Discussion Paper No. 02-82

Firm Level Implications of Early Stage Venture Capital Investment – An Empirical Investigation –

Dirk Engel and Max Keilbach

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Nicht technische Zusammenfassung

Der Beitrag von Venture Capital Finanzierung auf Unternehmenswachstum und Innovationsgeschehen ist derzeit ein stark diskutiertes Thema. Generell wird davon ausgegangen, dass Venture Capital finanzierte Unternehmen signifikant höhere Innovationsaktivitäten aufweisen und deren Unternehmenswachstum außergewöhnlich hoch ist. Das vorliegende Papier möchte zu dieser Debatte beitragen. Wir analysieren den Einfluss von Venture Capital Finanzierung auf Innovationsverhalten und Unternehmenswachstum für Start-Ups in Deutschland. Neben anderen Variablen enthält unser Unternehmenspanel Daten zu Venture Capital Finanzierung und zu Patentanmeldungen am Deutschen Patentamt. Auf Basis eines statistischen Matchingverfahrens ziehen wir eine adäquate Kontrollgruppe von Unternehmen, die nicht Venture Capital finanziert, jedoch ansonsten sehr ähnlich sind. Die Analyse zeigt, dass innovative Firmen mit höherer Wahrscheinlichkeit einen Venture Capital Deal abschließen können. Sie zeigt weiterhin, dass Venture Capital finanzierte Firmen tatsächlich höhere Wachstumsraten aufweisen, wenn auch der Unterschied wesentlich geringer ist, als allgemein angenommen. Das Innovationsverhalten von Venture Capital finanzierten Firmen unterscheidet sich nach Eintritt des Venture Capitalisten nicht mehr von den Unternehmen der Kontrollgruppe. Wir schließen daraus, dass Venture Capitalisten eher innovative Firmen finanzieren, dass sie jedoch mit Beginn des Engagements verstärkt auf die Vermarktung der Produkte hinwirken; dies führt dann zu höherem Unternehmenswachstum.

Non technical summary

Recently, the impact of venture capital to innovation and economic growth has widely been discussed. It is claimed that venture funded firms are more innovative and show tremendously higher growth rates. This paper aims to contribute to that debate. The paper analyses the impact of venture capital finance on growth and innovation activities of young German firms. Amongst other variables, our panel of firm data includes data on venture capital funding and patent applications. With a statistical matching procedure we draw an adequate control group of non venture funded firms. The analysis gives evidence that innovative firms will be able to close a venture capital deal with higher probability. Once the firms are venture funded, they display higher growth rates but do not differ in their innovative output from otherwise comparable firms. We conclude from these findings that in an attempt to maximize sales, venture capital investors assist their portfolio firms in their effort to commercialization, rather than in further innovation. Commercialization is probably done by financial means but also by means of management assistance. It is also possible that venture investors are more aware of possible commercialization channels.

Firm Level Implications of Early Stage Venture Capital Investment.* – An Empirical Investigation –

Dirk Engel† Max Keilbach‡

Abstract

The paper analyses the impact of venture capital finance on growth and innovation activities of young German firms. Among other variables, our panel of firm data includes data on venture capital funding and patent applications. With a statistical matching procedure we draw an adequate control group of non venture funded firms. The analysis gives evidence that innovative firms will be able to close a venture capital deal with higher probability. Once the firms are venture funded, they display higher growth rates but do not differ in their innovative output from otherwise comparable firms. We derive strategic implications.

Keywords: Firm Demography, Firm Start-Ups, Firm Growth, Venture Capital, Patented Inventions, Microeconometric Evaluation Methods
JEL-Classification: L 21, D21, D92, C14, C33

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1 Introduction

Between 1995 and 2000 the German venture capital market has made an extraodinary evolution in that the the volume of newly closed deals has increased by a factor of nearly 8. One major factor in this regard was certainly the introduction of the “Neuer Markt”, the German correspondence to the NASDAQ, and the exit opportunities related to it. A second major factor was the diffusion and adoption of information and communication technologies that were expected to exhibit large growth rates but required large initial investments that classic banks were usually not able to finance. Finally, a third factor in Germany was the influence of the “Technologiebeteiligungsgesellschaft (tbg)”, a public organization that co-invests with private lead investors to double the volume of the deal. Moreover, it acts similar to an insurance, i.e. it partly covers the risk of failure of a deal.

The commitment of the German government to ease the access of technology oriented firms to funds is based on the assumption, that young and technology oriented firms are more innovative and therefore will more easily be able to open or capture new market niches. Thus, these firms are supposed to exhibit higher growth rates and therefore to foster structural adjustments of the economy. If these firms are provided with venture capital and with the corresponding services (such as mangement support) - so the implicit assumption - they will be able to perform even better.

In this paper, we investigate this assumptions empirically. Is it true that venture funded firms perform better in terms of employment growth rates and innovative output? To do so, we set up a new dataset on young German firms. For each of these firms, apart of a number of firm-specific, industry specific or regional variables, we identify whether the firm has been venture capital funded or not. By merging this dataset with data from the German Patent Office, we are able to describe the innovative behaviour of these firms by proxying innovative output with the number of patent applications. Then venture capital funded firms are compared with others in terms of growth rate and innovative output using a statistical matching approach. This approach reduces statistical biases that would occur if firms of different characteristics would be compared.

The paper gives evidence on several levels: Firms with high innovation output are able to engage a venture capitalist with higher probability. Once a venture capitalist is involved, firms show higher employment growth rates but no significant differences in innovative output. We conclude from this findings that after venture capitalists’ involvements, firms switch from innovation to commercialization of their products and

this way are able to realize superior growth rates.

The following section gives an overview on the literature on the implications of venture capital funding on firm growth and innovation, section 3 presents the dataset, section 4 presents the evalutation procedure, results are dicussed in sections 5 and 6.

2 On the Impact of Venture Capital Funding on Growth and Innovative Behaviour of Firms - A Survey on the Literature

venture capital is a financing form suitable for projects or ventures that involve large financial requirements and high uncertainty about risks involved but at the same time a high potential for growth hence potentially large profits. A deal between a venture capitalist and a Portfolio Firm implies that the former provides venture Funding but also management advice to close the gap in managing non-technical shortcomings (Amit *et al.*, 1998, Berger and Udell, 1998, Gompers and Lerner, 1999).

Very often, the selection of portfolio firms is made under the assumption that *innovative firms* have a higher growth potential and therefore offer larger potential profits. In this section we give a survey on the literature on venture capital an its relation to firm performance and innovation.

2.1 On Venture Capital and Firm Growth

A number of recent studies examine empirically the relationship between receiving venture capital and firm performance (see Schefczyk(2000) for a detailed overview). Sapienza(1992) found that the provided services are positively related to the performance of venture funded firms. Jain and Kini(1995) show that venture funded firms publicly offered at stockmarkets have a higher cash flow and sales growth. Lerner (1999) evaluates the longrun success of firms participating in the Small Business Innovation Research (SBIR) program, a major public assistance initiative in the United States for hightechnology firms. Those firms receiving assistance from SBIR achieve significantly higher employment and sales growth rates than similar No-SBIR assisted firms between 1983 and 1995. These differences are even more pronounced in ZIP codes with high venture capital activity. The findings of Manigart and Hyfte(1999) for 187 Belgian venture funded firms are quite different. Belgian venture funded firms do not achieve a significant higher employment growth compared to non venture funded

firms of the same industries, of similar size, and similar age. However, higher growth rates in total assets and cash flow are obvious. Buergel *et al.*(2000) do not observe any significant effect of venture capital finance on firms' sales and employment growth. Their multivariate analysis of the determinants of firm growth is based on a questionnaire of 500 German and British high-tech start-ups. In a study by Coopers&Lybrand and EVCA it is found that venture funded firms grew more than seven times faster than the European top 500 firms. This is impressive, however it remains unclear what drives this difference since the choice of the control group seems not to be made appropriately within that study.[1] The approach to be used in this paper (discussed in section 4) will take this into account.

2.2 On Venture Capital and Firms' Innovative Bevahiour

Despite the increasing importance of venture capital investment, the relation between this type of investment and the innovative behaviour of firms has been analyzed only rarely. For Germany, to our knowledge, there does not exist any analysis. Kortum and Lerner(1998, 2000) examine the influence of venture capital on patented innovation in the US. Their analysis is based on data on manufacturing industries between 1965 and 1992, using observations on counts of issued patents and venture funding. Using a number of different structural forms of a patent production function, they estimate the productivity of venture capital financed innovation projects to be significantly higher as compared to projects financed by private R&D funds, although these estimates differ widely according to the specification of the regression equation[2].

The authors also address the concern that this result might be due to a different patenting behaviour of venture funded firms due to strategic reasons. Obviously, a firm in search for venture capital will increase its chances to close a deal when it proofs its innovative performance to be high. Then, a corresponding strategy would be to apply for a maximum of patents. A second reason for firms seeking for venture investment to have stronger incentives to patent might be the fact that every application for venture funding implies disclosure of underlying ideas. These might subsequently be exploited by venture investors if not protected by patents. Both reasons would lead to a significant positive bias in the number of patent applications, and probably in the number of subsequently issued patents. However, if this bias is a mere consequence

[1] Section 4 discusses this problem in detail.

[2] Depending on the form of the regression equation, they estimate this difference between 1.5 and 40, most of the estimation results lying between 1.5 and 3.

of strategic behaviour, we should expect a negative correlation between the number of awarded patents of a firms and the value of these patents.

Using then a sample of 530 firms, Kortum and Lerner could show that venture funded firms do not only receive a larger number of patent awards but also higher scores concerning different value correlated variables (such as citations and law suits). They take these findings as evidence in favor of the hypothesis that venture funded firms are more innovative, producing a larger and higher valued stock of patents.

The approach chosen in this paper is different compared to the one chosen by Kortum and Lerner in that it uses firm level data instead of industry data. This approach enables us to identify a number of firm specific variables that can be expected to influence firms' growth and innovative performance. We are also able to identify the time of venture vapitalists' engagement and hence to compare the firms' performance before and after that. Based on a generalized matching approach we are able to compare firms with and without venture financing but otherwise similar. The following section describes the data, section 4 gives a short overview on the matching process.

3 The Data

Our analysis is based on the ZEW-Foundation Panels. This firm specific data is provided to the ZEW since 1990 by *Creditreform*, the largest German credit rating agency (see Almus, Engel and Prantl (2000) for more details). This dataset comprises virtually all firms registered in the German trade register. However, the entry probability of unregistered firms depends on the scope of their credit demand and of their business relations to other firms. Firms are entered in the database only with a time lag. Thus, only 60 percent of the start-ups being founded since 2000 are recorded for the first time enquired by Creditreform by January 2002. Therefore, the analysis focuses on new firms with foundation date between 1995 and 1998 to avoid selection problems inside the cohorts. With this database we cover virtually all firm start-ups from that time period that received venture capital. The Data is updated regularly through biannual data deliveries (waves) by Creditreform which allows us to build up a panel structure. Updates cover information on previously surveyed firms and information about newly created firms.

This database covers a number of firms specific variables, such as number of firms' employees, foundation date, main economic activity (i.e. industry affiliation expressed by NACE classification), legal state, details on natural and legal owners, owners lia-

bility status and finally firms' addresses. A number of variables concerning the environment of firms can be derived from the latter. This includes e.g. information on the population density of the region of the firm or distances to different types of scientific research centers. The database does not explicitly cover information on whether the firm is venture funded, on the firms' growth rate or on the number of patents applied for by each firm. These variables are computed or merged with information from other sources.

The identification of *venture funded firms* is based on a computer-assisted string search (including information on names and office of venture capital companies) in the variables covering ownership information. All venture capital companies that are private equity investors and full members of European venture capital Association (EVCA) or German venture capital Association e.V. (BVK) are considered (BVK, 2000b, 2000a; EVCA, 2000). Associate members are not taken into consideration because their business activities focus on management support. Additionally, members of U.S. National venture capital Association are considered with activities in 1999 at the U.S. venture capital market (VentureOne, 1999) and a search for key words like "venture capital", "Private Equity" is done to identify firms with obvious venture capital activities. We did not include ventures with a silent partner (such as e.g. business angels) since they are not recorded in the trade register (Jacobs and Scheffler, 1998). However, exclusively silent partnerships do not play an important role in early stage financing of profit accounting venture capitalists (see Engel(2001) for further explanations).

The *Rate of Average Annual Employment Growth* g_i for each firm i is computed as

$$g_i = \frac{\ln E_{i,t_l} - \ln E_{i,t_k}}{t_l - t_k}, \tag{1}$$

where t_k, t_l denote time instances $(t_l > t_k)$ and $E_{i,t}$ denotes the number of employees of firm i at time t. Note that t_k and t_l might be different for firms of different cohorts.

Innovative behaviour is measured using count data on patent applications at the German Patent Office (DPA). To apply for a patent at the DPA implies lower fees as compared to applications ath the European Patent Office (EPO). This implies that smaller firms that are not able (or not willing) to bring up the higher fees will apply at the DPA alone. On the other hand, applications at the EPO that cover the German territory will be appear in the DPA dataset(PATDPA). Hence, we can expect the German database to be more complete.

The assignment of patent applications to firms is realized using a computer-assisted merging procedure similar to the one used for identification of venture funded firms.

Both data bases, the firm data and the patent application data cover information on the firms' names and their location. The merging algorithm synchronizes both databases using the information in these strings.

We limit the analysis to industries with ocurrence of at least one venture funded firm. Also, we do not consider firms with legal forms other than Limited Partnership (GmbH or GmbH & Co. KG) or Public Limited Companies (AG) since, due to their liablity status, the registration of entry time in the underlying database can be very biased. Thus, our database covers 50,754 non venture funded firms and 274 venture funded firms (corresponding to 0.53 % of the sample).

Table 1 enumerates the variables in the dataset. Columns 2 and 3 of this Table show the mean value of each variable for each of these set of firms as well as the results of a statistical test for identity. The values express shares unless expressed otherwise where shares are not meaningful. In this dataset we included only firms that have at least two entries with respect to their firm size such that a growth rate can be computed according to equation (1). This reduces the number of non venture funded firms to 21,375 and of venture funded-firms to 142 (i.e. 0.66%).

Table 1: Difference between venture funded firms and control group

	Shares (unless denoted otherwise)	
Firm characteristics at foundation	**VF**	**NVF**
Firm-specific characteristics		
Startup size (number of employees)	6.979	5.165∗∗
Limited Partnership (GmbH & Co KG	0.148	0.092∗
Public limited company (AG)	0.099	0.016∗∗∗
Involvement of other (non VC) firms	0.472	0.279∗∗∗
Team foundation	0.620	0.451∗∗∗
Founding team of mixed gender	0.106	0.123
Founders are of female gender	0.014	0.103∗∗∗
Gender Unknown	0.120	0.083
Qualification of Founders		
Doctoral Degree	0.289	0.078∗∗∗
Postgraduate Degree	0.528	0.385∗∗∗
Higher Education on the Job	0.014	0.074∗∗∗
Medium Education on the Job	0.254	0.389∗∗∗
Low Education	0.021	0.028
Education Level unknown	0.296	0.244
Patenting Behavior		

Continued on next page

Table 1: (continued)

Firm characteristics at foundation	Shares (unless denoted otherwise) **VF**	**NVF**
No patents until foundation date	0.894	0.979∗∗∗
One patent until foundation date	0.035	0.009∗
2...4 patent until foundation date	0.028	0.008
5...19 patent until foundation date	0.042	0.004∗
20...49 patent until foundation date	0.000	0.000
Industry affiliation (with Nace code)		
Manuf. of food products etc. (15)	0.007	0.021∗
Manuf. of wearing apparel etc. (18)	0.007	0.005
Manuf. of wood and its products etc. (20)	0.014	0.015
Publishing, printing etc. (22)	0.021	0.045∗
Manuf. of chemicals and chemical products (24)	0.028	0.014
Manuf. of rubber and plastic products (25)	0.007	0.020∗
Manuf. of other non-metallic mineral products (26)	0.021	0.023
Manuf. of fabricated metal products etc. (28)	0.021	0.071∗∗∗
Manuf. of machinery and equipment n.e.c. (29)	0.021	0.060∗∗∗
Manuf. of office machinery and computers (30)	0.021	0.011
Manuf. of electrical machinery and apparatus n.e.c. (31)	0.042	0.015
Manuf. of radio, television and communication equipment (32)	0.021	0.010
Manuf. of medical, precision and optical instruments etc. (33)	0.035	0.039
Manuf. of motor vehicles, trailers and semi-trailers (34)	0.014	0.012
Manuf. of furniture; manufacturing n.e.c. (36)	0.007	0.022∗∗
Recycling (37)	0.021	0.014
Postal and telecommunication services (64)	0.007	0.005
Computer and related activities (72)	0.197	0.129∗∗
Research and development (73)	0.148	0.024∗∗∗
Other business activities (740)	0.007	0.006
Business Related Services (741)	0.148	0.144
Architectural and engineering activities (742)	0.049	0.135∗∗∗
Technical testing and analysis (743)	0.000	0.000
Advertising (744)	0.042	0.047
Industrial cleaning (747)	0.007	0.016
Misc. business activities n.e.c. (748)	0.085	0.098
Foundation date		
1995	0.070	0.152∗∗∗
1996	0.134	0.237∗∗∗

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Table 1: (continued)

	Shares (unless denoted otherwise)	
Firm characteristics at foundation	**VF**	**NVF**
1997	0.373	0.304∗
1998	0.423	0.307∗∗∗
Regional Characteristics		
Firm is located in Eastern Germany	0.204	0.207
Located in Bavaria	0.197	0.151
Firm is located in Brandenburg	0.028	0.036
Population Density in 1996 (corresponding counties)	6.940	6.389∗∗∗
Distance to nearest science or technology part	2.704	2.760
Scientific personnel in Universities within 50 km dist.	7.609	7.657
Distance to next Fraunhofer-Institute	2.725	3.126∗∗∗
Distance to next Helmholtz-Institute	3.053	3.492∗∗∗
R&D Employees in industry	7.350	6.523∗∗∗
Other		
Estim. average unbounded Prop. Score $X'\hat{\beta}$	−2.081	−2.797∗∗∗
Average Annual Employment Growth	0.326	0.174∗∗∗
Entry has been edited within last year	0.923	0.877∗∗
Nr. of observations	142	21,375

****/**/* Difference of mean is significant from zero at 1/5/10 per cent level of significance.*
VF: venture funded firms, begin of involvement is latest twelve months after foundation date, NVF: non venture funded firms.
Data sources: ZEW Foundation Panels, German Patent Agency, Federal Office for Regional Planning.

This table shows that in average, venture funded firms have a larger startup size, they have a larger management[3], their founders are higher qualified, they have a larger number of patents at foundation date, they are less frequent in traditional sectors (such as mechanical engineering) but more frequent in R&D intensive and computer related industries. Finally, they are more than proportional they are founded after 1996 (the take-off year of the German venture capital Market) and they are created in more densely populated areas but with larger distance to applied research centers. Also, we see at the bottom of Table 1 that firms differ significantly in their average annual employment growth rate.

[3]We derive this from that they more fequently are founded as Public Limited Company and have more that one founder.

Table 2 compares average growth rates of venture funded and non venture funded firms grouped into different industry aggregates. Based on these figures, we are driven to the conclusion that venture funded firms grow faster on average, however this difference is driven only by the technology intensive service (which includes software developers) subgroup. Section 5 will show if these results hold after applying a microeconometric matching procedure.

Table 3 compares average number of patent applications of firms in the sample on the industry level using different industry aggregeates. Based on these tests, we are driven to the conclusion that venture funded firms show a significantly larger number of patent-applications compared to their non venture funded colleagues. The figures in this table differ in magnitude from those given by Kortum and Lerner(2000, Table 6), the ratio of patent applications from venture funded firms to non venture funnnded firms is however roughly the same. This difference is due to the fact that we consider only young firms. Again, these results will be reconsidered in section 5.

	Means		p-value*
	VF	*NVF*	
All Firms	0.367	0.193	0.003
(Number of firms)	(216)	(37,122)	
Manufacturing Industry	0.286	0.180	0.183
(Number of firms)	(65)	(14,118)	
Technology Intensive Services	0.451	0.203	0.005
(Number of firms)	(88)	(10,934)	
Other Business Related Services	0.334	0.198	0.224
(Number of firms)	(63)	(12,070)	

VF: Venture-Funded; NVF: Non-Venture-Funded

**p-values express probabilities of Means*

to be identical, based on a two sided t-test.

Table 2: Comparison of annual growth rates of venture funded and non venture funded firms

4 Description of the Evaluation Procedure

4.1 Background: Evaluation and The Selection Problem

To assess the contribution of venture capital funding to firms' growth and innovative behaviour, we aim to quantify the difference between the state of the firms after fund-

	Means		p-value*
	VF	*NVF*	
All Firms	1.084	0.134	0.000
(Number of firms)	(274)	(50,754)	
Manufacturing Industry	2.524	0.265	0.000
(Number of firms)	(82)	(17,957)	
Technology Intensive Services	0.620	0.090	0.000
(Number of firms)	(108)	(14,919)	
Other Business Related Services	0.274	0.052	0.122
(Number of firms)	(84)	(17,878)	

VF: Venture-Funded; NVF: Non-Venture-Funded

**p-values express probabilities of Means*

to be identical, based on a two sided t-test.

Table 3: Comparison of patenting behaviour of venture funded and non venture funded firms

ing and the hypothetical state of their innovative behaviour if they had not been funded by a venture capitalist. This latter state – called *counterfactual* – is of course hypothetical i.e. it is not observable, and therefore has to be estimated (e.g. Heckman *et al.*, 1999). Denote $Y^{(1)}$ the outcome of the target variable of treated firms (in our case the innovative behaviour of venture funded) firms and $Y^{(0)}$ the outcome of this variable for non-treated firms. Then the evaluation task is expressed formally as measuring the average treatment effect

$$\theta^{(1)} \quad = \quad E[\bar{Y}^{(1)} - \bar{Y}^{(0)} | VC = 1] \quad = \quad E[\bar{Y}^{(1)} | VC = 1] - \underbrace{E[\bar{Y}^{(0)} | VC = 1]}_{c},$$

where *c* denotes the counterfactual. If we were able to assume that venture capital funded firms did not differ significantly non-funded firms in their characteristics, it would be straightforward to estimate this counterfactual using observations on the latter. However, two factors will lead to a selection bias that makes it impossible to maintain this assumption. First, venture capitalists are investing only into those venture firms that have survived an extensive pre-investment screening process. That is, venture funded firms have been selected in on the basis of superior performance. Second, firms can be exptected to self-select into venture funding e.g. if they consider themselves not to be able to pass the screening process. These firms would even not expose themselves to a selection process. Hence, a priori, non venture funded firms are not suitable for comparison with their venture funded counterparts (Lechner, 1998 discusses this problem in extend).

Table 1 makes these differences explicit. However, given the structural differences between those firms and the implied selection bias, this cannot yet be taken as evidence in favour of a positive contribution of venture funding to firm growth or to firms' innovative behaviour. This selection bias can be corrected for by explicitly modelling the selection process. Different approaches have been suggested to doing so (e.g. Heckman *et al.*(1999) or Keilbach(2003) for a survey). In this paper we choose a statistical matching procedure, to be described in the following section.

4.2 Description of the Matching Procedure

Any microeconomic evaluation study would be straightforward if participants (i.e. the "treated" firms in our case) are chosen at random and the number of firms is sufficiently large to assure that we can find identical ("twin") firms, one of which is treated while the other is not. This approach of *randomized experiment* is used in other disciplines such as pharmaceutics. However, due to the selection bias discussed above, we cannot expect such a random assignment[4]

Assume however that we can identify a set of *k* variables X that are correlated with the selection process. The *conditional independence assumption* (CIA), put forward by Rubin(1977) states that different firms with however identical realizations of X_i differ in their target variable Y_i significantly only, through the implications of their treatment. Put formally, in the case of venture capital financing, the CIA states

$$\mathrm{E}[\mathrm{Y}^{(0)}|VC=1,\mathrm{X}=\mathrm{x}] \quad = \quad \mathrm{E}[\mathrm{Y}^{(0)}|VC=0,\mathrm{X}=\mathrm{x}],$$

where $VC=1$ indicates venture capital financing. If this assumption is met, the average treatment effect $\theta^{(1)}$ can be estimated as

$$\widehat{\theta}^{(1)} \quad = \quad \mathrm{E}[\bar{\mathrm{Y}}^{(1)}|VC=1,\mathrm{X}=\mathrm{x}]-\mathrm{E}[\bar{\mathrm{Y}}^{(0)}|VC=0,\mathrm{X}=\mathrm{x}].$$

Given however the large number of variables, their metric nature and the implied high dimensionality of the matching procedure it is virtually impossible to find two firms with identical realisation of X.[5] That is, it is virtually impossible to find exact (i.e. "twin") pairs venture funded an non venture funded firms.

[4] In setting up public policy measures, such experiments would amount to undertaking a social experiment, which is explicitly prohibited by law in a number of countries. In the case of venture capital financing, such experiments would presumambly not correspond to the interest of the venture capitalist since his interest is not into evaluation but rather into earning miney.

[5] The first column of Table 1 enumerates the variables in the database.

Rosenbaum and Rubin(1983) show that if there exists a function $b : \mathbb{R}^k \mapsto \mathbb{R}^1$, the use of $b(\mathrm{X})$ is equivalent, i.e. the average treatment effect $\theta^{(1)}$ can be estimated with

$$\widehat{\theta}^{(1)} = \mathrm{E}[\overline{\mathrm{Y}}^{(1)}|VC = 1, b(\mathrm{X}) = b(\mathrm{x})] - \mathrm{E}[\overline{\mathrm{Y}}^{(0)}|VC = 0, b(\mathrm{X}) = b(\mathrm{x})].$$

Once this function is identified, the matching task simplifies considerably since the dimensionality of the task reduces to 1 and a corresponding agent can be found through a nearest-neighbor Matching Method (Heckman *et al.*, 1999, p. 1953). An intuitive and often used realization of $b(\cdot)$ is the *propensity score* that expresses the firms' conditional probability (the "propensity") to be subject to venture funding(conditional on X). This probability can be estimated with a standard Probit model. That is we have

$$\mathrm{E}(VC_i|\mathrm{x}_i) = \Pr(VC_i = 1|\mathrm{x}_i) = \Phi(\mathrm{x}_i'\beta) \qquad \forall\, i = (1, 2, \ldots, N).$$

where $\Phi(\cdot)$ represents the cumulated density function of the standard normal distribution.

Based on these estimation results, it is possible to compute each firm's propensity score via

$$\widehat{ps}_i = \mathrm{x}_{i'}'\widehat{\beta} \tag{2}$$

which is a scalar for each firm.[6] With an estimated propensity score for each firm at hand, the matching procedure simplifies to finding for each venture funded firm i a non venture funded counterpart j such as to $\min_{i,j}(ps_i - ps_j)$.[7] Once the matching partners are identified (i.e. we have determined $\widehat{Y}^{(c)}$), we can estimate the average treatment effect (i.e. the average contribution of venture capital funding to firms' innovative behavior) consistently as (Lechner, 1998)

$$\hat{\theta}^{(1)} = \frac{1}{N^{(1)}} \left(\sum_{i=1}^{N^{(1)}} Y_i^{(1)} - \sum_{j=1}^{N^{(1)}} \widehat{Y}_j^{(c)} \right). \tag{3}$$

The variance of $\hat{\theta}^{(1)}$ can be estimated with

$$\mathrm{Var}\left(\hat{\theta}^{(1)}\right) = \frac{1}{N^{(1)}} \left([S^{(1)}]^2 + [S^{(c)}]^2 \right), \tag{4}$$

$S^{(j)}$ being the standart deviation of subsample j.

[6] We give average values of estimations of the propensity score at the bottom of Table 1.

[7] A number of generalizations of this *propensity score matching* approach have been suggested. We do not consider these here. See Heckman *et al.*(1999) or Keilbach(2003).

4.3 Implementation and Result of the Matching Procedure

In the case of venture capital funding, variables that should enter X, i.e. variables that can be expected to be responsible for selection into venture capital funding by venture firms are mainly the industry to which the firm adheres and previous excellence in innovation. We approximate *self selection* through contacts and networks through locational variables, i.e. population density and distance to scientific facilities.[8] Thus, the matching approach assumes implicitly that both groups do not differ with respect to unobservable variables such as commitment of firm founders or scope of the business idea.

Based on this set of variables we run a probit estimation of the propensity score using 142 venture funded firms and 21,571 control firms, results of which are reproduced in Table 4. These estimation results can be interpreted economically. Thus Table 4 provides evidence that firms size has a positive influence on the probability of being venture funded or not. However, firms with limited legal forms are funded with significantly higher probabity. The same applies for high education degrees and for firms with more than two patents at foundation date or for firms founded after 1996. The estimation results for industry variables point into the expected direction, i.e. firms in R&D oriented industries are venture funded with higher probability. Again, this probably reflects the recent dynamic evolution of the German venture capital market, especially in for early stage investments. It is remarkable that the probabllity of being venture funded decreases significantly with regional the density of scientific personnel. We leave this for further investigation.

Based on the results of this estimation we can compute the propensity score for each firm as is specified in equation (2). We then identify matching partners as described above. Since the matching is made on the basis of a simple minimal distance measure of each firm's estimated propensity score, a necessary condition of this matching to be successful is that the range of the propensity score of treated firms (venture funded firms) is covered by the range of control firms.

[8] Indeed, venture funded firms and non-funded firms differ significantly respect to these variables. See Table 1.

Table 4: Determinants of venture capitalist's involvement, Probit estimation

Dependent Variable: Involvement of venture capital Company within one year after foundation date **Characteristics at foundation date**	*Coeff.*	*p-value**
Firm-specific characteristics		
Startup size (number of employees)	0.0080	0.023
Limited Partnership (GmbH & Co. KG)	0.0810	0.522
Public limited company (AG)	0.5964	0.000
Involvement of other (non VC) firms	0.1996	0.024
Team foundation	0.1977	0.006
Founding team of mixed gender	−0.1690	0.128
Founders are of female gender	−0.5302	0.023
Gender Unknown	−0.0159	0.896
Qualification of Founders		
Doctoral Degree	0.4158	0.000
Postgraduate Degree	0.1448	0.096
Higher Education on the Job	−0.3187	0.170
Low level of Education	0.0656	0.772
Low Education	0.2799	0.004
Patenting Behavior		
One patent until foundation date	0.4426	0.036
2...4 patent until foundation date	0.3657	0.114
5...19 patent until foundation date	0.9311	0.000
Industry affiliation (with NACE code)		
Manuf. of food products etc. (15)	−0.1601	0.638
Manuf. of wearing apparel etc. (18)	0.4644	0.242
Manuf. of wood and its products etc. (20)	0.2462	0.384
Publishing, printing etc. (22)	−0.1725	0.447
Manuf. of chemicals and chemical products (24)	0.2364	0.317
Manuf. of rubber and plastic products (25)	−0.2004	0.575
Manuf. of other non-metallic mineral products (26)	0.0451	0.849
Manuf. of fabricated metal products etc. (28)	−0.1575	0.478
Manuf. of machinery and equipment n.e.c. (29)	−0.3049	0.197
Manuf. of office machinery and computers (30)	0.2841	0.289
Manuf. of electrical machinery and apparatus n.e.c. (31)	0.5718	0.005
Manuf. of radio, television and communication equipment (32)	0.3221	0.230
Manuf. of medical, precision and optical instruments etc. (33)	−0.0055	0.976
Manuf. of motor vehicles, trailers and semi-trailers (34)	0.0653	0.810
Manuf. of furniture; manufacturing n.e.c. (36)	−0.1284	0.711
Recycling (37)	0.3057	0.219

Continued on next page

Table 4: (continued)

Dependent Variable: Involvement of venture capital Company within one year after foundation date		
Characteristics at foundation date	Coeff.	p-value*
Post and telecommunications (64)	0.0092	0.984
Computer and related activities (72)	0.2020	0.123
Research and development (73)	0.5732	0.000
Other business activities (740)	0.1671	0.682
Business Related Services (741)	0.0312	0.818
Architectural and engineering activitiesx (742)	−0.2780	0.093
Advertising (744)	0.0917	0.617
Foundation date		
1996	0.0232	0.865
1997	0.3319	0.008
1998	0.3445	0.006
Regional Characteristics		
Firm is located in Eastern Germany	−0.0652	0.515
Located in Bavaria	0.0920	0.337
Firm is located in Brandenburg	0.1114	0.610
Population Density in 1996 (corresponding counties)	0.0869	0.056
Distance to nearest science or technology part	−0.0124	0.711
Scientific personnel in Universities within 50 km dist.	−0.0609	0.009
Distance to next Fraunhofer-Institute	−0.0043	0.904
Distance to next Helmholtz-Institute	−0.0295	0.332
R&D-employees in resp, industry	0.0359	0.218
constant	−3.5279	0.000
Number of Observations (of which venture funded)	21,571 (142)	
Wald-test (*p-value*)	332.9	0.000
Pseudo R^2	0.1548	
**p-value: Probability of coefficient estimate to differ significantly from zero.*		
Data sources: ZEW Foundation Panels, Germany Patent Agency, Federal Office for Regional Planning.		

5 Results

We are now able to compute the average treatment effects and their standard deviation as expressed in equations (3) and (4). Since we consider two implications of venture-funding (firms' growth and innovation) simultaneously, we run two different realizations of the matching procedure. In both runs, we used the estimated propensity score. Moreover, we imposed matching partners to be of the same industry and to be

founded in the same year. We also want matching partners to be as similar as possible with respect to startup size when analyzing firm growth and with respect to the number of patents at firm-foundation when analyzing innovation behaviour. We therefore imposed for matching partners the metric distance of these variables to be minimal.

5.1 Estimated Differences for Firm Growth

Table 5 shows the difference for the annual growth rates of both types of firms. venture funded firms show a significant larger (more than twice as large) annual growth rate in comparison to their non venture funded homologues. This difference is significant and its magnitude is roughly the same for firms in the East- and West-German subsample and for firms in different industry subsamples. Contrarily to the results in Table 2, the differences now are all significant. Obviously, in the data underlying Table 2 there were fast growing firms in the manufacturing sector and in the other business related services that were not venture funded. The differenceis however much lower in magnitude than in other studies such as e.g. Coopers&Lybrand and EVCA. This result clearly shows the effect of the correction of the sample selection bias as effectuated by the matching procedure.

Difference and significance are strongest for firms founded in 1998. This is the year (together with 1999), where the venture capital market has experienced its strongest boom. We therefore hypothesize that this boom had a strong influence on the develoopement of venture funded firms.

5.2 Estimated Differences for Innovative Behaviour of Firms

A different picture occurs if we consider the patenting behaviour of firms. As Table 6 shows, venture funded firms show still a stronger innovative behaviour[9], however this difference is only weakly significant. While it is significant at the 10% level for the complete set of matched firms, it is not significant anymore for the industry aggregates, nor for the tow regional subsets. The difference is weakly significant for firms created in 1997 but not for other cohorts.

Hence, the overwhelming evidence is that once we correct for the number of patent application at firm-foundation, venture-funding does not make a significant contribution to firms' patenting behaviour. This result contradicts those of Table 3. Implicitely, it also contradicts the findings of Kortum and Lerner(2000).

[9]Indeed, the difference is roughly in the same magnitude as in Table 3.

Table 5: Employment growth of venture funded new firms and difference to control group

		Average Growth Rate		
	# of Firms	*VF*	*NVF*	*p-value**
All Firms	142	0.326	0.156	0.000
By Region				
West Germany	113	0.300	0.143	0.002
East Germany	29	0.427	0.199	0.046
By Industry Affiliation				
Manufacturing Industry	44	0.299	0.110	0.022
Technology Intensive Services	50	0.317	0.181	0.043
Other Business Related services	48	0.361	0.173	0.046
By Foundation Date				
1995 / 1996	29	0.151	0.130	0.749
1997	53	0.274	0.170	0.158
1998	60	0.457	0.157	0.000

Notes: VF: Venture-Funded; NVF: Non-Venture-Funded

**p-value: Probability of difference to be insignificant, based on a two sided t-test.*

6 Summary

In this paper, we investigate the implication of venture capital funding on firms' growth performance and innovative behaviour. This is done using a sample of roughly 50,000 German firms of which roughly 1 per-cent is venture funded. We find evidence that firms with higher innovative output (measured by patent applications, corrected for size) and with a higher educated management have a larger probability of being venture funded.

Then we compare venture funded and non venture funded firms with respect to growth and innovative behaviour. This is done using a statistical matching approach that compares venture funded firms with non venture funded "twin"-firms. The aim of this approach is to make sure that the results are not biased with respect to firms characteristics.

Based on this approach we find evidence that venture funded firms display significantly higher growth rates compared to their non venture funded homologues. On the other hand, there is only very weak evidence for the innovative behaviour of both

Table 6: Difference of Patenting behaviour between venture funded new firms and control group

		Average Number of Patents		
	# of Firms	*VF*	*NVF*	*p-value**
All Firms	142	0.732	0.070	0.087
By Region				
West German Firms	113	0.336	0.061	0.101
East German Firms	29	2.276	0.120	0.226
By Industy Affiliation				
Manufacturing Industry	44	1.545	0.091	0.211
Technology Intensive Services	50	0.520	0.100	0.230
Other Business Related services	48	0.208	0.021	0.322
By Foundation Date				
1995 / 1996	29	2.138	0.276	0.293
1997	53	0.623	0.019	0.082
1998	60	0.150	0.017	0.177

Notes: VF: Venture-Funded; NVF: Non-Venture-Funded

**p-value: Probability of difference to be insignificant, based on a two sided t-test.*

groups to be different.

In our view, these results can be interpreted as follows: venture capital firms screen potential portfolio firms to select out those with the best growth perspectives. The innovative potential (as signalled by patent applications and by the founders' education levels) play an important role in that respect. This screening process is very selective though successful since venture capital funded firms display indeed higher (twice as large) growth rate as compared to firms of a control group. This stronger growth rate seems to be a result of a commercialization of previous innovations since innovation outputs of venture funded firms do not differ from non venture funded but otherwise strongly similar group of firms of a control group. A plausible explanation for this finding could be that venture capital investors assist their portfolio firms in this commercialization effort, rather than in further innovation effort, in an attempt to maximize sales, hence value, of their portfolio firms. Commercialization is probably done by financial means but also by means of management assistance. It is also possible that

venture investors are more aware of possible commercialization channels. However, these hypotheses need further investigation. Nevertheless, these findings underline the importance of commercialisation and marketing of innovation. Non venture funded firms might improve their growth perspectives by putting mor emphasis on these aspects of the business. Again, this is left further research.

References

Almus, M., Engel, D. and Prantl, S. (2000). *The Mannheim Foundation Panels* (ZEW Documentation No. 00-02). Mannheim: ZEW.

Amit, R., Brander, J. and Zott, C. (1998). Why Do Venture Capital Firm Exist? Theory and Canadian Evidence. *Journal of Business Venturing*, *13*, 441-466.

BVK. (2000a). *Directory.* Berlin: BVK.

BVK. (2000b). *Jahrbuch.* Berlin: BVK.

Berger, A. N. and Udell, G. F. (1998). The Economics of Small Business Finance: The Roles of Private Equity and Debt Markets in the Financial Growth Cycle. *Journal of Finance*, *22*, 613-73.

Buergel, O., Fier, A., Licht, G. and Murray, G. (2000). *Internationalisation of High-Tech Start-Ups and Fast Growth - Evidence for UK and Germany* (Discussion Paper No. 00-35). Mannheim: ZEW.

Coopers&Lybrand and EVCA. (no year given). *The Economic Impact of Venture Capital in Europe.*

EVCA. (2000). *Yearbook.* Zaventem: evca.

Engel, D. (2001). *Identifizierung VC-finanzierter Unternehmen in den ZEW-Gründungspanels.* (ZEW Working Paper)

Gompers, P. and Lerner, J. (1999). *The Venture Capital Cycle.* Cambridge, Mass.: MIT Press.

Heckman, J. J., LaLonde, R. J. and Smith, J. A. (1999). The Economics And Econometrics of Active Labor Market Programs. In *Handbook of Labor Economics, Vol. 3A.* Elsevier.

Jacobs, O. and Scheffler, W. (1998). *Unternehmensbesteuerung und Rechtsform, Handbuch zur Besteuerung deutscher Unternehmen* (2 ed.). München: Beck.

Jain, B. and Kini, O. (1995). Venture Capitalist Participation and the Post-issue Operating Performance of IPO Firms. *Managerial and Decision Economics*, *5*, 593-606.

Keilbach, M. (2003). Quantitative, Non-Experimental Approaches to the Microeconomic Evaluation of Public Policy Measures – A Survey. In W. Polt and J. Rojo (Eds.), *Handbook on the Evaluation of Research and Technology Policies: Concepts, Tools and Indicators. (in Print).* Edward Elgar.

Kortum, S. and Lerner, J. (1998). *Does Venture Capital Spur Innovation?* (Working Paper No. W6846). NBER.

Kortum, S. and Lerner, J. (2000). Assessing the Contribution of Venture Capital to Innovation. *RAND Journal of Economics*, *31*(4), 674-692.

Lechner, M. (1998). *Training the East German Labour Force - Microeconometric Evaluations of continuous Vocational Training after Unification.* Heidelberg: Physica.

Lerner, J. (1999). The Government as Venture Capitalist. *Journal of Business, 27,* 285-318.

Manigart, S. and Hyfte, M. (1999). *Post-Investment Evolution of Belgian Venture-Capital Backed Companies: An Empirical Study.* Paper presented at the Babson Entrepreneurship Conference.

Rosenbaum, P. and Rubin, D. B. (1983). The Central Role of the Propensity Score in Observational Studies for Causal Effects. *Biometrica, 70,* 41-55.

Rubin, D. B. (1977). Asignment of Treatment Group on the Basis of Covariate. *Journal of Educational Statistics, 2,* 1-26.

Sapienza, H. J. (1992). When Do Venture Capitalists Add Value? *Journal of Business Venturing, 7,* 9-27.

Schefczyk, M. (2000). *Erfolgsstrategien deutscher Venture Capital-Gesellschaften* (2 ed.). Stuttgart: Schaeffer-Poeschel.

VentureOne. (1999). *The Venture Capital Industry Report.* San Francisco: VentureOne.