welsch, 1980).

amount invested by GVC may have a positive impact on firm probability of receiving a first PVC round or achieving a PVC successful exit. On the other hand, GVC-backed firms that received high amount of money by GVC may not be interested anymore in contacting and dealing with another venture capital investor, and they may simply not be on the market for PVC. This implies a lower probability of receiving a first round of PVC for these firms. For similar reasons, a second round of PVC is less likely for PVC-backed firms that received high amounts of money from GVC. In all the cases, the dependent variables of all our models are likely to be influenced by the amount invested by GVC. We therefore control for $GVCamount_{i,t-1}$, i.e. the cumulated amount invested by GVC till $t-1$. As to firm-level characteristics, we control for size and innovative performance. Firm size is measured with total assets, lagged of 1 year ($TotalAssets_{i,t-1}$). Firm innovative performance is measured by $Patents_{i,t-1}$, firm's stock of patents, cumulated and depreciated in time, lagged of 1 year (see Griliches 1992 and Bertoni and Tykvovà 2012 for a similar approach). These variables are included in all our models. We also use the age of the firm by the time of the PVC investment ($AgeByPVC_i$) as a control in the second step of the analysis. This variable cannot be explicitly present in the first step because the hazard function already considers age as the exposure time of each firm (τ). We expect the events of our analysis to be also influenced by context variables. During the internet Bubble period it was very easy for high-tech companies, especially operating in software and internet industries, to receive a PVC financing. Therefore we define a set of three dummy variables that indicates respectively if the year falls in the pre Bubble period (before 1999), during the Bubble period (1999-2000) or in the post Bubble period (after 2000). These dummy variables are likely to fail the proportional hazard test, because they are related to the passing of time. Therefore they are not included in the regression directly but are used to stratify the hazard function (Collett, 1994). Besides industry and country fixed effects, we also control for the PVC fundraising in the each year, natural measure of the availability of PVC ($PVCsupply_{t-1}$). We downloaded information on PVC supply from ThomsonOne database. We control for the successful exit opportunities for venture capital by considering the number of firms that were listed ($numberIPO_{c,t}$) or acquired ($numberM\&A_{c,t}$) in each country in each year. We collected this information respectively from EURIPO and ThomsonOne and normalized the variables by country GDP (source: Word Bank). Finally, only in the second step of the analysis, we control for $PVCamount_{t-1}$, the lag of the cumulated amount invested by PVC in the firm.

Variables are described in Table 4.2 and summarized in Table 4.3 and 4.4 respectively for the first and the second step of the analysis.[29]

Table 4.2. Variables description

Variable	Description
$AgeByPVC_i$	Age of firm *i* by the time of the PVC investment. Source: VICO database
$TotalAssets_{i,t}$	Logarithm of total assets of firm *i* at time *t*. Source: Amadeus
$Patents_{i,t}$	Cumulated and discounted number of patents of firm *i* till time *t*. Source: PATSTAT
$PVCsupply_t$	Net Period Amount Raised by PVC in Billion €, in time *t*. Source: ThomsonOne
$numberIPO_{c,t}$	Number of companies listed in country *c* at time *t*, normalized to country GDP. Source: EURIPO
$numberM\&A_{c,t}$	Number of companies acquired in country c at time *t*, normalized to country GDP. Source: ThomsonOne
$PVCamount_{i,t}$	Cumulated amount invested by PVC in firm *i* till time *t*, thousands €. Source: VICO database
$GVC_{i,t}$	Dummy equal to 1 if the firm *i* is invested by a GVC in year *t*. Source: VICO database
$GVCamount_{i,t}$	Cumulated amount invested by GVC in firm *i* till time *t*, thousands €. Source: VICO database

[29] As it is frequent for large databases, VICO database presents some missing values in the accounting variables. Missing values for the total assets of firms ($TotalAssets_{i,t-1}$) have been imputed based on the lagged values of the variable, country, period and industry dummies, the age of the firm, the lag of the intangibles over total assets and the lag of the leverage of the firm. Since total assets are control variables, we this procedure is not a source of problems for our analysis, but helps in having a larger sample for the study. As robustness checks, we also performed the regressions without this control variable. Results are unchanged.

Table 4.3. Variables descriptive statistics: observations used in the first step of the analysis

	Variable	N	n	Mean	Median	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8
1	$TotalAssets_{i,t}$	986	9905	6.36	6.33	1.78	0.00	15.64	1.00							
2	$Patents_{i,t}$	986	9905	0.25	0.00	1.58	0.00	44.83	0.16	1.00						
3	$PVCsupply_{t}$	986	9905	6.44	5.52	5.91	0.3	27.10	0.02	0.02	1.00					
4	$numberIPO_{c,t}$	986	9905	0.02	0.01	0.03	0.00	0.18	0.00	0.03	0.32	1.00				
5	$numberM\&A_{c,t}$	986	9905	0.30	0.20	0.25	0.00	1.82	0.00	-0.02	0.25	0.66	1.00			
6	$PVCamount_{i,t}$	986	9905	0.08	0.00	1.04	0.00	59.54	0.05	0.05	0.13	0.07	0.03	1.00		
7	$GVC_{i,t}$	986	9905	0.11	0.00	0.31	0.00	1.00	0.09	0.04	0.04	-0.04	-0.04	0.11	1.00	
8	$GVCamount_{i,t}$	986	9905	0.08	0.00	0.33	0.00	6.05	0.11	0.04	0.07	0.00	-0.02	0.37	0.66	1.00

Table 4.4. Variables descriptive statistics: observations used in the second step of the analysis

	Variable	N	n	Mean	Median	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9
1	$AgeByPVC_{i}$	220	1808	2.45	1.00	2.64	0.00	13.00	1.00								
2	$TotalAssets_{i,t}$	220	1808	7.02	6.71	1.65	0.00	12.85	0.23	1.00							
3	$Patents_{i,t}$	220	1808	1.23	0.00	2.93	0.00	29.46	-0.06	0.15	1.00						
4	$PVCsupply_{t}$	220	1808	6.73	5.52	5.38	1.16	27.1	0.01	0.04	-0.03	1.00					
5	$numberIPO_{c,t}$	220	1808	0.02	0.01	0.03	0.00	0.18	0.11	0.05	0.00	0.41	1.00				
6	$numberM\&A_{c,t}$	220	1808	0.25	0.15	0.22	0.07	1.34	0.21	0.05	-0.02	0.32	0.71	1.00			
7	$PVCamount_{i,t}$	220	1808	6.68	2.25	15.68	0.01	175.11	-0.06	0.15	0.35	0.00	-0.03	-0.05	1.00		
8	$GVC_{i,t}$	220	1808	0.44	0.00	0.50	0.00	1.00	0.26	0.24	0.13	-0.03	0.03	0.05	0.06	1.00	
9	$GVCamount_{i,t}$	220	1808	0.96	0.00	2.09	0.00	21.40	0.01	0.25	0.34	-0.04	-0.05	-0.06	0.26	0.52	1.00

4.5. RESULTS

Tables 4.5, 4.6 and 4.7 present the results of the econometric analysis. The model in the first column of each table accounts only for the control variables. In the second and in the third columns we add respectively the presence of GVC, $GVC_{i,t-1}$, and the amount invested by GVC, $GVCamount_{i,t-1}$. In the fourth column we consider simultaneously the two variables. A measure of model fit is provided by Pseudo Log-likelihood statistic.

Table 4.5. Hazard of receiving a first round of PVC

	First round PVC							
	I		II		III		IV	
$TotalAssets_{i,t-1}$	0.213	***	0.209	***	0.206	***	0.206	***
	(0.055)		(0.058)		(0.056)		(0.057)	
$Patents_{i,t-1}$	0.056	**	0.058	**	0.060	**	0.059	**
	(0.025)		(0.025)		(0.025)		(0.025)	
$PVCsupply_{t-1}$	0.003		0.004		0.004		0.004	
	(0.011)		(0.011)		(0.011)		(0.011)	
$numberIPO_{c,t}$	9.002	***	8.675	***	9.251	***	8.835	***
	(2.946)		(2.922)		(2.957)		(2.928)	
$numberM\&A_{c,t}$	0.430		0.481		0.413		0.457	
	(0.572)		(0.570)		(0.577)		(0.574)	
$GVC_{i,t-1}$			0.871	***			0.675	*
			(0.225)				(0.358)	
$GVCamount_{i,t-1}$					0.747	***	0.268	
					(0.164)		(0.315)	
NUTS1 dummies	Included		Included		Included		Included	
Industry dummies	Included		Included		Included		Included	
Period dummies	Used to stratify		Used to stratify		Used to stratify		Used to stratify	
n	9905		9905		9905		9905	
N	986		986		986		986	
N failures	220		220		220		220	
Risk	9807.8		9807.8		9807.8		9807.8	
$\chi2$	4602.3 (51)	***	5556.8 (52)	***	5280.3 (52)	***	4971.1 (53)	***
Pseudo R^2	0.069		0.074		0.073		0.074	
Pseudo lnL	-1141.317		-1135.539		-1136.852		-1135.3	
χ^2 PH Assumption[a]	46.27 (51)		58.79 (52)		48.92 (52)		58.73 (53)	

The table reports the estimated coefficients (β) and, in brackets, the robust standard error of the coefficients. Hazard rates can be computed with the transformation e^{β}. We used Breslow (1974) correction for ties. * $p < 0.10$; ** $p< 0.05$; *** $p<0.01$. [a] This is the proportional hazard assumption based on the analysis of Schoenfeld residuals. The null hypothesis is that the assumption holds.

Table 4.5 presents the results on the impact of GVC certification on the firm's hazard rate of receiving a first round of PVC. Both $GVC_{i,t-1}$ and $GVCamount_{i,t-1}$ have positive and significant (at 99% confidence level) coefficients when considered separately. However, when the variables are included simultaneously, only the coefficient of $GVC_{i,t-1}$ is positive and significant. The hazard ratio of $GVC_{i,t-1}$ is 1.96 ($e^{0.675}$), implying that GVC backed firms have a hazard rate of receiving a first round of PVC which is 1.96 times the one of non-GVC backed firms. These results show that GVC investors certify their portfolio firms, increasing their chances of receiving a first PVC round. The coefficients of the control variables are quite similar across models. $TotalAssets_{i,t-1}$ and $Patents_{i,t-1}$ have a positive and significant coefficient (respectively at 99% and 95% confidence levels): bigger and more innovative firms have a higher hazard rate of receiving a first PVC round. The hazard rate is also higher when the external conditions are favorable to PVC in terms of exit opportunities, as the coefficient of $numberIPO_{c,t}$ is positive and significant at 99% confidence level. $PVCsupply_{t-1}$ and $numberM\&A_{c,t}$ on the contrary, do not play a significant role on the hazard rate of receiving a first PVC round.

In Table 4.6 we study the hazard rate of PVC-backed firms of receiving a second round of PVC. $GVC_{i,t-1}$ has a positive and significant coefficient in the second and the fourth columns (respectively at 95% and 99% confidence levels). On the contrary the coefficient of $GVCamount_{i,t-1}$ is not significant in the third and the fourth columns. Results indicate that the hazard ratio of reaching the second round of financing is 2.3 ($e^{0.833}$), implying that PVC-backed firms invested by GVC investors have an hazard rate that is 2.3 times the hazard rate of PVC-backed firms that were not invested by GVC. Moreover, the amount invested by PVC ($PVCamount_{t-1}$) has a positive and significant impact on the hazard rate of receiving a second round of financing (at 95% confidence level, depending on the model). The hazard rate is lower for firms that were older by the time of the first PVC round, as the coefficient of $AgeByPVC_i$ is negative and significant (at 90% or 95% confidence level). The other control variables do not have a significant coefficient.

Table 4.6. Hazard of PVC-backed firms of receiving a second round of PVC

	Second PVC round			
	I	II	III	IV
$TotalAssets_{i,t-1}$	0.058	0.010	0.056	0.020
	(0.092)	(0.092)	(0.095)	(0.093)
$Patents_{i,t-1}$	0.043	0.042	0.043	0.040
	(0.034)	(0.035)	(0.034)	(0.035)
$PVCsupply_{t-1}$	-0.001	0.003	-0.001	0.003
	(0.015)	(0.015)	(0.014)	(0.015)
$numberIPO_{c,t}$	2.536	2.767	2.533	2.905
	(3.868)	(3.895)	(3.865)	(3.949)
$numberM\&A_{c,t}$	-0.857	-0.735	-0.854	-0.726
	(1.365)	(1.378)	(1.365)	(1.387)
$AgeByPVC_i$	-0.101 *	-0.117 **	-0.102 *	-0.114 **
	(0.053)	(0.054)	(0.053)	(0.053)
$PVCamount_{i,t-1}$	0.030 ***	0.029 ***	0.029 **	0.044 ***
	(0.010)	(0.010)	(0.012)	(0.014)
$GVC_{i,t-1}$		0.606 **		0.833 ***
		(0.252)		(0.267)
$GVCamount_{i,t-1}$			0.013	-0.173
			(0.086)	(0.105)
NUTS1 dummies	Included	Included	Included	Included
Industry dummies	Included	Included	Included	Included
Period dummies	Used to stratify	Used to stratify	Used to stratify	Used to stratify
n	1300	1300	1300	1300
N	220	220	220	220
N failures	100	100	100	100
Risk	1132.3	1132.3	1132.3	1132.3
$\chi 2$	39468.6 (52) ***	32970.2 (52) ***	39324.7 (52) ***	63356.6 (54) ***
Pseudo R^2	0.083	0.088	0.083	0.090
Pseudo lnL	-421.117	-418.734	-421.109	-417.892
χ^2 PH Assumption [a]	33.08 (52)	39.42 (53)	38.13 (53)	41.75 (54)

The table reports the estimated coefficients (β) and, in brackets, the robust standard error of the coefficients. Hazard rates can be computed with the transformation e^{β}. We used Breslow (1974) correction for ties. Legend: * $p < 0.10$; ** $p< 0.05$; *** $p<0.01$. [a] This is the proportional hazard assumption based on the analysis of Schoenfeld residuals. The null hypothesis is that the assumption holds.

Table 4.7. Hazard of PVC-backed firms of achieving a PVC successful exit

	PVC successful exit			
	I	II	III	IV
$TotalAssets_{i,t-1}$	0.224 **	0.225 **	0.230 *	0.227 **
	(0.111)	(0.114)	(0.120)	(0.114)
$Patents_{i,t-1}$	0.031	0.019	0.031	0.023
	(0.039)	(0.039)	(0.052)	(0.046)
$PVCsupply_{t-1}$	0.000	0.003	0.006	0.003
	(0.032)	(0.033)	(0.035)	(0.033)
$numberIPO_{c,t}$	14.525 **	14.666 **	16.034 **	14.604 **
	(6.412)	(6.582)	(6.812)	(6.588)
$numberM\&A_{c,t}$	-3.245	-2.939	-3.690	-2.928
	(2.397)	(2.597)	(2.600)	(2.598)
$AgeByPVC_i$	-0.034	-0.057	-0.030	-0.059
	(0.055)	(0.053)	(0.058)	(0.053)
$PVCamount_{i,t-1}$	0.019 **	0.017 **	0.021 **	0.017 **
	(0.008)	(0.008)	(0.010)	(0.008)
$GVC_{i,t-1}$		0.759 *		0.782 *
		(0.413)		(0.422)
$GVCamount_{i,t-1}$			0.016	-0.011
			(0.063)	(0.060)
NUTS1 dummies	Included	Included	Included	Included
Industry dummies	Included	Included	Included	Included
Period dummies	Used to stratify	Used to stratify	Used to stratify	Used to stratify
n	1808	1808	1808	1808
N	220	220	220	220
N failures	61	61	61	61
Risk	1640.3	1640.3	1640.3	1640.3
$\chi 2$	38392.3 (50) ***	172.5 (36) ***	171.6 (36) ***	172.4 (37) ***
Pseudo R^2	0.157	0.163	0.157	0.163
Pseudo lnL	-253.288	-251.415	-253.244	-251.375
χ^2 PH Assumption [a]	28.54 (50)	26.68 (36)	45.31 (36)	30.1 (37)

The table reports the estimated coefficients (β) and, in brackets, the robust standard error of the coefficients. Hazard rates can be computed with the transformation e^{β}. We used Breslow (1974) correction for ties. Legend: * $p < 0.10$; ** $p< 0.05$; *** $p<0.01$. [a] This is the proportional hazard assumption based on the analysis of Schoenfeld residuals. The null hypothesis is that the assumption holds.

In Table 4.7 we report the results of the analysis for the hazard rate of PVC-backed firms of achieving a PVC successful exit (IPO or M&A). $GVC_{i,t-1}$ has a positive and slightly significant coefficient in the second and the fourth columns, indicating that PVC backed firms invested by GVC are more likely to be listed or acquired then other

PVC backed firms. According to the fourth column, PVC-backed firms certified by GVC have a hazard rate of achieving a successful exit that is 1.7 ($e^{0.782}$) times the hazard rate of other PVC-backed firms. Similarly to what we find for the probability of a second round of PVC, the role of the amount of money invested by GVC ($GVCamount_{i,t-1}$) on the hazard rate of PVC successful exit is negligible. On the contrary, the exit opportunities ($numberIPO_{c,t}$) and the amount invested by PVC ($PVCamount_{i,t-1}$) have a positive and significant (both at 95% and 99% confidence level) impact on the hazard rate of PVC successful exit. As to control variables, the hazard rate is higher for bigger firms, as the coefficient of $TotalAssets_{i,t-1}$ is positive and significant (at 90% or 95% confidence level, depending on the model).

Summing up, we find that PVC investors are more attracted by GVC-backed entrepreneurial ventures, even after controlling for the amount invested by GVC. This evidence is consistent with the view that the receipt of GVC is associated with the certification of high-tech entrepreneurial ventures to PVC investors. We also find that PVC investments in firms certified by GVC are not less successful than other PVC investments. On the contrary, they are more successful in terms of probability of receiving a second round of PVC and, although less significantly, achieving a successful PVC exit (IPO and M&A). We find support for the idea that GVC is able to screen the market correctly and that their portfolio firms may originate successful PVC investments.

Robustness checks

We extend our analysis with some additional control variables to examine two alternative explanations for our results in the second step of the analysis. First, a possible alternative explanation of our results may be that syndicated deals are more successful than stand-alone deals. Therefore, deals in which PVC "follows" GVC are better than others because of the value of a "second opinion" (Lerner, 1994a). We thus control for the number of investors that syndicate in each firm each year, lagged by 1 year ($Ninvestors_{i,t-1}$). Results in the first two columns of Table 4.8 show that the coefficient of $GVC_{i,t-1}$ is still positive and significant in the models for the probability of receiving a second round of PVC and a successful PVC exit.

Table 4.8. Robustness checks on second step analysis

The table reports the estimated coefficients (β) and, in brackets, the robust standard error of the coefficients. Hazard rates can be computed with the transformation e^{β}. We used Breslow (1974) correction for ties. Legend: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. [a] This is the proportional hazard assumption based on the analysis of Schoenfeld residuals. The null hypothesis is that the assumption holds.

	Second PVC round		PVC successful exit		Second PVC round		PVC successful exit	
$TotalAssets_{i,t-1}$	0.017		0.228	**	-0.038		0.280	***
	(0.092)		(0.111)		(0.093)		(0.102)	
$Patents_{i,t-1}$	0.040		0.021		0.023		0.015	
	(0.035)		(0.041)		(0.036)		(0.036)	
$PVCsupply_{t-1}$	0.002		0.004		0.001		-0.010	
	(0.015)		(0.034)		(0.015)		(0.035)	
$numberIPO_{c,t}$	3.341		14.837	**	2.744		16.812	**
	(3.869)		(6.775)		(4.019)		(7.116)	
$numberM\&A_{c,t}$	-0.603		-2.962		-0.705		-2.870	
	(1.343)		(2.614)		(1.407)		(3.484)	
$AgeByPVC_i$	-0.120	**	-0.061		-0.135	**	-0.060	
	(0.056)		(0.051)		(0.062)		(0.062)	
$PVCamount_{i,t-1}$	0.028	***	0.017	**	0.033	***	0.012	
	(0.009)		(0.008)		(0.012)		(0.008)	
$Ninvestors_{i,t-1}$	0.007		-0.019					
	(0.056)		(0.069)					
$lnPVCmeanAge_i$					-0.117		0.123	
					(0.135)		(0.141)	
$GVC_{i,t-1}$	0.575	**	0.767	*	0.802	***	0.478	
	(0.259)		(0.414)		(0.281)		(0.315)	
NUTS1 dummies	Included		Included		Included		Included	
Industry dummies	Included		Included		Included		Included	
Period dummies	Used to stratify		Used to stratify		Used to stratify		Used to stratify	
n	1300		1808		1176		1629	
N	220		220		199		199	
N failures	100		61		89		56	
Risk	1132.3		1640.3		1025.6		1478.6	
$\chi2$	42456.9 (53)	***	29523.0 (52)	***	33068.3 (52)	***	84.4 (21)	***
Pseudo R^2	0.084		0.147		0.100		0.074	
Pseudo lnL	-420.51		-257.351		-361.789		-253.234	
χ^2 PH Assumption [a]	38.79 (53)		28.23 (37)		24.19 (52)		28.88(21)	

Second, GVC may be more effective in certifying their portfolio firms to certain types of PVC than others. For instance, if GVC increases firms' chances of being invested experienced PVC, the good investment performance that we observe in the second step of the analysis may be due to the higher experience of PVC, not to the GVC screening ability. We thus control for PVC experience, using as a proxy the number of years from PVC foundation to the PVC round (see Hochberg et al., 2007, for a similar approach). In particular, we compute the logarithm of the average years of experience for the private investors involved in the deal by the time of the first PVC round ($lnPVCmeanAge_i$). This information is missing for 21 of our PVC-backed firms. Results are shown in the third and fourth columns of Table 4.8. The hazard of receiving a second PVC round is still higher for firms certified by GVC, while the coefficient of $GVC_{i,t-1}$ is positive but not significant in the model estimating the hazard rate of a PVC successful exit. Even if we do not find a significant effect, the evidence is still consistent with good screening abilities of GVC investors, since PVC investments originated by GVC certification have the same hazard of ending with a successful exit of PVC than other PVC investments.

We also test the robustness of our model specification in three ways. First, 76 of the sample firms received GVC and the first round of PVC in the same year. Even if this may still be a GVC certification story, one may argue that in these cases it is not clear whether it was PVC or GVC to select the target firm, so it is difficult to understand who screened the market. We thus perform our models excluding these cases.

Second, our empirical model is a multistage selection model. In the first stage, a PVC investor select the firm while, in the second stage, it invest in a second round of financing or exit successfully via IPO or M&A. On a general multistage model, the past history of the process may affect its future evolution even once the current stage is accounted for (Balakrishnan & Rao, 2004). Therefore it is important to control for the first step selection in the second step models. To consider this issue, we use Eckhardt et al. (2006)'s approach. We model the selection of PVC using the first step of the analysis specification and compute a correction variable, λ, based on Lee's (1983) generalization of Heckman's two-stage selection model (Heckman, 1979). We then add λ in the second step models. This approach allows us to consider in the second step the unobserved heterogeneity of the firms with respect to their probabilities of receiving a first PVC round.

Results are qualitatively robust to both these modifications in the model specifications.[30]

Third, we use an alternative econometric model to control for endogeneity of the GVC financing. In our analysis we use a matching technique to select non-GVC backed firms that were comparable to GVC-backed firms before any PVC investment. However, the matching technique controls only for the observable variables that are used as matching regressors. As a robustness check, we employ an endogenous switching regression model to control for the unobservable characteristics that affect the probability of receiving a GVC investment. As explained in details in Chemmanur, Krishnan, and Nandy (2011), this methodology allows to do a “what if” analysis. In particular, we evaluate whether the firms certified by GVC would have received a first PVC round if they were not certified. Vice-versa, we evaluate whether the firms not certified by GVC would have received a first PVC round if they were certified. We do the same analysis also for the second PVC round and the successful PVC exit for PVC backed firms that were certified by GVC and those that were not certified. The analysis of the endogenous switching regression model consists in two stages. The first stage is a probit model in which the dependent variable is whether or not a firm obtains GVC in a given year. The time series for each firm that obtains GVC terminates in the year of obtaining it. The independent variables in the regression are the same used in the main model ($PVCsupply_{t-1}$, $TotalAssets_{i,t-1}$, $Patents_{i,t-1}$, $numberIPO_{c,t}$, $numberM\&A_{c,t}$, country, industry and period dummies) plus the availability of GVC in each country in each year and firm age by time t. The second stage regressions are three probit models in which the dependent variables are dummy variables that take value 1 when the firm receives a first PVC round, when the PVC-backed firm receives a second PVC round and when the PVC-backed firms achieve a successful exit, respectively. The independent variables are the same used in the first stage, with the exclusion of the availability of GVC in each country in each year. Moreover, an inverse Mills ratio computed after the first stage is

[30] Results are omitted here but are available from the authors upon request.

added to the regressors. The second stage analysis is done separately for firms that received a GVC investment, and for the matched sample. After the second stage, we estimate the probability of each event for the GVC-backed firms based on the model of non GVC-backed firms. These probabilities correspond to what would happen if the GVC-backed firms were not invested by GVC. Similarly, we estimate the probability of each event for the non GVC-backed firms based on the model for GVC-backed firms. These are the probabilities of each event if the non GVC-backed firms were invested by GVC.

Results of the "what-if" analysis are shown in Table 4.9.[31] First, firms certified by GVC would have been less likely to receive a first PVC round if they were not certified ($p<0.01$). Similarly, firms that have not been certified by GVC would have been more likely to receive a first PVC round if they were certified ($p<0.01$). Results are consistent with the idea that GVC investors are able to certify their portfolio firms to PVC investors. Second, we do not find that PVC-backed firms certified by GVC would be more likely to receive a second PVC round or to achieve a successful exit if they were certified. We interpret this as the fact that GVC investors do not have a direct impact on investment success, but, however, they are able to screen the market and certify promising firms to PVC investors. Third, PVC-backed firms not certified by GVC would be more likely to be listed or acquired if GVC certified them ($p<0.05$). This evidence is consistent with a certification effect of GVC to IPO and M&A markets. We think that these results may be a good starting point for a further study on GVC certification.

[31] Results from the first and second stage analysis are omitted for a space constraint but are available from the authors upon request.

Table 4.9. Switching regression with endogenous switching: "what if" analysis

Panel A: Receiving a first PVC round		t-test p-value
Firms certified by GVC		
Actually received of a first PVC round	0.476	
Estimated probability of a first PVC round if they were not certified	0.158	
Difference	0.318	***
	(0.012)	
Firms not certified by GVC		
Actually received of a first PVC round	0.104	
Estimated probability of a first PVC round if they were certified	0.375	
Difference	-0.272	***
	(0.004)	
Panel B: Receiving a second PVC round, PVC-backed firms only		
Firms certified by GVC		
Actually received of a second PVC round	0.420	
Estimated probability of a second PVC round if they were not certified	0.404	
Difference	0.016	
	(0.017)	
Firms not certified by GVC		
Actually received of a second PVC round	0.280	
Estimated probability of a second PVC round if they were certified	0.299	
Difference	-0.019	
	(0.014)	
Panel C: Achieving a successful exit, PVC-backed firms only		
Firms certified by GVC		
Actually achieved a PVC successful exit	0.132	
Estimated probability of achieving a successful exit if they were not certified	0.121	
Difference	0.011	
	(0.013)	
Firms not certified by GVC		
Actually achieved a PVC successful exit	0.079	
Estimated probability of achieving a successful exit if they were certified	0.099	
Difference	-0.020	**
	(0.010)	

This table reports the "what-if" analysis associated with an endogenous switching regression model. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively, for a t-test of mean difference. The standard error is reported in brackets.

Additional evidence

Cox proportional hazard model assumes that the impact of each model covariate on the hazard is proportional in every moment of the exposure time. This assumption can be explicitly tested by interacting the variables for which non-proportional hazards are suspected with some function of time (Box-Steffensmeier & Zorn, 2001). In addition to amounting to a test for non-proportionality, this approach has the added advantage of explicitly modeling the nature of the non-proportionality, resulting in a more accurately specified model and greater validity of the overall results (Box-Steffensmeier & Zorn 2001, p. 978). The natural log of time is the most common transformation (Collett, 1994). To test the non-proportionality of the hazards for our variable of interest, $GVC_{i,t-1}$, in Table 4.10 we include the interaction between $GVC_{i,t-1}$ and the logarithm of the time variable, t.[32] While $GVC_{i,t-1}*ln(t)$ does not have an impact on PVC-backed firms hazard rate of receiving a second PVC round or of achieving a successful exit (second and third columns), its coefficient it is significant at 99% confidence level in the model for the probability of receiving a first PVC round (first column). Moreover, in this model, the coefficient of $GVC_{i,t-1}$ is no longer significant.

To better understand the meaning of this result, we can look at Figure 4.2, where the average hazard rates of receiving a first round of PVC are plotted against the exposure time τ in the post-Bubble strata. The continuous line represents the baseline hazard rate, i.e. the hazard rate when all the covariates are equal to 0. Remembering that the exposure time τ in the first step of the analysis is equal to firm age, the graph shows that the hazard rate of receiving a first round of PVC pecks for 1 year old firms, and decreases with firm age. The dotted line shows the hazard rate of receiving a first round of PVC for GVC-backed firms, when controlling for the non proportionality of the hazards. For comparison purposes, we also show the hazard rate of a GVC-backed firm when we ignore the non-proportionality of GVC_{t-1} (dashed line). The interpretation of the graph in Figure 4.2 is the following: GVC is not effective in increasing 1 year old firms' hazard of receiving a first PVC round, but is able to keep this hazard high for a longer period as the firm ages. In other words, GVC make the window in which a

[32] We also tried other specifications for the non-proportionality of $GVC_{i,t-1}$ coefficient. However the logarithm of time is the transformation that best fits the data.

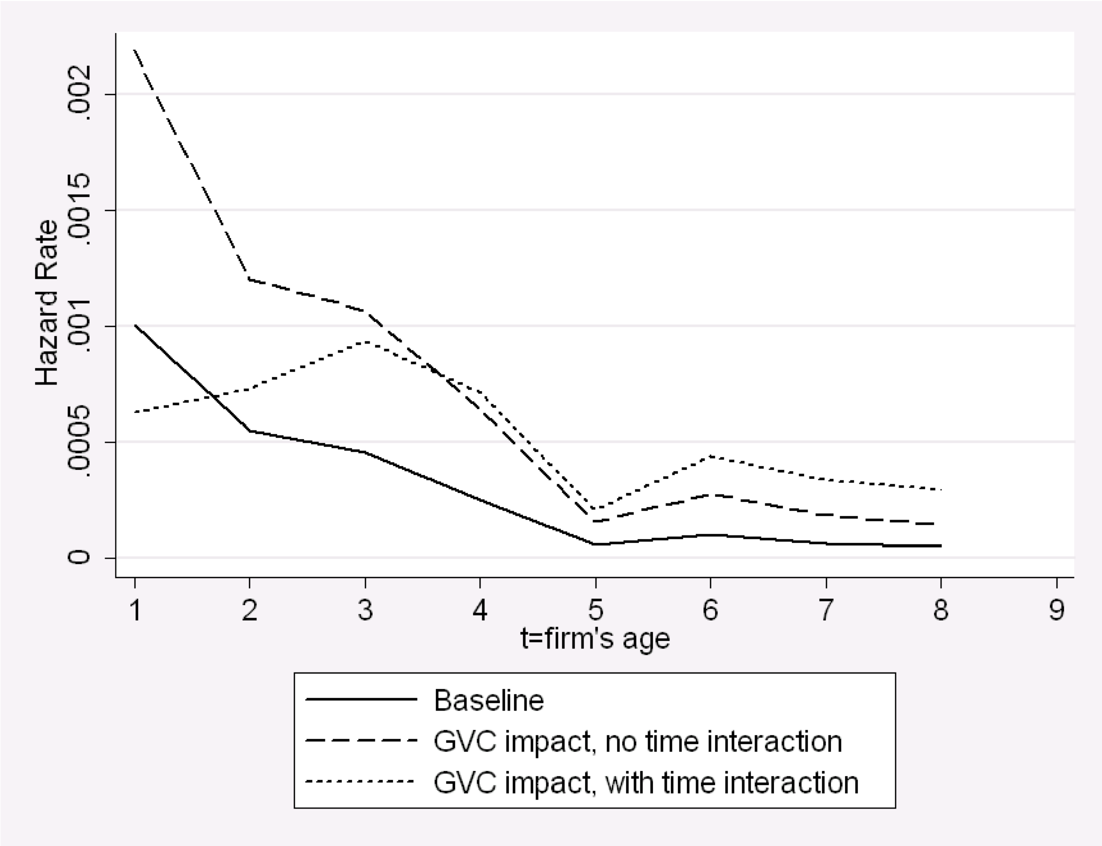
company is attractive to PVC longer. In particular, while for firms not certified by GVC the maximum hazard of receiving a PVC investment is reached when the firm is 1 years old, for certified firms this maximum is reached when they are 3 years old.

Table 4.10. Testing the non-proportionality of the hazards for *$GVC_{i,t-1}$*

The table reports the estimated coefficients (β) and, in brackets, the robust standard error of the coefficients. Hazard rates can be computed with the transformation e^{β}. We used Breslow (1974) correction for ties. Legend: * $p < 0.10$; ** $p< 0.05$; *** $p<0.01$.

	First round PVC		Second round PVC		PVC successful exit	
$TotalAssets_{i,t-1}$	0.213	***	0.009		0.220	*
	(0.058)		(0.092)		(0.116)	
$Patents_{i,t-1}$	0.060	**	0.042		0.019	
	(0.025)		(0.035)		(0.039)	
$PVCsupply_{t-1}$	0.003		0.003		0.002	
	(0.011)		(0.015)		(0.033)	
$numberIPO_{c,t}$	8.617	***	3.060		14.187	**
	(3.005)		(3.942)		(6.569)	
$numberM\&A_{c,t}$	0.504		-0.778		-2.731	
	(0.568)		(1.390)		(2.609)	
$AgeByPVC_i$			-0.116	**	-0.057	
			(0.054)		(0.054)	
$PVCamount_{i,t-1}$			0.029	***	0.017	**
			(0.010)		(0.008)	
$GVC_{i,t-1}$	-0.476		0.754	**	0.369	
	(0.515)		(0.359)		(0.886)	
*$GVC_{i,t-1}$*log(t)*	1.091	***	-0.065		0.067	
	(0.351)		(0.121)		(0.124)	
NUTS1 dummies	Included		Included		Included	
Industry dummies	Included		Included		Included	
Period dummies	Used to stratify		Used to stratify		Used to stratify	
n	9905		1300		1808	
N	986		220		220	
N failures	220		100		61	
Risk	9807.8		1132.3		1640.3	
$\chi 2$	4415.2 (53)	***	33901.5 (54)	***	31394.0 (52)	***
Pseudo R^2	0.078		0.088		0.148	
Pseudo lnL	-1130.74		-418.637		-257.256	

Figure 4.2: Hazard rates of receiving a first PVC round in the Post Bubble period



4.6. CONCLUSIONS

In this chapter, we tested whether the certification hypothesis (Lerner, 2002) is verified for European GVC. In particular, we examined whether European GVC investors have been able to certify high-tech entrepreneurial ventures to PVC investors, and whether PVC investments in firms certified by GVC have been at least as successful as other PVC investments. The empirical analysis has been conducted on a sample of 189 GVC-backed high-tech entrepreneurial ventures and a matched sample of 797 non GVC-backed firms. Out of the total 986 firms, 220 received a first round of PVC. Results show that GVC-backed firms have a higher probability of receiving a first round of PVC, even after controlling for the amount invested by GVC. Our interpretation is that GVC effectively certifies the firms they back to PVC investors. More specifically, receipt of GVC makes the window in which the firm is appealing for PVC relatively longer. Finally, PVC-backed firms that were certified by GVC have a higher probability of receiving a second round of PVC and, less significantly, of a successful exit of PVC. As these events are usually linked with investment success, these results indicate that PVC investments in firms certified by GVC are at least as successful as other PVC investments. We interpret this as an evidence of the screening ability of GVC investors.

With this work we contribute to the existent literature on the certification role of government intervention towards private investors (Feldman & Kelley, 2006; Lerner, 1999; Meuleman & De Maeseneire, 2012). While this literature has tested the certification hypothesis of government subsidies, we verify it for GVC. Few papers have dealt specifically with GVC certification (e.g. Brander, Du, & Hellmann 2010). We add to the existing literature in three ways. First, we focused on the European case, which has been unexplored despite its relevance. Second, we were able to evaluate the treatment effect of GVC, considering a counter factual of non GVC-backed firms, and so we were able to reduce the selection bias. Third, we explicitly tested whether PVC-backed firms certified by GVC are as successful as other PVC-backed firms, by looking at what happens after the first round of PVC. As far as we know, we are the first one to do this. Our results support the certification hypothesis for GVC in Europe.

We also contribute to the literature on GVC effects on firm performance. This literature has shown that GVC investors provide limited value-enhancing services to portfolio companies (Luukkonen et al., 2011). The effects seem to be more positive when GVC investors syndicate with PVC investors (Bertoni & Tykvovà, 2012; Brander, Du, et al., 2010). Although we do not focus specifically in syndication, we provide positive evidence on the ability of GVC to attract PVC investors in the deal.

Finally, our study contributes to the policy debate on the effectiveness of GVC programs in seeding PVC market in Europe. There is a number of papers that considered the hypothesis that GVC may crowd out PVC investments, instead of fostering them, and find support for this idea analyzing data at country level (e.g. Armour & Cumming, 2006; Cumming & MacIntosh, 2006). Conversely other studies find support that GVC programs have a positive impact on the aggregate pool of PVC investments (e.g. Jeng and Wells, 2000; del-Palacio, Zhang, & Sole, 2012). Our evidence is strongly coherent with these latter studies.

The implications of our work are important. First, we find that the certification of GVC is not linked with the amount of money invested by GVC in the target firm. This can have important implications for the design of GVC funds which are aimed at certifying high-potential ventures, more than enhancing their value without the intervention of PVC.

Second, our work supports the importance of government interventions in the form of direct investments in the portfolio firm. However, a comprehensive interpretation of the results is hampered by the fact that we do not take into account the relationship between social gain and public expense linked with the GVC certification.

Finally, we think that future work is still needed to evaluate under which conditions the certification of GVC is stronger. For instance, it is likely that the characteristics of the institutional contexts, such as country or industry specificities, have a huge impact on the certification ability of GVC. Moreover, in this chapter we did not consider some sources of heterogeneity within GVC programs, such as whether the GVC is regional, national or EU-based, whether or not it is hybrid, what kind of experience it has and so on. Similarly, the heterogeneity of PVC types should also be taken into account in future work.

5. General Conclusions

The European Commission has long acknowledged that high tech entrepreneurial ventures are the key drivers to develop an economy based on knowledge and innovation (European Commission, 1998). However, the high information asymmetries and agency costs affecting high tech entrepreneurial ventures deter traditional financial institutions from providing the financial resources that these firms need to growth. As a result these firms are often financially constrained. Under these circumstances, firms will be forced to use internal financial resources, i.e. their cash flows, to finance growth. While financial constraints have been thoughtfully studied with respect to their impact on firm's investments, in **Chapter 3** we provide evidence on the consequences of financial constraints on the employment policies of high tech entrepreneurial ventures. In particular, we find that employment is sensitive to cash flows (i.e. there is employment cash flow sensitivity, ECFS). We also highlight that ECFS is more subtle than normally assumed by the extant literature. Depending on firm's ability to generate internal financing, ECFS can be positive or negative. When a firm is able to generate internal financing, and cash flows are positive, a negative shock in available internal capital determines an increase in the marginal cost of capital, since more, costlier, external capital is needed to fund the growth. Under these circumstances, the lower the cash flow level, the more the firm will be forced to keep a low level of employment and fire employees. When firms are not able to generate internal capital, and cash flows are negative, the survivorship of a firm is possible only if the returns from its investments (in labor or capital) are sufficiently high. A negative shock in cash flows, under these circumstances, determines an increase in the level of employment to keep the firm alive. Financial constraints therefore destabilize the employment policy of the firm, subject to the availability of internal financing. High skilled employees, interested in a long-term relationship and not willing to face search and transfer costs to switch employer often, may be particularly attracted by firms whose employment policy is not driven by their contingent availability of cash. Financial constraints can therefore have acute negative consequences on the employment policies of high tech entrepreneurial ventures.

It is therefore important for high tech entrepreneurial ventures to raise external sources of capital. Venture capital is generally considered as the most important source of finance for high tech entrepreneurial ventures, as the European Commission itself as acknowledged (European Commission, 2010).

However, European VC is not a homogeneous phenomenon. Independent, Corporate, Bank affiliated and Governmental VC investors coexist in the European VC market. Despite their different structures, objectives and complementary assets, they basically are all oriented to linking potential investors with high tech entrepreneurial ventures (Dimov & Gedajlovic, 2010). How the actors coexist in the same environment and what are the relationships between them is undoubtedly interesting. In particular, this thesis sheds light on the *roles that each VC investor type plays in the ecology of VC financing.*

First, in **Chapter 2**, we have analyzed the investment specialization patterns of the four different types of VCs (IVCs, CVCs, BVCs and GVCs) between 1994 and 2004. We have shown that these VC types tend to select European companies with different characteristics relating to their industry of operation, age, size, stage of development, localization and distance from the premise of the VC at the time of the investment. The four types of VCs also differ in their propensity to syndicate and in the duration and type of exit of their investments. In addition, we have documented that the investment specialization patterns of different types of VCs are quite stable over time, with few exceptions. This evidence confirms the view proposed by previous studies (e.g., Dimov & Gedajlovic, 2010) that IVC, CVC, BVC and GVC play different roles in the VC ecosystem and often do not compete with each other for the same types of deals. Moreover, we have shown that there are similarities but also remarkable differences between the investment specialization patterns of VC investments in Europe and those observed in the USA in the same period. In this respect, the most striking difference is that, in Europe, IVCs refrain from investing in very young, small, seed-stage companies. This investment gap is filled by GVCs, which in Europe account for a sizable share of total VC investments, contrary to the situation in the USA.

Second, we focus on IVC and GVC investors, whose roles in the European VC ecosystems are poles apart. IVC are especially interested in realizing portfolio firms' growth potential, in order to obtain high capital gains from their investments, and have the complementary assets necessary to achieve this objective (i.e. financial and managerial resources). As high tech entrepreneurial ventures growth is particularly hampered by the financial constraints, in **Chapter 3** we study *IVC role of realizing the growth potential of promising firms by relaxing their financial constraints*. We show that IVC may relax the sensitivity of employment to cash flow (ECFS) of the portfolio firms, even though this only occurs for companies whose ECFS is positive. The firms for which liquidation concerns are material, still exhibit a negative ECFS after receiving IVC. This can be interpreted as the result of an increase in the risk profile or intangibility of firm's investments driven by the presence of IVC. We also find that IVC does improve the ability of high tech entrepreneurial ventures to attract and retain high-skilled labor, especially when ECFS is strongest.

GVC programs as well aim at the growth of high tech potential ventures, whose investments often generate R&D spillovers for the society, in terms of employment and innovation. However, GVC do not have the complementary assets necessary to realize firm potential. Therefore *GVC function in the VC ecosystem is to foster private venture capital investments*. In **Chapter 4** we study the role of GVC in European VC ecology as certifying body. In particular, we examined whether European GVC investors have been able to certify high-tech entrepreneurial ventures to IVC, CVC or BVC investors (PVC), and whether PVC investments in firms certified by GVC have been at least as successful as other PVC investments. Results show that GVC-backed firms have a higher probability of receiving a first round of PVC, even after controlling for the amount invested by GVC. Our interpretation is that GVC effectively certifies the firms they back to PVC investors. More specifically, receipt of GVC makes the window in which the firm is appealing for PVC relatively longer. Finally, PVC-backed firms that were certified by GVC have a higher probability of receiving a second round of PVC and, less significantly, of a successful exit of PVC. As these events are usually linked with investment success, this evidence shows that PVC investments in firms certified by GVC are at least as successful as other PVC investments. We interpret this result as an evidence of the screening ability of GVC investors.

Taken together, the results of this thesis provide very important insights on some of the criticalities of European VC market. Some of these insights can be the motivation for further studies on the characteristics of European VC ecology. Others already provide some implications for policy makers.

For a start, **Chapter 3** highlights that a number of high tech entrepreneurial ventures in Europe is still financially constrained and forced to use internal financial resources, i.e. their cash flows, to finance their employment policy. This effect is particularly high for smaller firms, typically more risky than other firms, because of typical liability of smallness and a more difficult access to external financial resources. Our results are in accordance with Acemoglu (2001) and Wasmer and Weil (2004) works, which argue that credit market frictions may be an important contributor to high unemployment in Europe, especially with respect to USA. Moreover, we show that financial constraints make the creation of high-skilled labor particularly difficult for high tech entrepreneurial ventures. The sensitivity of employment to cash flows limits firms ability to hire high skilled employees, which are on the contrary a key driver of the success of high tech entrepreneurial ventures (Cardon & Stevens, 2004; Colombo & Grilli, 2005; Davila et al., 2003; Katz et al., 2000). This is particularly relevant from the perspective of policymakers interested in the development and growth of these firms and emphasizes the need to reduce the equity gap in high tech markets.

Chapter 3 suggests that IVC impact on firm success is potentially very important as IVCs relax firm's financial constraints, reducing ECFS and improving the ability of high tech entrepreneurial ventures to attract and retain high-skilled labor, especially for smaller firms. However, two important criticalities emerge from **Chapter 2** and **Chapter 3** in how IVC pursue its role *of* realizing the growth potential of promising firms in the European VC ecosystem. First, the results of **Chapter 2** show that IVC investors are very risk averse in Europe. Compared with other European VC investor types, and even to USA IVC investors, European IVCs tend to select relatively older and larger companies in their expansion stages, operating in Internet and TLC services sectors. By selecting in a very narrow section of the market, IVC investors may leave the calls for financing of many promising firms unanswered. Policy interventions may have a role in changing the risk averse mentality of IVC investors, as suggested by Bruton, Fried, and Manigart (2005), for instance by regulating the level of protection of minority shareholders. Second, the results **Chapter 3** highlight that the effect of IVC on the reduction of the financial constraint is sometimes not complete. The relaxation of ECFS occurs only when ECFS is positive, and not for firms that are not able to generate internal capital. This situation is possibly the result of the institutional environment in which investors operate, for instance, in terms of effectiveness of the regulation on liquidation and restructuring for small companies. Further research is due to evaluate whether this is the case, and to formulate proper policy recommendations.

Chapter 2 and **Chapter 4** study what is GVC role in the VC ecosystem, and how it is pursued. According to some authors, the role of GVC is to fill the equity gap left by PVC investors. The evidence reported in Chapter 2 indicates that GVC in Europe are effectively doing so. We find that GVCs are specialized in investments that are not attractive to PVC: younger, smaller high-tech companies operating in industries, such as biotechnology, in which there are long lead times and substantial resources are needed for new product development. However, different authors have also recommended that GVC do not try to substitute PVC investors in the most risky segments of the industry, but instead foster PVC investments in these segments. While Chapter 2 suggests that GVC is not particularly prone to syndicate with other investors for their first investment round, in Chapter 4 we find that GVC investors have been able to certify their portfolio high-tech entrepreneurial ventures to PVC investors and increase their probability of receiving a first round of PVC later on. Nevertheless, when we look at the results of Chapter 2, we do not find any relevant change in the investment patters of PVC before and after the Internet Bubble, that could make us think that GVC is fostering PVC investments in younger and smaller firms, in their early stages of development of the market. Chapter 4 indeed shows that the effect of certification is not relevant for very young firms, but gets stronger as firms age. Overall, the results are consistent with the view that GVC is able to screen the market, select firms that are not attractive to PVC investors and certify them to the PVC market once they get older. Moreover, these investments are at least as likely to be successful as other PVC investments not originated by GVC certification. According to this thesis, GVC is pursuing a fundamental function in European VC ecosystem.

This evidence is however preliminary. We saw that firm age could have some moderation effect on GVC certification effectiveness, but it is likely that other characteristics are important as well. It is important to study which firm-specific characteristics moderate the certification effect of GVC. Further research is also needed to shed light on the other circumstance under which the GVC certification is more effective. For instance, as in Chapter 2 we find significant differences in the investment patterns of different types of PVC (IVC, CVC and BVC), an interesting direction for future research is to consider towards which type of PVC the certification of GVC is more effective.

Lastly, a very promising direction for future research is to study how institutional factors moderate the roles of VC investor types within the European ecosystem. First, as this study shows that the investment patterns of VC investor types are different in Europe and USA, it would be interesting to analyze if there is any heterogeneity of these patterns across European countries. Second, it is possible that some institutional factors affect the sign and magnitude of the ECFS. Pagano and Pica (2012) find, in an analysis at country level, that the financial development of a country decreases the sensitivity of labor to cash-flow shocks, by increasing the fraction of unconstrained firms. Similarly, we expect that the efficiency of the bankruptcy laws reduce the ECFS when cash flows are negative, as entrepreneurial ventures would be less prone to struggle for survive. Some cultural factors may as well be important (Li & Zahra, 2012). While in the USA bankruptcy laws allow entrepreneurs who fail to start again relatively quickly and failure is considered to be part of a learning process, in Europe those who go bankrupt tend to be considered as "losers" and face great difficulty in obtaining finance for a new venture (European Commission, 1998). Third, also the certification effect of GVC to PVC is likely to be moderated by institutional factors. For instance, Bruton, Fried & Manigart (2005) suggest that the risk adverse mentality of PVC investors (and therefore the need of a certification effect of GVC) is the result of the institutional environment in which investors. Higher levels of protection of minority shareholders could play a role in this regard.

APPENDIX: THE VICO DATABASE

The samples used in this thesis are drawn from the VICO database, built by the VICO project ("Financing Entrepreneurial Ventures in Europe: Impact on Innovation, Employment Growth, and Competitiveness", http://www.vicoproject.org), supported by the European Commission under the 7th Framework Programme and involving 9 European universities. A full description of the database is provided by Bertoni and Martí Pellón (2011).

The database provides detailed longitudinal information on about 8,000 young European entrepreneurial companies operating in high-tech sectors and independent at birth. Table A.1 reports the high tech sectors included in the VICO database.

Table A.1: Sectors included in the VICO database

Sector	NACE rev.1	NACE rev.2
Pharmaceutical	24.4	21
ICT manufacturing	30.02 + 32 + 33	26
Robotics	29.5	28.99.20
Aerospace	35.5	30.30
TLC services	64.2	61
Internet	72.60	63.11.30 + 63.12
Software	72.2	62
Web Publishing	72.2	5.2
Biotechnology	73.1	72.11

The companies included in the database are located in seven European countries: Belgium, Finland, France, Germany, Italy, Spain, and the United Kingdom.

The data were collected at the local level and were checked for reliability and internal consistency by a central data collection unit. The main source for firm-level data was Amadeus (and its local equivalent) but some further sources of information were used by each team to improve data availability and reliability. PATSTAT was used to collect information on each firm patenting activity.

About 1 out of 10 firms included in VICO database received a VC investment during their lives. Limits were put on the VC-backed firms. First, VC-backed firms received their first round of investment less than 10 years after foundation. Second, due to data limitations in years before the early 1990s, VICO database only considers VC-backed companies invested for the first time after 1994. Third, since a minimum number of post-investment observations should be present to evaluate the impact of VC on firm performance, VICO database considers only VC-backed firms which received their first round of VC before 2004. Several country-specific sources were used to identify the VC-backed companies included in the sample: the yearbooks of the Belgium Venture Capital and Finnish Venture Capital Associations, the ZEW Foundation Panel (Germany), the RITA directory and Private Equity Monitor (Italy), the José Martí Pellón Database (Spain), the Library House (now Venture Source, UK), the websites and annual reports of VCs, press releases and press clippings, and initial public offering (IPO) prospectuses. Moreover, commercial databases, notably, VentureXpert (now Thomson One), VCPro-Database, and Zephyr, were also used. The distribution of first VC investments is described more in details in section 2.3.

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