Small Bus Econ (2014) 42:849–870
DOI 10.1007/s11187-013-9499-3

The impact of venture capital on the persistence of innovation activities of start-ups

Spyros Arvanitis · Tobias Stucki

Accepted: 23 July 2013 / Published online: 18 August 2013

Abstract In this study we investigate the impact of early stage venture capital on innovation activities of start-ups. This is done based on a cohort of start-ups that is representative of all firms founded in Switzerland in 1996/97, as recorded by a census of the Swiss Federal Statistical Office for this period. We analyze not only the impact of early stage venture capital on innovation performance 3 years after firm foundation, but also 6 and 9 years after firm start, respectively, for those firms that survived and reported continuously innovation activities (persistence of innovation). The results support neither the hypothesis of a positive impact on *initial* innovation activities nor the hypothesis of a positive *time-persistent* effect on innovation performance of start-ups.

Keywords Venture capital · Start-ups · Innovation performance

JEL Classifications L20 · O31 · L26

S. Arvanitis · T. Stucki (✉)
KOF Swiss Economic Institute, ETH Zurich, 8092 Zurich, Switzerland
e-mail: stucki@kof.ethz.ch

S. Arvanitis
e-mail: arvanitis@kof.ethz.ch

1 Introduction

Innovation activity is a costly task in that new firms often cannot finance themselves as they generate only limited cash flows and seed capital is often scarce. They may also have difficulties gaining access to external capital, as there is asymmetric information between the owners of the start-ups and outside investors (see, e.g., Stiglitz and Weiss 1981; Binks and Ennew 1996). Obtaining external financial resources is especially burdensome when the start-ups intend to engage in innovation activities because investment in innovation is quite risky and increases the informational problems with external investors (see, e.g., Hall 2002; Savignac 2008). Venture capital can solve this problem of financial constraints of innovative start-ups. In exchange for the high risk that venture capitalists have to bear by investing in innovative start-ups, they usually get a significant portion of the company's ownership. Hence, venture capital is widely believed to stimulate innovation activities of start-ups and policy-makers around the globe attempt to create or expand their local venture capital industries (Hirukawa and Ueda 2011).

Existing literature mostly focuses on indirect effects of venture capital by means of enhancing the growth of innovative firms. In general they identified a positive impact (see, e.g., Cumming 2012 for a review of this literature). There is also evidence for a positive impact of venture capital at more aggregate levels of industries or regions (see, e.g., Kortum and Lerner

2000; Cumming 2012). Contrary to the existing vast literature on the effects of venture capital on economic performance (mostly firm growth, profitability or stock market performance) relatively little is known about the empirical relationship between venture capital and innovation activities of start-ups, particularly with respect to European start-ups.[1] Based on US sectoral panel data, Kortum and Lerner (2000) investigate the relationship between venture capital and patenting. They look at a panel of 20 US manufacturing industries between 1965 and 1992 and find that venture capital funding is associated with sectors that have higher contemporaneous patent production. Moreover, the effect of venture capital on patenting is significantly larger than the effect of R&D funding. The authors estimated that venture capital may have accounted for 8 % of industrial innovations in the period 1983–1992. Hirukawa and Ueda (2011) confirm partly these findings by examining the relationship between innovation and venture capital in a longer time series of data for US manufacturing covering the years 1968–2001. Using both total factor productivity growth and patent counts as measures of innovation, they find only little evidence for a positive effect of venture capital on innovation.

In a recent study on the determinants of venture capital investment for 23 European countries between 1995 and 2009 Bogliacino and Lucchese (2011) find that the countries that are characterized by a higher share of R&D expenditure, both public and business R&D, show a significantly positive relationship to venture capital investments. They conclude that higher technological potential appears to stimulate the supply as well as the demand of venture capital funds.

The tendency to positive effects of venture capital on innovation (mostly patenting) in studies based on more aggregated data is only partly confirmed at firm level, where it is easier to account for the timing of venture capital and innovation. With respect to innovation input, Da Rin and Penas (2007) analyze the role of venture finance in influencing the innovation strategies of the funded companies based on Dutch data. They find that venture capitalists push firms towards building absorptive capacity and towards more permanent in-house R&D efforts. Peneder (2010) analyzes the impact of venture capital on the share of sales from innovation for established firms in Austria. Using a matching-approach he finds no significant impact of venture capital on innovation output. Based on data for Italian IPOs, Caselli et al. (2009) find that funded companies even have registered fewer patents than non-funded firms in the period after funding. The study of Engel and Keilbach (2007) is based on German start-up data. They find that the involvement of a venture capital company within 1 year after foundation date does neither affect the propensity nor the intensity of patent application of the start-ups (see Sect. 2 for a more detailed overview of the firm level literature).

In this study we investigate the impact of early stage venture capital on innovation activities of Swiss start-ups. Compared to previous research our study contributes to new knowledge in three ways. First, our empirical basis is a sample of start-ups that is representative of all firms founded in 1996/97 in Switzerland as recorded by a census of the Swiss Federal Statistical Office for this period. So far, empirical evidence for the link between venture capital and innovation activities of start-ups is scarce. As new firms imply substantially high degrees of risk and uncertainty (see Rosenbusch et al. 2013), one may expect that the mode of dependence on venture capital is different for young firms than for established firms. Second, while previous studies mainly focused on patent applications as a measure for innovation activities, we analyze the impact of venture capital on different measures that capture innovation input as well as innovation output. Patent applications as a measure of innovation is subject to some limitations because (a) not all innovations are patentable and (b) particularly for start-ups applying for a patent is quite time-intensive and often too costly (see Griliches 1990; Hall et al. 2001). A third feature of our study is that it is based on data of the surviving firms of the cohort 1996/97 for three cross-sections, so that we can follow the development of the start-ups over a period of almost 10 years. This allows us to analyze the impact of early stage venture capital not only on initial innovation activities (3 years after firm foundation) but also on the persistence of innovation activities.

[1] See Da Rin et al. (2011) for a comprehensive survey (including also the scarce literature on the effects on innovation); Revest and Sapio (2012) with a focus on European studies; and Rosenbusch et al. (2013) for meta-analysis of 75 empirical studies on the economic effects of venture capital. Wright et al. (2009) reviewed the empirical literature on the economic impact not specifically of venture capital but in general of private equity.

This is of special relevance, as venture capital may not have an effect on innovation in the initial stage (as found by Engel and Keilbach 2007), but may instead stimulate long-term innovation activities. In addition, our survey provides us detailed information, especially with respect to founder characteristics, that could be taken into account in the empirical analysis. This allows us to use a matching framework that accounts for endogenous selection.

The paper is organized as follows. Section 2 presents the conceptual background, a review of empirical literature at firm level and the research hypotheses that are tested in the empirical part. Section 3 provides a short descriptive analysis of the data used in the paper. In Sect. 4 the specification of the empirical models is presented. Section 5 deals with the estimation results. Section 6 concludes.

2 Conceptual background, related empirical literature and research hypotheses

2.1 Conceptual background

Previous literature dealing with venture capital identified two important functions of venture capital that may stimulate the performance of funded firms (see Rosenbusch et al. 2013 for a detailed overview of this literature). Firstly, venture capital has a selection function. Venture capitalists are typically specialized in a narrow set of business and should thus be able to identify particularly promising start-ups. Besides this "scout" function (Baum and Silverman 2004), venture capital has a value creating function, as (a) the capital itself increases the firms' financial resources and (b) venture capitalists often act as "coaches" (Hellmann 2000), supporting firms with financial as well as other resources such as managerial experience, access to informal networks and professional business models. Based on this conceptual background Hirukawa and Ueda (2011) formulate two different hypotheses: the "venture capital first hypothesis" and the "innovation first hypothesis". While the second hypothesis focuses on the selection effect, assuming that innovations induce venture capital investments, the first hypothesis deals with the value creating function, assuming that venture capital spurs innovation activities. We concentrate here on the effect of venture capital on the innovation performance of the funded firms.

In our study we want to analyze the direct impact of venture capital on innovation activities, thus focusing on the "venture capital first" hypothesis. The identification of the direct effect of venture capital implies, however, that we are able to capture the pure selection effect, as firms, that were selected by venture capitalists because they previously showed strong innovation capabilities, and are also expected to show higher innovation activities afterwards. To overcome this problem we apply a matching approach that controls in detail for the initial innovation capabilities of the firms (see Sect. 5.1 for a further discussion on this issue).

Based on the discussion above we formulate the following hypotheses:

Hypothesis 1 Early stage venture capital does stimulate initial innovation activities of start-ups.

For both possible categories of venture capital funded firms, those that developed innovation activities at the initial stage due to venture capital support and those that were already innovative when they received venture capital support, it is important to be able to keep the pace of innovation for the critical years after foundation. For the persistence of innovation activities, financial backing in the form of venture capital in addition to the firms' own limited finance sources (e.g., revenues from product sales) is thus of critical importance. As venture capital funding is a long-term engagement and capital requirement is even larger for persistent innovation activities, we also expect that:

Hypothesis 2 Early stage venture capital does stimulate the persistence of innovation activities of start-ups.

2.2 Related empirical literature

There are relatively few studies linking venture capital funding to innovation performance. Most related to our study is the study of Engel and Keilbach (2007) that is based on German start-up data. They find that the involvement of a venture capital company within 1 year after foundation date neither affects the propensity nor the intensity of patent application of the start-ups.

Furthermore, a group of studies analyzes the impact of venture capital on innovation activities for established firms. Peneder (2010) analyzes the impact of venture capital on the share of sales from innovation for established firms in Austria. Using a matching-approach he does not find any significant impact of venture capital on innovation output. Based on data for 37 Italian IPOs, Caselli et al. (2009) find that innovation is a crucial factor during the selection phase but once the investment is made, the firms do not promote innovation and concentrate all efforts to improve other economic and managerial aspects. As a result, funded companies even have registered fewer patents than non-funded firms in the period after funding. Focusing on innovation input rather than output, Da Rin and Penas (2007) based on Dutch firm data from the Community Innovation Survey CIS-3 and CIS-4 analyze the role of venture finance in influencing the innovation strategies of the funded companies. They find that venture capitalists push firms towards building absorptive capacity and towards more permanent in-house R&D efforts.

Further evidence on the linkage between innovation and venture capital can be found in three US studies. Hellmann and Puri (2000) use a sample of 170 firms in Silicon Valley, including both ventured-backed and non-venture firms, for which data for 1996/97 was collected based on a survey. They find that firms pursuing an innovator strategy rather than an imitator strategy are more likely to obtain venture capital (causality direction from innovation to venture capital). Further, they show that venture-funded companies are faster to bring products to market. Moreover, this effect is more significant for innovating firms, for which time to market is of greater importance than for imitating firms (opposite causality direction from venture capital to innovation). In a recent study based on data for firms that received venture capital financing between 1980 and 2006, Tian and Wang (2013) develop a measure of venture capital investors' "failure tolerance" based on the time it takes to shut down failing firms. They find that firms backed by more failure-tolerant venture capital investors are more innovative. Based on a large dataset consisting of a sample of ventured-backed firms in the United States, Chemmanur et al. (2011) show that corporate venture capitalists help funded firms achieve a higher degree of innovation performance as measured by patenting compared to independent venture capitalists.

On the whole, empirical evidence at the firm level for a positive effect is rather scarce.[2] Both studies from the German-speaking countries could not find any effect on innovation, presumably due to the fact that the venture capital industry in these countries is less developed than in the United States or in the United Kingdom (see Revest and Sapio 2012). Nevertheless, many policy makers not only in the United States but also in Europe have a perception that venture capital has much to do with the rising leadership of US firms in high-technology industries, although relatively little is known about the real effects of venture capital (Gompers and Lerner 2001).

3 Description of the data

3.1 Construction of the dataset

The firm data we use in this study refers to the cohort of Swiss enterprises that were founded between 1996 and 1997. This cohort was registered by the Swiss Federal Statistical Office and contained all "green-field" start-ups (that is, without mergers and manager-takeovers) that were founded in this period and reported at least 20 h of business activities per week.[3] At the beginning the cohort contained 7,112 firms.

In 2000, we checked which firms of this cohort still existed. We defined a firm to have exited when it did not answer our questionnaire and (a) was not registered in the Swiss Commercial Register anymore or (b) the exit was verified by telephone. A graphical overview of the evolution of the sample over time is presented in Fig. 1. A total of 3,288 (46.2 %) of these start-ups were still in business in 2000. Among the firms that still existed by that time, data were collected by means of a postal survey. Of them, 49.4 % (1625) answered the questionnaire; 1,339 (82.4 %) of these firms survived the next 3 years. In 2003 a follow-up

[2] Even more scarce is the literature about the role of venture capital in Switzerland. To our knowledge, only the study of Hopp (2007) deals with venture capital in Switzerland. The aim of this paper is the investigation of the behavior of venture capital in Switzerland with respect to financing mechanisms employed and the extent to which collaboration between venture capitalists is used to cope with informational barriers.

[3] The firms were recorded by the Swiss Federal Statistical Office independent of whether they were enrolled in the Swiss Commercial Register or not.

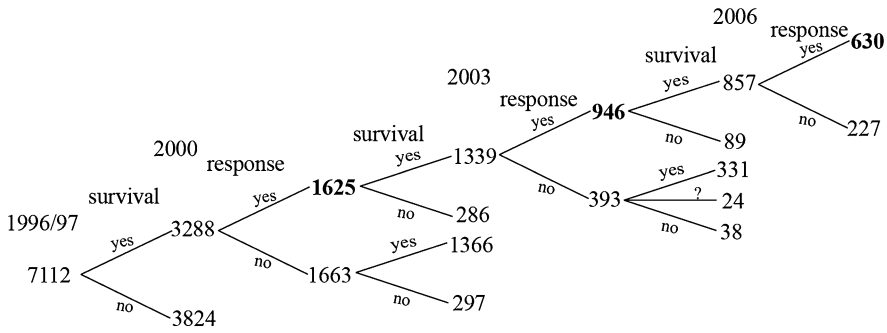


Fig. 1 Evolution of the sample over time

survey was conducted among these firms. Answers were received from 70.6 % (945). In 2006, 9–10 years after firm foundation, 857 (90.7 %) of the participants of the 2003 survey still existed, from which 73.5 % (630) were willing to fill out a third questionnaire. For many firms we thus have data at different points in time. For firms which exited the sample we know whether the firm still existed at the time of exit, also whether the firm survived the following period of 3 years.

3.2 Characteristics of the start-ups

Detailed descriptive sample information is presented in Table 7. Most of the start-ups in the dataset are firms in the service sector. In each point of time service firms represent about 83 % of the observations. About 9 % belong to the construction sector, the remaining 8 % to the manufacturing sector. These shares remained almost constant during the period 2000–2006. In the service sector the sub-sector of modern (knowledge-intensive) services (e.g., banking and insurance, business services) has a larger share than the sub-sector of traditional services (e.g., trade, hotels and catering); the share of modern services increased considerably between 2000 and 2006. In the manufacturing sector there are slightly more low-tech than high-tech start-ups.

The observed start-ups are for the most part small firms. In each survey more than 80 % of the enterprises employed less than five employees (measured in full-time equivalents). The average firm size only slightly increased from one period to the next. While in 2000 the firms had on average a size of 2.6 employees, the average size increased to 3.3 employees in 2003 and 4.8 employees in 2006. In 2006, 10 years since their foundation, only 6.5 % of the firms employed more than ten employees.

Besides this basic firm information, the questionnaire covered questions about firm success and activity level, resource endowment, innovative activities, the market environment and the financial structure. In 2000, the questionnaire included some additional questions about the founder characteristics (e.g., gender, age, education, experience and the wealth of the firm founders).

Many firms in our sample did not have innovation activities. Half of them did not introduce new or modified products in the first 3 years after firm foundation, and only about 3 % already had a patent application in this period. Furthermore, only a small fraction of the firms had persistent innovation activities (see Table 8 for descriptive information about the frequency of innovation activities). This is not a surprising result, as the small firm size indicates that not all firms had the resources for persistent innovation activities.

The identification of venture-funded firms is based on a variable that measures the importance of venture capital within a list of other internal and external sources of capital during the first 3 years after firm foundation (five-level ordinal variables; level 1: 'very low'; level 5: 'very high'). This variable was transformed to a binary variable that takes value one if the value of the original variable was above one and value zero if not.[4] Our definition of venture capital finance is thus based on early stage investments. To make sure that our control group is not affected by venture capital at a later stage, we drop all firms that received venture capital only after 2000.

As not all responding firms answered all the questions, the final sample used for model estimation

[4] To test the robustness with respect to this transformation, we also tested a more restrictive definition of venture-financed firms (see Sect. 5.2 and Table 6B).

is somewhat smaller. In the final estimates 1,228 observations remain for cross-section 2000, 683 for cross-section 2003 and 445 for cross-section 2006. Thus, 117, 61 and 40 of them, respectively, received early stage venture capital (for a detailed characterization of these firms see Sect. 5.1). Accordingly, the share of venture-financed firms remained almost constant over time at nearly 10 % for each cross-section.[5]

4 Econometric framework

4.1 Potential econometric problems

To be able to make a statement on the impact of venture capital on innovation performance, we have to overcome two problems (see Engel and Keilbach 2007 for a detailed description of these problems in the context of the assessment of the performance effects of venture capital). The first one is a missing data problem. We have only one observable outcome per firm, either with treatment or without treatment. Thus, it is difficult to assess how a firm with venture capital would have performed without venture capital. The second problem is that self-selection into treatment is usually at work by venture capital financing. Before firms get venture capital, venture capitalists usually analyze the costs and benefits of such an investment. Accordingly, selection into treatment should be strongly related to the expected benefits of such an investment. This makes it difficult to identify the performance effects that are generated by venture capital, e.g., it is not advisable to take the mean outcome of non-treated firms as an approximation.

There are different solutions to overcome these problems. In line with previous firm-level studies in this area, we apply the matching approach as it seems to be well suited for our data.[6] The basic idea of this approach is to compare the average outcome of the treated firms with average outcomes of structurally similar firms that are not treated. To ensure that the matching approach identifies and consistently estimates the treatment effect of interest, two key assumptions are required. First, the 'conditional independence assumption' (CIA) implies that, given a vector of observed variables which are not affected by treatment, assignment to treatment is independent of the outcomes. Second, the 'common support condition' (CSC) ensures that firms with the same vector of observed firm-specific variables have a positive probability of belonging to both treatment and control group. In our case, the two key assumptions should not be violated. As our study is based on a representative sample of start-ups, we have a large group of firms that did not receive venture funding, what should ensure the finding of good matches for the treated firms. Furthermore, the data set includes detailed information on the founder characteristics, the internal firm characteristics as well as the external market conditions. This allows us to control in detail for factors that may influence the treatment status and the outcome variables but are not affected themselves by treatment.

4.2 Implementing the matching approach

Due to the high dimensionality of the covariate vector that explains selection into treatment, we will use the propensity score matching (PSM) approach introduced by Rosenbaum and Rubin (1983). The idea of this procedure is to match firms based on balancing scores, i.e. on the probability of treatment given a vector of observed characteristics (for a detailed description of this approach see Caliendo and Kopeinig 2008). To evaluate these propensity scores, a selection equation is estimated in a first step. In a second step, firms from the treatment group and firms from the control group are matched, and the outcome of a treated firm with the outcomes of comparison group members are contrasted. We compare the

[5] Note that this share is based on the final estimation sample that excludes firms that received venture funding only after 2000. Obviously the share of firms that received early stage venture capital would be lower, when all firms are included. Furthermore, the share of venture financed firms significantly decreases when we use a more restrictive definition (firms with a value of the original variable above 3). However, such a modification affects our results only marginally (see Table 6B).

[6] An alternative solution to estimate causal effects would have been to apply an instrumental variable (IV) approach. In contrast to the matching approach, IV estimation can provide consistent results even in the presence of hidden bias. However, this typically comes at the costs of a reduced precision of the estimates and introduces new uncertainty from its reliance on additional untestable assumptions (see DiPrete and Gangl 2004).

outcomes for five different measures of innovation activities.

4.2.1 Estimating the propensity scores

As the receiving of venture capital is a binary treatment, probit models are used to estimate the propensity scores. To support the CIA a broad set of variables is tested as explanatory variables in the selection equation. A first group of variables describes the founder characteristics (age, gender, type of education,[7] measure for creativity), and a second one controls for sources of finance other than venture capital (personal savings, retained earnings, private loans, bank loans, customer pre-payment, supplier credit and public funding). A third group deals with the general firm characteristics (legal form, independency of the firm, education level of the employees, availability of a business plan, number of customers, sales share of exports, firm size), a fourth one controls for external market conditions (intensity of price competition, intensity of non-price competition). Furthermore, we control in detail for geographical region and industry affiliation.[8] The information for these variables comes from the survey that is described in Sect. 3.1. The variables used in the propensity equation include some of the most important determinants of innovation and/or economic performance at firm level.

4.2.2 Matching procedure

In view of the complexity of the innovation process characterized by several stages from basic research to the penetration of the market with new products, an approach relying on a single measure of innovation may leave out important relationships and produce results that are not robust (see, e.g., Rogers 1998; Kleinknecht et al. 2002). In this study we use five binary innovation measures covering the input as well as the output side of the innovation process. In our model, innovation output is measured (a) by the introduction of new products, (b) the introduction of significantly modified products and (c) the introduction of either new or modified products. The existence of R&D activities indicates innovation input. The patent application variable captures input as well as output characteristics (see Griliches 1990). As our study is based on a broad sample of green-field start-ups that are mostly small, innovation intensity of most firms is expected to be low. Accordingly, we expect that the switch between 0 and 1 would represent the most important information with respect to their innovation decisions. The binary variables should thus be adequate proxies for the innovation activities of the firms in our sample.

As our dataset follows the development of the cohort of start-ups over a period of 10 years, we can analyze not only whether venture capital affects initial innovation activities, but also whether it affects the persistence of innovation activities. For each of the five innovation variables mentioned above we thus estimate three different models. The first one analyzes the impact of venture capital on innovation activities in the first 3 years (1996/97–2000), the second deals with its impact on the persistence of innovation activities in the first two periods (innovation activities in the period 1996/97–2000 and 2000–2003) and the third model analyzes the impact on innovation persistence over the whole sample period (innovation activities in the periods 1996/97–2000, 2000–2003 and 2003–2006).

As matching method we chose the nearest-neighbor matching algorithm without replacement because the number of firms in the control group (about ten times the number in the treatment group) seems to be sufficiently large to find good matches.[9] To impose a common support we dropped treatment observations whose propensity score was higher than the maximum or less than the minimum propensity score of the

[7] As most firms in our sample are small, the education variable for the whole firm captures to a large extent also the impact of the education level of the firm founders. As measures for the education level of the firm founders and our measure for the qualification level of all employees are strongly correlated, it was not possible to control for both effects separately.

[8] Despite the inclusion of this broad set of variables, there are of course still certain aspects that we cannot control for but may have an effect on both innovation and the propensity of venture capital funding (e.g., founder personality, risk preferences). However, most of these unobserved aspects are expected to stimulate innovation and would lead to an upward bias of our results. As we find an insignificant effect of venture capital on innovation, this argument would strengthen the plausibility of our results.

[9] Results were similar in alternative estimates where we allowed replacement.

controls. Furthermore, bootstrapping was applied to correct the standard errors.

5 Estimation results

5.1 Selection model

In line with related studies that use a matching framework in order to investigate the effects of venture funding on innovation performance (see Engel and Keilbach 2007; Peneder 2010), the selection equation includes different variables that describe the founder characteristics, the financial structure of the firms, the general firm characteristics and the external market conditions (see Table 1 for a detailed description of the variables). Furthermore, we control in detail for regional aspects and industry affiliation. In accordance with theoretical and empirical findings (e.g., Arvanitis and Stucki 2012) these variables describe in detail the initial innovation capabilities of the firms and thus allow to capture potential selection effects.[10] As some firms dropped out of our sample between two cross-sections, the number of observations that can be used to identify the treatment effect varies substantially between different definitions of the target variables. While 1,228 observations can be used to identify the impact of venture capital on the propensity of innovation activities in the initial period 1996/97–2000, only 445 observations remain to identify the impact on the persistence of innovation activities over the whole sample period 1996/97–2006. To increase the matching quality, selection models are estimated for the same set of observations that could also be used to identify the treatment effect afterwards. Accordingly, we estimate for each observation period a separate selection model. The results of the final selection models are presented in Table 2.

The quality of the selection model is quite impressive for a model based on firm-level survey data. Pseudo-R^2 varies between 0.24 and 0.30, log-likelihood values between 77.99 and 187.42.[11] Due to the much lower number of observations available in models 2 and 3 it is not surprising that not all significant effects of model 1 can be identified. Most effects remain, however, robust across the different samples. The results show that the founder characteristics are important selection criteria with respect to venture capital. Young and male founders with a technical education background and a high degree of creativity have a significant higher propensity to be venture-funded. Furthermore, the financial structure differs for firms that receive venture capital funding. While private loans, customer prepayments and public funding seem to be complementary sources of funding, personal savings are shown to be substitutes of venture capital. Compared with the first two groups of explanatory variables, general firm characteristics are of lower relevance for describing the propensity of venture capital funding. Firms with a limited legal form and legally independent subsidiaries tend to have a higher venture capital propensity. Furthermore, venture financed firms seem to focus on fewer customers. General market conditions measured as intensity of competition do not affect the venture capital decision.

Besides the fact that our results seem intuitively plausible, they are also mostly in line with results of previous studies. The study of Engel and Keilbach (2007) is based on related data and allows a comparison of some of the results. In line with our finding, they also find a positive gender effect and a positive effect for limited companies. However, in contrast to their study, we cannot identify a positive firm size effect. This difference is probably driven by a lower variance in firm size in our sample. Furthermore, they could identify a positive education level effect. In our sample the positive effect of the share of tertiary employees is not statistically significant.[12]

[10] Actually, a few of the model variables refer to the starting period 1996/97–2000 and not to the foundation of the firm (see Table 1). Accordingly, some of the variables do not directly describe the firms' 'initial' innovation capabilities. This is, however, only a marginal limitation, as the low variance of these variables between the different cross-sections indicates that they primarily measure time invariant firm characteristics.

[11] In further estimates not presented here, we reduced the variance of the estimates by dropping potential explanatory variables if they did not have a significant impact. This modification did not affect our results.

[12] While Engel and Keilbach (2007) use the education level of the firm founders as proxy for the education level, we use the education level within the whole firm. However, due to the small average firm size these two variables are strongly correlated in our case. Accordingly, it is not surprising that we also cannot identify a significant effect for the education level of the firm founders.

Table 1 Variable definition and measurement

Variable	Definition/measurement
Propensity of new products	Development and introduction of new products yes/no
Propensity of modified products	Development and introduction of modified existing products yes/no
Propensity of either new or modified products	Development and introduction of new/modified existing products yes/no
Propensity of R&D activities	R&D activities yes/no
Propensity of patent application	Patent applications yes/no
Average_age	Average age of the firm founders
Dominant_gender	Dominant gender of the firm founders: male/female (value 1: 'male'; value 0: 'female'; the most frequently reported gender is regarded as representative for the firm founders; when the number of 'females' equals the number of 'males', we set 'female')
Technical_share	Share of firm founders with a technical education
Creativity	Creativity is an important strength of the founding team [five-level ordinal variables (level 1: 'very weak'; level 5: 'very strong')]
Personal_savings	Importance of personal savings to finance the firm activities [five-level ordinal variables (level 1: 'very weak'; level 5: 'very strong')]
Retained_earning	Importance of retained earnings to finance the firm activities [five-level ordinal variables (level 1: 'very weak'; level 5: 'very strong')]
Bank_loan	Importance of bank loans to finance the firm activities [five-level ordinal variables (level 1: 'very weak'; level 5: 'very strong')]
Customer_prepayments	Importance of customer prepayments to finance the firm activities [five-level ordinal variables (level 1: 'very weak'; level 5: 'very strong')]
Supplier_credit	Importance of supplier credits to finance the firm activities [five-level ordinal variables (level 1: 'very weak'; level 5: 'very strong')]
Public_limited_company	Public limited company [dummy variable with other legal forms as reference group (e.g., sole proprietorship or general partnership)]
Private_limited_company	Private limited company [dummy variable with other legal forms as reference group (e.g., sole proprietorship or general partnership)]
Legally_independent	Firm is legally independent yes/no (dummy variable with legally independent subsidiaries as reference group)
Tertiary_employees	Employees with tertiary-level education yes/no
Business_plan	Firm started with a business plan yes/no
Many_customers	Firm has many customers yes/no
Export_share	Share of exports on sales; natural logarithm
Firm_size	Number of employees at time of firm foundation (dummy variables for three firm size classes: (a) more than 1 and less than 2 full time equivalents (FTE); (b) more than 2 and less than 4 FTE; (c) more than 4 FTE; reference group: '1 or less FTE')
Price_competition	Intensity of price competition (five-level ordinal variable: level 1: 'very weak'; level 5: 'very strong')
Non_price_competition	Intensity of price competition (five-level ordinal variable: level 1: 'very weak'; level 5: 'very strong')
Region dummies	Dummies for six regions (Northwestern Switzerland; Zurich; Eastern Switzerland; Central Switzerland; Lac Léman; Ticino; reference region: 'Espace Midland')
Industry dummies	Dummies for 18 industries

As mentioned before, propensity score matching is only a valid procedure if the CIA and CSC hold. Separate tests on these two assumptions for the different models are presented in Tables 9, 10 and 11 in the Appendix. In a first step, the success of the matching was tested. Propensity score matching requires that the treatment group and the control group are similar in each aspect. To check this

Table 2 Selection equations for the different target variables

Selection equation	(1)	(2)	(3)
Founder characteristics			
average_age	−0.012*	−0.027**	−0.025*
	(0.007)	(0.012)	(0.015)
dominant_gender	0.345**	0.157	0.057
	(0.156)	(0.215)	(0.267)
technical_share	0.244*	0.090	0.057
	(0.145)	(0.215)	(0.270)
creativity	0.128**	0.339***	0.403***
	(0.065)	(0.115)	(0.154)
Financial structure			
personal_savings	−0.137***	−0.076	0.070
	(0.044)	(0.067)	(0.093)
retained_earning	0.117***	0.199***	0.141*
	(0.039)	(0.058)	(0.072)
private_loans	0.175***	0.144**	0.192**
	(0.040)	(0.059)	(0.075)
bank_loan	0.054	0.103	0.121
	(0.050)	(0.075)	(0.095)
customer_ prepayments	0.114*	0.123	0.144
	(0.063)	(0.079)	(0.097)
supplier_credit	−0.072	−0.092	−0.128
	(0.086)	(0.119)	(0.181)
public_funding	0.343***	0.435***	0.465**
	(0.093)	(0.127)	(0.202)
Firm characteristics			
public_limited_ company	0.780***	0.718***	0.527
	(0.172)	(0.263)	(0.362)
private_limited_ company	0.472***	0.468**	0.408
	(0.150)	(0.221)	(0.273)
legally_independent	−0.957***	−1.473***	−2.136***
	(0.280)	(0.413)	(0.624)
tertiary_employees	0.210	0.283	0.159
	(0.153)	(0.225)	(0.274)
business_plan	0.105	0.176	0.225
	(0.127)	(0.186)	(0.243)
many_customers	−0.217*	−0.143	−0.210
	(0.129)	(0.190)	(0.239)
export_share	−0.065	−0.038	−0.036
	(0.042)	(0.059)	(0.084)
firm_size_1–2	0.169	−0.183	−0.371
	(0.142)	(0.216)	(0.276)
firm_size_2–4	0.236	−0.078	−0.155
	(0.177)	(0.266)	(0.332)
firm_size_ > 4	−0.204	−0.487	−1.039
	(0.245)	(0.391)	(0.654)
Market conditions			
price_competition	0.132	0.060	−0.141
	(0.119)	(0.173)	(0.218)
non_price_ competition	0.143	0.233	0.066
	(0.128)	(0.186)	(0.234)
Control variables			
Region dummies	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes
N	1,228	683	445
Log-likelihood	187.42***	125.78***	77.99***
Pseudo R^2	0.24	0.30	0.29

See Table 1 for the variable definitions; standard errors are in brackets under the coefficients

***, **, * Statistical significance at the 1, 5 and 10 % test level, respectively

assumption, we first tested whether the mean value of each model variable after matching was the same in the treatment group and in the control group. Based on *t* tests, the null hypothesis that the conditions of the two groups do not differ after matching could not be rejected at the 10 % significance level for any explanatory variables in the three models. Furthermore, likelihood-ratio tests indicated joint insignificance of all the right-hand variables after matching. In a next step, we graphically examined the CSC. The graphics showed that after dropping treatment observations whose propensity score was higher than the maximum or less than the minimum propensity score of the controls ('off support' observations), there was to a large extent an overlap of the propensity scores of the treated and untreated firms for each model. We can thus assume that common support is given.

5.2 Treatment effect

5.2.1 Main results

Estimations for the average treatment effect for the treated (ATT) that are based on our representative sample of start-ups are presented in Tables 3, 4 and 5. Table 3 presents the results for initial innovation activities in the period 1996/97–2000, Table 4 the results for the persistence of innovation activities during the first 5–6 years, and Table 5 the results for the persistence over the whole sample period 1996/97–2006.

In line with general expectations we find that on average venture financed firms have a higher

Table 3 Treatment effect for the treated with respect to innovation activities in the period 1996/97–2000

Target variable	Propensity of new products	Propensity of modified products	Propensity of either new or modified products	Propensity of R&D activities	Propensity of patent applications
Unmatched difference	0.072**	0.100**	0.121**	0.010	0.038**
t value	2.11	2.10	2.50	0.24	2.49
ATT	0.017	0.017	0.017	−0.026	0.043
z value	0.31	0.25	0.26	−0.42	1.64
95 % confidence interval	[−0.089; 0.123]	[−0.119; 0.153]	[−0.111; 0.145]	[−0.145; 0.094]	[−0.008; 0.094]
N treated	117	117	117	117	117
N untreated	1,110	1,110	1,110	1,110	1,110
N off support	1	1	1	1	1

Bootstrapping is used to correct standard errors of ATT (1,000 replications)

***, **, * Statistical significance at the 1, 5 and 10 % test level, respectively

Table 4 Treatment effect for the treated with respect to persistent innovation activities in both periods 1996/97–2000 and 2000–2003

Target variable	Propensity of new products	Propensity of modified products	Propensity of either new or modified products	Propensity of R&D activities	Propensity of patent applications
Unmatched difference	0.039	0.063	0.105*	0.044	0.022
t value	1.44	1.14	1.70	0.97	1.55
ATT	0.016	−0.016	−0.033	0.0	0.033
z value	0.32	−0.19	−0.34	0.00	1.12
95 % confidence interval	[−0.083; 0.116]	[−0.187; 0.155]	[−0.224; 0.158]	[−0.145; 0.145]	[−0.025; 0.090]
N treated	61	61	61	61	61
N untreated	620	620	620	620	620
N off support	2	2	2	2	2

Bootstrapping is used to correct standard errors of ATT (1,000 replications)

***, **, * Statistical significance at the 1, 5 and 10 % test level, respectively

propensity of initial innovation activities than other firms (see Table 3). The difference is significant for four out of five measures of innovation propensity. Only with respect to R&D activities, our measure for innovation input, the difference is statistically insignificant. However, the statistical significance of these differences disappear when we control for the initial innovation capabilities of the firms. After matching, venture-financed firms do not show a significantly higher propensity of innovation activities than their non-venture funded firm counterparts, with the exception of a rather weak effect with respect to patenting propensity. Thus, hypothesis 1 does not receive empirical support.

Table 4 presents the results for the investigation of differences between venture-financed firms and non-venture funded firms with respect to the *persistence* of innovation activities over the period 1996/97–2003. In this case, unmatched venture-financed firms show on average a higher propensity than non-venture funded companies only with respect to the introduction of either new or significantly modified products. As for

Table 5 Treatment effect for the treated with respect to persistent innovation activities in all three periods 1996/97–2000, 2000–2003 and 2003–2006

Target variable	Propensity of new products	Propensity of modified products	Propensity of either new or modified products	Propensity of R&D activities
Unmatched difference	0.033	0.049	0.143**	0.034
t value	1.40	0.82	2.08	0.69
ATT	0.05	0	0.1	0.075
z value	1.06	0.00	0.87	0.98
95 % confidence interval	[−0.042; 0.142]	[−0.200; 0.200]	[−0.125; 0.325]	[−0.075; 0.225]
N treated	40	40	40	40
N untreated	405	405	405	405
N off support	0	0	0	0

Bootstrapping is used to correct standard errors of ATT (1,000 replications). Due to the low number of firms that made patent applications in all three periods, no statistics are presented for this measure of innovation activities

***, **, * Statistical significance at the 1, 5 and 10 % test level, respectively

the initial stage, no statistically significant differences for the five innovation measures could be found with respect to the persistence of innovation activities over the period 1996/97–2003 after matching. The results for the persistence of innovation activities over the longer period 1996/97–2006 look quite similar (see Table 5). Before matching, only the propensity to introduce either new or significantly modified products is significantly higher for venture-financed firms. After matching, all differences are statistically insignificant. Accordingly, also hypothesis 2 is not supported by empirical evidence.

Our results are also in line with the findings of the two studies for Germany (Engel and Keilbach 2007) and Austria (Peneder 2010). Thus, venture capital does not make the individual firm more innovative, but it selects more innovative firms and possibly helps them to grow faster, which is not tested in this paper but often reported in existing literature.

We also find that statistically significant differences of innovation performance in favor of venture-financed firms disappear after matching. Thus, venture-financed firms do not perform significantly better than other firms. In accordance with the 'innovation first hypothesis' we can also conclude that the observed differences in innovation performance before matching seem to reflect the selection effects prior to funding and not to be driven by the direct causal impact of venture capital funding itself.

To our knowledge, the impact of venture capital on the persistence of innovation activities has not been analyzed so far. Contrary to the results for initial innovation for the period between 1996/97 and 2000, venture-financed firms do not show before matching a significantly higher persistence of innovation activities than other firms. As a consequence, our results indicate that with respect to the persistence of innovation activities neither the value-providing function nor the selection function of venture capital seem to be effective. A reason for the low relevance of the selection function in the longer period may be that even for specialized experts it is difficult to predict a firm's long term innovation activities based on its initial characteristics.

5.2.2 *Robustness checks*

Our results may be driven by the special characteristics of our data. First, all our innovation measures are based on binary variables. Accordingly, our results may hold with respect to innovation propensity, but probably not for measures of innovation intensity. However, the results of previous studies show that this does not seem to be the case. To the best of our knowledge, no previous firm-level study has found a significantly positive impact of venture capital on the intensity of innovation activities after controlling for the selection effect.

Second, the results with respect to persistence of innovation activities may be insignificant, as we use a quite restrictive definition of persistence. To test the robustness of the results that are based on the long period (Table 5), we alternatively use a less restrictive definition of persistence. For these estimates we define innovation as persistent when a firm had innovation activities at least in two out of three periods. The estimation results confirm previous results (see Table 6A). While the modification slightly increases the unmatched differences (whereupon most differences are still not statistically significant), the treatment effect is still statistically insignificant for all innovation measures.

A third special characteristic of our data is that our definition of venture funding is based on a binary variable that does not measure the volume of received funding. Intuitively we would expect that the impact of venture capital on future innovation activities is positively correlated with the volume of funding. Accordingly, our results may be driven by firms that received only little funding from venture capitalists. To deal with this point, we alternatively estimate the model for the initial stage presented in Table 3 based on a more restrictive definition of venture funding.[13] To this end, we transform our five-level ordinary variable to a binary variable that takes value 1 if the value of the original variable was above 3 and value 0 if not. Results for the respective estimates are presented in Table 6B. While this modification tends to increase the unmatched differences between venture-financed firms and other firms, the differences after matching remain insignificant, with the exception of patenting propensity. The respective difference is after matching statistically significant at the 10 %-level. As patenting is probably a quite costly form of innovation activities, at least for new small firms, it is not surprising that the difference for this variable becomes statistically significant when we control for funding intensity.

Another problem could be that the time distance between venture capital funding and measurement of the innovation propensity is too short. To deal with this fact we tested in alternative estimates, whether the impact of venture capital increases, when we increase the time lag (see Table 6C1, C2). These estimates confirm the results of our main estimates with respect to hypotheses 1 and 2.

[13] As the more restrictive definition of venture funding significantly decreased the number of treated firms, it was not possible to re-estimate the models dealing with the persistence of innovation as well.

6 Summary and conclusions

In this study we investigate the impact of early stage venture capital on innovation activities of Swiss start-ups. This is done based on a cohort of start-ups that is representative of all firms founded in Switzerland in 1996/97 as recorded by a census of the Swiss Federal Statistical Office for this period. The further development of still existing firms is pursued through three surveys in 2000, 2003 and 2006, respectively, during a period of 10 years. In accordance with the literature we test the direct impact of venture capital on innovation activities, thus focusing on the "venture capital first" hypothesis. The identification of the direct effect of venture capital implies, however, that we are able to capture the pure selection effect, as firms that were selected by venture capitalists because they previously showed strong innovation capabilities are also expected to show higher innovation activities afterwards. To overcome this problem we apply a matching approach that controls in detail for the initial innovation capabilities of the firms including several characteristics of the founding persons. We analyze not only the impact of early stage venture capital on innovation performance 3 years after firm foundation but also 6 and 9 years after firm start, respectively, for those firms that survived so long and reported continuous innovation activities (persistence of innovation).

The results support neither the hypothesis of a positive impact on *initial* innovation activities nor the hypothesis of a positive *time-persistent* effect on innovation performance of start-ups. As expected, venture-funded start-ups show a significantly higher innovation propensity than non-funded firms but this superiority disappears after matching. These findings can be interpreted as hints that venture capitalists do select for funding start-ups with a potential of above-average innovation performance but this funding does not seem to contribute to a statistically discernible higher innovation performance as compared with start-ups with similar structural characteristics that do not receive venture capital. Additional estimates

Table 6 Model extensions (ATT for different sub-samples)

Target variable	Propensity of new products	Propensity of modified products	Propensity of either new or modified products	Propensity of R&D activities	Propensity of patent applications
A: Less restrictive definition of persistence (estimates for period 1996/97–2006)					
Unmatched difference	0.071	0.10	0.146*	0.075	0.042**
t value	1.53	1.24	1.76	1.17	2.45
ATT	0.075	0.1	0.125	0.075	0.05
z value	0.94	0.81	1.11	0.71	1.27
95 % confidence interval	[−0.081; 0.231]	[−0.142; 0.342]	[−0.096; 0.346]	[−0.133; 0.283]	[−0.027; 0.127]
N treated	40	40	40	40	40
N untreated	405	405	405	405	405
N off support	0	0	0	0	0
B: Only intensive use of venture capital (impact on innovation activities in the period 1996/97–2000)					
Unmatched difference	0.169***	0.085	0.196**	0.141**	0.097***
t value	3.05	1.10	2.51	2.08	3.97
ATT	0.146	−0.024	0.122	0.073	0.098*
z value	1.38	−0.20	1.08	0.64	1.70
95 % confidence interval	[−0.061; 0.353]	[−0.267; 0.218]	[−0.099; 0.343]	[−0.150; 0.297]	[−0.015; 0.210]
N treated	41	41	41	41	41
N untreated	1,186	1,186	1,186	1,186	1,186
N off support	1	1	1	1	1
C: Increase time lag between venture capital funding and measurement of innovation activities					
C1: Treatment effect for the treated with respect to innovation activities in the period 2000–2003					
Unmatched difference	0.068	0.019	0.082	0.046	0.016
t value	1.63	0.30	1.24	0.91	0.90
ATT	0.049	−0.098	−0.066	0.016	0.016
z value	0.68	−1.06	−0.69	0.19	0.52
95 % confidence interval	[−0.093; 0.191]	[−0.280; 0.084]	[−0.251; 0.120]	[−0.152; 0.185]	[−0.046; 0.078]
N treated	61	61	61	61	61
N untreated	620	620	620	620	620
N off support	2	2	2	2	2
C2: Treatment effect for the treated with respect to persistent innovation activities in both periods 2000–2003 and 2003–2006					
Unmatched difference	0.060*	0.050	0.151**	0.049	
t value	1.76	0.72	2.02	0.96	
ATT	0.050	0.025	0.125	0.100	
z value	0.76	0.24	1.03	1.17	
95 % confidence interval	[−0.078; 0.178]	[−0.183; 0.233]	[−0.112; 0.362]	[−0.067; 0.267]	
N treated	40	40	40	40	
N untreated	405	405	405	405	
N off support	0	0	0	0	

Bootstrapping is used to correct standard errors of ATT (1,000 replications). Due to the low number of firms that made patent applications in both periods, no statistics are presented for this measure of innovation activities

***, **, * Statistical significance at the 1, 5 and 10 % test level, respectively

based on (a) an alternative specification of the venture capital variable and (b) on a less restrictive definition of persistence yield no additional insights, but demonstrate the robustness of the main results. On the whole, the results of our study are in accordance with the findings of the few other studies that analyze the direct linkage between venture capital and a firm's innovation activities. Results of previous studies, however, indicate that there may be an indirect linkage on the aggregated level. As venture capital (a) selects more innovative firms and (b) seems to stimulate the economic performance (e.g., growth) of these firms, aggregated innovation may nevertheless be positively affected by venture capital funding.

Specific features of the study that demonstrate the original elements it contributes to the literature are that (a) it is based on a sample of greenfield start-ups that is representative for the entire cohort 1996/97 of Swiss start-ups, (b) it uses several innovation measures (other than patenting), and (c) examines the effect on innovation persistence. This last point is relevant also for policy makers that pursue policy concepts of innovation promotion through venture capital funding and can be seen as a warning of too optimistic expectations with respect to the effectiveness of such concepts.

Appendix

See Tables 7, 8, 9, 10 and 11.

Table 7 Descriptive statistics based on model (1); $N = 1{,}228$

Statistic	Mean	Std. dev.	Min	Max
new_products	0.15	0.35	0	1
modified_products	0.42	0.49	0	1
new/modified_products	0.50	0.50	0	1
R&D_activities	0.25	0.43	0	1
patent_applications	0.03	0.16	0	1
Founder characteristics				
average_age	39.47	9.19	18	65
dominant_gender	0.74	0.44	0	1
technical_share	0.44	0.45	0	1
creativity	3.87	1.05	1	5
Financial structure				
personal_savings	4.09	1.27	1	5
retained_earning	2.61	1.62	1	5
private_loans	1.86	1.40	1	5
bank_loan	1.60	1.14	1	5
customer_prepayments	1.28	0.85	1	5
supplier_credit	1.19	0.63	1	5
public_funding	1.08	0.45	1	5
Firm characteristics				
public_limited_company	0.18	0.38	0	1
private_limited_company	0.26	0.44	0	1
legally_independent	0.97	0.16	0	1
tertiary_employees	0.67	0.47	0	1
business_plan	0.41	0.49	0	1
many_customers	0.53	0.50	0	1
export_share	0.10	0.24	0	1
firm_size_1–2	0.28	0.45	0	1
firm_size_2–4	0.11	0.31	0	1
firm_size_ >4	0.06	0.24	0	1
Market conditions				
price_competition	0.42	0.49	0	1
non_price_competition	0.54	0.50	0	1

Table 8 Descriptive information about the frequency of innovation activities for the firms that answered all three questionnaires ($N = 630$)

Variable	Frequency of innovation activities		
	No (%)	Discontinuous (%)	Persistent (%)
new_products	75.4	22.4	2.2
modified_products	34.9	50.6	14.4
new/modified_products	30.5	47.8	21.7
R&D_activities	68.1	22.7	9.2
patent_applications	96.0	3.8	0.2

Table 9 Test balancing property and common support of model (1)

Variable	Sample	Treated	Control	t	$p > \|t\|$
Founder characteristics					
average_age	Unmatched	37.458	39.682	−2.50	0.012
	Matched	37.508	38.112	−0.54	0.592
dominant_gender	Unmatched	0.80508	0.72793	1.81	0.071
	Matched	0.80342	0.79487	0.16	0.871
technical_share	Unmatched	0.48164	0.43559	1.05	0.294
	Matched	0.47721	0.45726	0.35	0.730
creativity	Unmatched	4.1271	3.8432	2.81	0.005
	Matched	4.1282	4.0855	0.34	0.734
Financial structure					
personal_savings	Unmatched	3.678	4.1297	−3.69	0.000
	Matched	3.7009	3.3846	1.60	0.111
retained_earning	Unmatched	3.0339	2.5649	2.99	0.003
	Matched	3.0342	3.2308	−0.94	0.348
private_loans	Unmatched	2.6441	1.7775	6.50	0.000
	Matched	2.6239	2.5983	0.12	0.903
bank_loan	Unmatched	1.8559	1.5748	2.54	0.011
	Matched	1.8547	1.8632	−0.05	0.958
customer_prepayments	Unmatched	1.5932	1.2477	4.22	0.000
	Matched	1.5726	1.5641	0.05	0.957
supplier_credit	Unmatched	1.3644	1.1667	3.26	0.001
	Matched	1.3675	1.3846	−0.15	0.883
public_funding	Unmatched	1.322	1.0559	6.26	0.000
	Matched	1.3248	1.2393	0.78	0.439
Firm characteristics					
public_limited_company	Unmatched	0.38983	0.15676	6.38	0.000
	Matched	0.38462	0.39316	−0.13	0.894
private_limited_company	Unmatched	0.32203	0.25135	1.67	0.095
	Matched	0.32479	0.40171	−1.22	0.223
legally_independent	Unmatched	0.89831	0.98288	−5.64	0.000
	Matched	0.90598	0.90598	−0.00	1.000
tertiary_employees	Unmatched	0.77119	0.65766	2.50	0.013
	Matched	0.76923	0.74359	0.46	0.649
business_plan	Unmatched	0.5339	0.3991	2.84	0.005
	Matched	0.52991	0.53846	−0.13	0.896
many_customers	Unmatched	0.5	0.53784	−0.78	0.434
	Matched	0.50427	0.57265	−1.05	0.296
export_share	Unmatched	0.88903	0.80618	0.57	0.567
	Matched	0.89663	0.91433	−0.09	0.932
firm_size_1–2	Unmatched	0.33051	0.27117	1.37	0.171
	Matched	0.32479	0.36752	−0.68	0.494
firm_size_2–4	Unmatched	0.17797	0.1045	2.41	0.016
	Matched	0.17949	0.17949	0.00	1.000

Table 9 continued

Variable	Sample	Treated	Control	*t*	$p > \|t\|$
firm_size_ >4	Unmatched	0.09322	0.05676	1.58	0.114
	Matched	0.09402	0.13675	−1.02	0.308
Market conditions					
price_competition	Unmatched	0.48305	0.41441	1.44	0.151
	Matched	0.48718	0.45299	0.52	0.602
non_price_competition	Unmatched	0.61864	0.53604	1.71	0.087
	Matched	0.61538	0.66667	−0.82	0.416
Summary of the distribution of the abs(bias)					
Mean abs(bias)	Unmatched	16.25			
	Matched	7.02			
LR chi^2	Unmatched	187.42***			
	Matched	20.93			

Furthermore, control variables for region and industry affiliation were included. All these variables are not significantly different for the matched treated and control units

***, **, * Statistical significance at the 1, 5 and 10 % test level, respectively

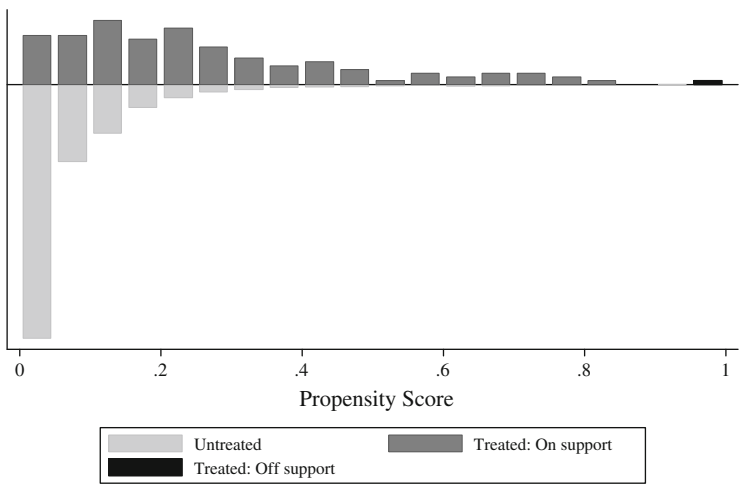


Table 10 Test balancing property and common support of model (2)

Variable	Sample	Treated	Control	*t*	$p > \|t\|$
Founder characteristics					
average_age	Unmatched	36.568	39.923	−2.86	0.004
	Matched	36.696	36.17	0.36	0.716
dominant_gender	Unmatched	0.74603	0.7129	0.55	0.579
	Matched	0.7541	0.68852	0.80	0.423
technical_share	Unmatched	0.44974	0.45726	−0.12	0.901
	Matched	0.45902	0.46175	−0.03	0.973

Table 10 continued

Variable	Sample	Treated	Control	t	$p > \|t\|$
creativity	Unmatched	4.254	3.8242	3.16	0.002
	Matched	4.2459	4.4426	−1.53	0.128
Financial structure					
personal_savings	Unmatched	3.8889	4.1661	−1.67	0.095
	Matched	3.8525	3.7705	0.30	0.764
retained_earning	Unmatched	3.4444	2.5677	4.12	0.000
	Matched	3.4098	3.377	0.12	0.908
private_loans	Unmatched	2.6349	1.829	4.32	0.000
	Matched	2.6066	2.7377	−0.44	0.658
bank_loan	Unmatched	1.9206	1.5419	2.52	0.012
	Matched	1.9344	2.0164	−0.34	0.736
customer_prepayments	Unmatched	1.746	1.2774	3.95	0.000
	Matched	1.7213	1.8033	−0.33	0.742
supplier_credit	Unmatched	1.4603	1.1548	3.69	0.000
	Matched	1.4262	1.4098	0.09	0.929
public_funding	Unmatched	1.4444	1.0565	6.46	0.000
	Matched	1.3443	1.3115	0.20	0.839
Firm characteristics					
public_limited_company	Unmatched	0.36508	0.14355	4.59	0.000
	Matched	0.36066	0.2623	1.17	0.244
private_limited_company	Unmatched	0.30159	0.23548	1.17	0.243
	Matched	0.31148	0.29508	0.20	0.845
legally_independent	Unmatched	0.90476	0.98387	−4.00	0.000
	Matched	0.90164	0.91803	−0.31	0.754
tertiary_employees	Unmatched	0.74603	0.66613	1.29	0.198
	Matched	0.77049	0.77049	0.00	1.000
business_plan	Unmatched	0.50794	0.40161	1.63	0.103
	Matched	0.5082	0.52459	−0.18	0.858
many_customers	Unmatched	0.52381	0.5629	−0.59	0.552
	Matched	0.52459	0.52459	0.00	1.000
export_share	Unmatched	1.0509	0.79274	1.31	0.192
	Matched	1.0853	1.0635	0.07	0.942
firm_size_1–2	Unmatched	0.26984	0.26129	0.15	0.883
	Matched	0.27869	0.21311	0.84	0.405
firm_size_2–4	Unmatched	0.14286	0.1	1.06	0.289
	Matched	0.14754	0.14754	0.00	1.000
firm_size_ >4	Unmatched	0.07937	0.05645	0.74	0.461
	Matched	0.08197	0.03279	1.16	0.246
Market conditions					
price_competition	Unmatched	0.49206	0.40161	1.39	0.165
	Matched	0.4918	0.44262	0.54	0.590

Table 10 continued

Variable	Sample	Treated	Control	t	$p > \|t\|$
non_price_competition	Unmatched	0.63492	0.52258	1.70	0.089
	Matched	0.62295	0.59016	0.37	0.714
Summary of the distribution of the abs(bias)					
Mean abs(bias)	Unmatched	19.99			
	Matched	8.62			
LR chi^2	Unmatched	125.78***			
	Matched	22.02			

Furthermore, control variables for region and industry affiliation were included. All these variables are not significantly different for the matched treated and control units

***, **, * Statistical significance at the 1, 5 and 10 % test level, respectively

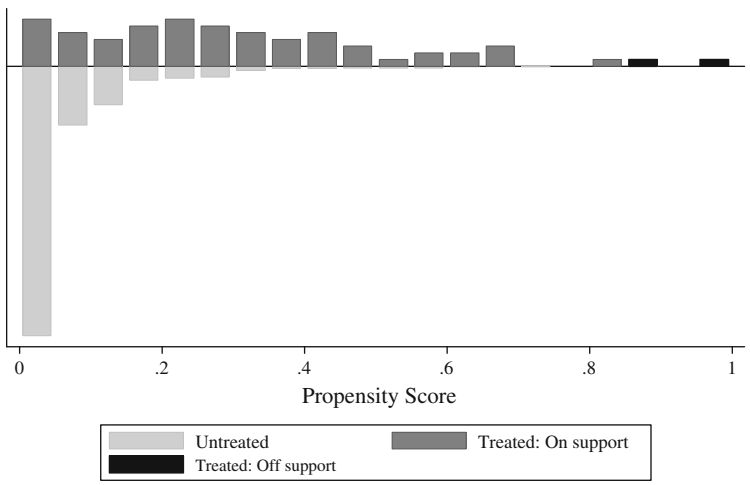


Table 11 Test balancing property and common support of model (3)

Variable	Sample	Treated	Control	t	$p > \|t\|$
Founder characteristics					
average_age	Unmatched	36.305	39.704	−2.32	0.021
	Matched	36.305	36.804	−0.30	0.769
dominant_gender	Unmatched	0.675	0.70864	−0.44	0.657
	Matched	0.675	0.625	0.46	0.644
technical_share	Unmatched	0.4375	0.46337	−0.34	0.733
	Matched	0.4375	0.52917	−0.91	0.364
creativity	Unmatched	4.275	3.8321	2.59	0.010
	Matched	4.275	4.375	−0.60	0.550
Financial structure					
personal_savings	Unmatched	4.075	4.1481	−0.36	0.722
	Matched	4.075	4.175	−0.34	0.732

Table 11 continued

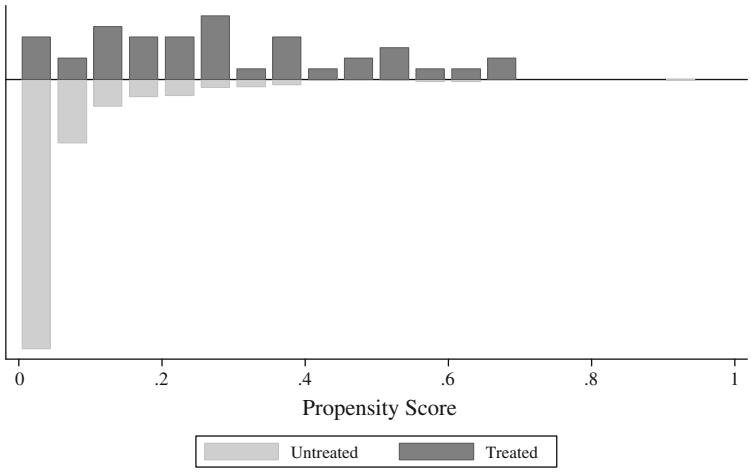
Variable	Sample	Treated	Control	t	$p > \|t\|$
retained_earning	Unmatched	3.225	2.6667	2.10	0.036
	Matched	3.225	3.375	−0.42	0.672
private_loans	Unmatched	2.775	1.7852	4.29	0.000
	Matched	2.775	2.7	0.19	0.846
bank_loan	Unmatched	2.025	1.5877	2.23	0.026
	Matched	2.025	2.1	−0.24	0.813
customer_prepayments	Unmatched	1.7	1.2914	2.67	0.008
	Matched	1.7	1.675	0.09	0.932
supplier_credit	Unmatched	1.425	1.1383	2.97	0.003
	Matched	1.425	1.275	0.77	0.446
public_funding	Unmatched	1.325	1.0494	4.45	0.000
	Matched	1.325	1.125	1.33	0.187
Firm characteristics					
public_limited_company	Unmatched	0.225	0.1358	1.53	0.126
	Matched	0.225	0.2	0.27	0.788
private_limited_company	Unmatched	0.35	0.26173	1.20	0.231
	Matched	0.35	0.375	−0.23	0.819
legally_independent	Unmatched	0.925	0.98765	−2.86	0.004
	Matched	0.925	0.9	0.39	0.697
tertiary_employees	Unmatched	0.7	0.66667	0.43	0.670
	Matched	0.7	0.7	0.00	1.000
business_plan	Unmatched	0.475	0.39506	0.98	0.326
	Matched	0.475	0.575	−0.89	0.377
many_customers	Unmatched	0.525	0.58025	−0.67	0.501
	Matched	0.525	0.55	−0.22	0.825
export_share	Unmatched	1.0025	0.7579	1.03	0.306
	Matched	1.0025	0.89279	0.31	0.756
firm_size_1–2	Unmatched	0.225	0.2716	−0.63	0.526
	Matched	0.225	0.2	0.27	0.788
firm_size_2–4	Unmatched	0.15	0.10617	0.84	0.399
	Matched	0.15	0.15	−0.00	1.000
firm_size_ >4	Unmatched	0.025	0.05926	−0.90	0.370
	Matched	0.025	0.025	−0.00	1.000
Market conditions					
price_competition	Unmatched	0.45	0.41975	0.37	0.713
	Matched	0.45	0.475	−0.22	0.825
non_price_competition	Unmatched	0.6	0.54815	0.63	0.530
	Matched	0.6	0.625	−0.23	0.821
Summary of the distribution of the abs(bias)					
Mean abs(bias)	Unmatched	19.53			
	Matched	9.08			

Table 11 continued

Variable	Sample	Treated	Control	t	$p > \|t\|$
LR chi^2	Unmatched	77.99***			
	Matched	13.59			

Furthermore, control variables for region and industry affiliation were included. All these variables are not significantly different for the matched treated and control units

***, **, * Statistical significance at the 1, 5 and 10 % test level, respectively



References

Arvanitis, S., & Stucki, T. (2012). What determines the innovation capability of firm founders? *Industrial and Corporate Change, 21*(4), 1049–1084.

Baum, J. A. C., & Silverman, B. S. (2004). Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology startups. *Journal of Business Venturing, 19*(3), 411–436.

Binks, M. R., & Ennew, C. T. (1996). Growing firms and the credit constraint. *Small Business Economics, 8*(1), 17–25.

Bogliacino, F., & Lucchese, M. (2011). Access to finance for innovation: The role of venture capital and the stock market. *IPTS Working Paper on Corporate R&D and Innovation—No. 5/2011*, European Union, Seville.

Caliendo, M., & Kopeinig, S. (2008). Some practical guidance for the implementation of propensity score matching. *Journal of Economic Surveys, 22*(1), 31–72.

Caselli, S., Gatti, S., & Perrini, F. (2009). Are venture capitalists a catalyst for innovation? *European Financial Management, 15*(1), 92–111.

Chemmanur, T. J., Loutskina, E., & Tian, X. (2011). Corporate venture capital, value creation, and innovation. Unpublished working paper.

Cumming, D. (2012). *The oxford handbook of entrepreneurial finance*. Oxford: Oxford University Press.

Da Rin, M., Hellmann, T.F., & Puri, M. (2011). A survey of venture capital research. *NBER Working Papers No. 17523*, Cambridge, MA.

Da Rin, M., & Penas, M. F. (2007). The effect of venture capital on innovation strategies. *NBER Working Papers No. 13636*, Cambridge, MA.

DiPrete, T. A., & Gangl, M. (2004). Assessing bias in the estimation of causal effects: Rosenbaum bounds on matching estimators and instrumental variables estimation with imperfect instruments. *Sociological Methodology, 34*(1), 271–310.

Engel, D., & Keilbach, M. (2007). Firm level implications of early stage venture capital investment—An empirical investigation. *Journal of Empirical Finance, 14*, 150–167.

Gompers, P., & Lerner, J. (2001). The venture capital revolution. *Journal of Economic Perspectives, 15*(2), 145–168.

Griliches, Z. (1990). Patent statistics as economic indicators: A survey. *Journal of Economic Literature, 28*, 1661–1707.

Hall, B. H. (2002). The financing of research and development. *Oxford Review of Economic Policy, 18*(1), 35–51.

Hall, B. H., Ham, T., & Ziedonis, R. H. (2001). The patent paradox: An empirical study of patenting in the US semiconductor industry, 1979–1995. *RAND Journal of Economics, 32*(1), 101–128.

Hellmann, T. (2000). Venture capitalists: The coaches of Silicon Valley. In W. Miller, C. M. Lee, M. G. Hanock, & H. Rowen (Eds.), *The Silicon Valley edge: A habitat for*

innovation and entrepreneurship (pp. 267–294). Stanford, CA: Stanford University Press.

Hellmann, T., & Puri, M. (2000). The interaction between product market and financing strategy: The role of venture capital. *Review of Financial Studies, 13*(4), 959–984.

Hirukawa, M., & Ueda, M. (2011). Venture capital and innovation: Which is first? *Pacific Economic Review, 16*(4), 421–465.

Hopp, C. (2007). Nothing ventured–nothing gained? Empirical evidence on venture capital financing in Switzerland. *Schweizerische Zeitschrift für Volkswirtschaft und Statistik, 1433*, 239–260.

Kleinknecht, A., van Montfort, K., & Brouwer, E. (2002). The non-trivial choice between innovation indicators. *Economics of Innovation and New Technology, 11*(2), 109–121.

Kortum, S., & Lerner, J. (2000). Assessing the contribution of venture capital to innovation. *The Rand Journal of Economics, 31*(4), 674–692.

Peneder, M. (2010). The impact of venture capital on innovation behaviour and firm growth. *Venture Capital: An International Journal of Entrepreneurial Finance, 12*(2), 83–107.

Revest, V., & Sapio, A. (2012). Financing technology-based small firms in Europe: What do we know? *Small Business Economics, 39*, 179–205.

Rogers, M. (1998). *The definition and measurement of innovation*. Parkville, VIC: Melbourne Institute of Applied Economic and Social Research.

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika, 70*(1), 41–55.

Rosenbusch, N., Brinckmann, J., & Müller, V. (2013). Does acquiring venture capital pay off for the funded firms? A meta-analysis on the relationship between venture capital investment and funded firm financial performance. *Journal of Business Venturing*, *28*(3), 335–353.

Savignac, F. (2008). Impact of financial constraints on innovation: What can be learned from a direct measure? *Economics of Innovation and New Technology, 17*(6), 553–569.

Stiglitz, J. E., & Weiss, A. (1981). Credit rationing in markets with imperfect information. *American Economic Review, 71*(3), 393–410.

Tian, X., & Wang, T. Y. (2013). Tolerance for failure and corporate innovation. *Review of Financial Studies*, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1399707. Accessed 27 July 2013.

Wright, M., Gilligan, J., & Amess, K. (2009). The economic impact of private equity: What we know and what we would like to know. *Venture Capital, 22*(1), 1–21.