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Working Paper

The Economic Impact of Venture Capital

Discussion paper Series 1 / Volkswirtschaftliches Forschungszentrum der Deutschen Bundesbank, No. 2004,18

Provided in cooperation with:
Deutsche Bundesbank, Forschungszentrum

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Discussion Paper
Series 1: Studies of the Economic Research Centre
No 18/2004

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ISBN 3–86558–004–1

Abstract:

This paper attempts to evaluate the macroeconomic impact of venture capital (VC). We test the assumption that VC is similar in several respects to business R&D performed by large firms and therefore contributes to economic growth through two main channels: innovation and absorptive capacity. The quantitative results, based on a panel of 16 OECD countries from 1990 to 2001, show that the social return of VC is significantly higher than the social return of business or public R&D. An increased VC intensity also makes it easier to absorb the knowledge generated by universities and firms.

Keywords: Venture Capital, Productivity Growth, Innovation, Absorptive Capacity

JEL-Classification: G24, D24, O32, O33

Non Technical Summary

The objective of this paper is to perform an evaluation of the macroeconomic impact of venture capital (VC). The main assumption is that VC can be considered as being similar in several respects to business R&D performed by large firms. We test whether VC contributes to economic growth through two main channels. The first one is innovation, characterized by the introduction of new products, processes or services on the market. The second one is the development of an absorptive capacity. (i.e. the development of know-how and skills that induce an effective use of existing knowledge to improve the production system). These hypotheses are tested quantitatively for a panel data set of 16 OECD countries from 1990 to 2001. The results show that the accumulation of VC is a significant factor contributing directly to productivity growth. The social rate of return to VC is significantly higher than the social rate of return to business or public R&D. VC has also an indirect impact on productivity growth in the sense that it improves the output elasticity of R&D. An increased VC intensity makes it easier to absorb the knowledge generated by universities and firms, and therefore improves aggregate economic performance.

Nichttechnische Zusammenfassung

Ziel dieses Diskussionspapiers ist es, eine Bewertung der makroökonomischen Auswirkungen von Risikokapital vorzunehmen. Die Hauptthese lautet, dass Risikokapital in mehrerer Hinsicht den F&E-Leistungen großer Unternehmen ähnelt. Wir prüfen, ob über zwei wichtige Kanäle vom Risikokapital ein Beitrag zum Wirtschaftswachstum geliefert wird. Der erste Kanal betrifft Innovationen, deren Wesensmerkmal die Einführung neuer Produkte, Verfahrensweisen oder Dienstleistungen am Markt ist. Der zweite Kanal bezieht sich auf den Aufbau von Absorptionskapazität (d.h. die Entwicklung von Know-how und Fertigkeiten, durch die das bestehende Wissen wirksam zur Verbesserung des Produktionssystems genutzt werden kann). Diese Hypothesen werden quantitativ anhand eines Datenpanels aus 16 OECD-Ländern für die Zeit von 1990 bis 2001 getestet. Die Ergebnisse zeigen, dass die Akkumulation von Risikokapital einen wichtigen, direkt zum Produktivitätswachstum beitragenden Faktor darstellt. Die gesamtwirtschaftliche Rendite des Risikokapitals ist bedeutend höher als die der F&E-Ausgaben des Unternehmens- oder öffentlichen Sektors. Risikokapital hat auch einen indirekten Einfluss auf das Produktivitätswachstum, indem es die Outputelastizität von Forschung und Entwicklung verbessert. Eine gesteigerte Risikokapitalintensität erleichtert die Absorption des von Hochschulen und Unternehmen generierten Wissens und verbessert somit die gesamtwirtschaftliche Leistungsfähigkeit.

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1. Introduction

Venture capitalists intervene as an intermediary in financial markets providing capital to small firms with high growth potential. Venture funded firms are generally very small and young, often called innovative start-up, and are plagued with very high levels of uncertainty and an important information asymmetry between investors and entrepreneurs (Gompers and Lerner 2001, Berger and Udell 1998). The venture capitalists provide financial support, as equity to support fast growth, and non-financial support as guidance and expertise (Sapienza, 1992). They may sit on boards of directors and may perform key corporate functions for the venture-backed companies or provide valuable governance and advisory support.

A growing number of empirical investigations outlines the crucial importance of VC for high-tech start-up growth (e.g., Engel (2002), and Davila, Foster and Gupta (2003)), product marketing strategy (Hellmann and Puri, 2002) and survival (Manigart and Van Hyfte, 1999). The aggregate role of VC in the economy begins also to be an important area of research but very few quantitative investigations have been performed so far. At the aggregate economic level, Baumol (2002) argues with a theoretical model that entrepreneurial activity may account for a significant part of the "*unexplained*" proportion of the historical growth of the Western nations' output (pp. 58-59).

The objective of this paper is precisely to attempt to provide evidence of Baumol's conjecture. We take the stock of VC as a proxy for entrepreneurial activity and we evaluate whether and to what extent VC contributes to economic growth. We set the hypothesis that VC can be considered as being similar to experimental development activities performed in large firms, the "*D*" of R&D. In this respect, the contribution of VC would take place through two main channels: innovation (i.e. the effective

* Astrid Romain has a research grant provided by the Région de Bruxelles-Capitale. We would like to thank Wolfgang Bessler (Justus-Liebig University Giessen), Lydia Greunz (ULB, DULBEA), Ant Bozkaya (ULB, CEB), Pierre Mohnen (MERIT) and Reinhilde Veugelers (KUL) for their useful comments. The participants to academic seminars organized at KUL in November 2002, at MERIT in January 2003, at the Institute of Innovation Research (IIR) of the Hitotsubashi University in July 2003 and at the Bundesbank Spring Conference in April 2004 also provided insightful suggestions. An earlier version of this paper has been published as a Working Paper of the IIR: WP#03-20.

introduction of new products and processes on the market), and absorptive capacity (i.e. the development of know-how and skills that induce an effective use of existing knowledge to improve the production system).

The paper is structured as follows: the next section focuses on the existing literature on the potential effect of VC, at the micro and macroeconomic level. The empirical model as well as the data and the econometric results are presented in the third section. The final section concludes.

2. Existing investigations

A number of factual evidences on the economic impact of VC have been published by specialized institutions, especially for the US economy. According to a study carried out by DRI-WEFA[1] on US VC-funded companies over the period 1970-2000, "*venture capital-backed companies had approximately twice the sales, paid almost three times the federal taxes, generated almost twice the exports, and invested almost three times as much in R&D as the average non-venture capital-backed public company, per each $1,000 of assets*" [NVCA, 2002]. The same study also shows that VC fosters local and regional economic growth in the USA. The European Venture Capital Association (EVCA, 1996 and 2001) argues that venture-backed companies stimulate the economy through the creation of jobs, their exceptional growth rate, their heavy investments and their international expansion. VC is considered as a factor decreasing substantially the required time to introduce an innovation on the market.

Empirical investigations on the impact of VC on firm's performance have been performed at the micro level. Hellmann and Puri (2000) implemented a survey of 149 recently formed firms in the Silicon Valley. Their empirical results suggest that VC stimulates innovative activities of firms. A start-up financed by a venture capitalist needs less time to bring a product to the market. They also show that firms pursuing an "innovator strategy" potentially have better and quicker access to VC funds. Nevertheless, these results should be interpreted with caution since the authors face a problem of causality and geographical concentration of firms. Indeed, as far as the

[1] DRI-WEFA now called Global Insight, Inc. was formed to bring together the two most respected economic and financial information companies in the world, DRI (Data Resources Inc.) and WEFA (Wharton Econometric Forecasting Associates).

causality problem is concerned, it is possible that the more a firm is innovative, the more it applies for VC. In this sense, it is not the VC that would stimulate firms to be more innovative. The validity of these conclusions is also limited by their sample, which 'only' includes Silicon Valley start-ups. For the authors VC can have an impact on the technological trajectory of a start-up company, and in particular on its product market position.

With a panel dataset of about 1,000 German start-ups, Engel (2002) shows that the surviving German venture-backed companies seem to achieve significant higher growth rates due to financial involvement and services provided by venture capitalists. The author also shows that the impact of VC on new firms' growth rate does not differ between high-tech and low-tech industries. Hellmann and Puri (2002) also examine the additional role played by venture capitalists compared to traditional financial intermediation. The authors focus on the development of 170 young high-technology firms in Silicon Valley. They find that venture capitalists intervene in a huge range of activities that are important for the professionalization and development of a start-up company (i.e., managerial advices, strategy formulation, communication skills, the formulation of human resource policies and the adoption of stock option plans etc.).

Kortum and Lerner (2000) perform an aggregate evaluation of the relation between VC and innovation. The authors examine the influence of VC on the propensity to patent inventions in the US from 1965 to 1992, with 20 industries and 530 venture-backed and non-venture-backed firms. They find - with a wide variety of specifications - that VC activity significantly increases the propensity to patent, to a much larger extent than corporate R&D. They further show that while from 1983 to 1992 the ratio of VC to R&D was on average smaller than 3%, VC may have accounted for 8% of industrial innovations during the same period. Tykvova (2000) provides further empirical validation of these results with German data.

For Gompers and Lerner (2001), a simple model of the relationship between VC, R&D and innovation is likely to give misleading estimates because both venture funding and patenting could be positively related to a third unobserved factor - the arrival of technological opportunities. This issue of causality is also analysed by Engel and Keilbach (2002) who compare 142 venture-funded firms with more than 20,000 non venture-funded firms in Germany. Their analysis provides evidence on several levels. Firms with an innovative performance, proxied by a patent performance indicator, are able to benefit from venture funds with a higher probability. Once a start-up is venture funded it shows higher employment growth rates but no significant difference in innovative output with non-venture funded firms.

The recent analysis of Ueda and Hirukawa (2003) focuses on the causality issue of VC investments and innovation in the US manufacturing industry using Multi-Factor Productivity (MFP) growth as a measure of innovation. They find that MFP growth is significantly and positively associated with subsequent VC investments. They add that in computer and communication sectors VC has an impact on innovation and innovation has an impact on VC. On the other hand, in drugs and scientific instrument industries, they find that MFP growth and VC investment are often significantly and negatively related.

Audretsch and Keilbach (2002) perform an aggregate analysis and evaluate the impact of entrepreneurship capital on the economic performances of German regions. Their results indicate that entrepreneurship capital (proxied by the number of start-ups in a region, relative to its population) is a significant and important factor shaping output and productivity. This paper follows the similar objective by employing VC as proxy of entrepreneurship capital.

In a nutshell, there is some evidence that VC and entrepreneurial activity fosters innovative, patenting and growth performances, at least in the USA and Germany. Nevertheless, there is no formal evaluation of the impact of VC on aggregate economic growth, and very few investigations in other industrialised countries. In what follows we attempt to evaluate the macroeconomic impact of VC in 16 OECD countries, over the period 1990-2001.

3. Empirical implementation

Our basic hypothesis is that VC investment is somewhat similar in its nature and concern to the experimental development that is mainly performed by large firms – the "*D*" of R&D. According to the definition of the OECD Frascati Manual (1993), *Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications*. More precisely, this definition can be divided into 3 types of R&D: basic research, applied research, and development. *Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. And experimental development is systematic work, drawing on existing knowledge gained from research and practical experience, that is directed to producing new materials, products and devices; to installing new processes, systems and services; or to improving substantially those already produced or installed*. This third definition of R&D is quite similar to the activities that are performed in small innovative companies. Since they are often financed by venture funds, it seems legitimate to assume that VC can be considered as a determinant of economic growth because it directly contributes transforming inventions into new products and processes. This idea is somewhat supported by Tykvova (2000), who argues that large and established companies may be less innovative than young small firms. This is due to their structure and internal organization. New companies with pioneering ideas and with a flexible structure can react to the concerns of the customers more appropriately. The author argues that VC can solve the lack of capital and managerial experience that these young and innovative firms face.

A second effect of VC would be rather indirect. Venture funded activities can be assimilated to intensive learning processes. We therefore assume that it allows developing a rapid and effective absorptive capacity of outside knowledge. The contribution of VC to aggregate productivity growth can therefore be evaluated through two main mechanisms. The first one would be the direct contribution of VC to productivity growth induced by the creation of new products and processes. The second mechanism would act through the development of an absorptive capacity.

In order to test the assumption that VC is a determinant of economic growth, we use VC as an additional source of knowledge in a traditional knowledge production function. Various sources of technical change are therefore taken into account including business and public R&D capital stocks, and a stock of VC. Business-cycle effects that strongly influence productivity in the short run are also included as 'control' variables. The model on which the estimated equation is based is a traditional Cobb-Douglas production function:

$$MFP_{it} = \exp\left[\phi_i + \varphi_t + \mu_{it}\right] \cdot SVC_{it-1}^{\beta_{svc}} \cdot SBRD_{it-1}^{\beta_{sbrd}} \cdot SPRD_{it-2}^{\beta_{sprd}} \cdot U_{it}^{\sigma_U} \cdot G^{\sigma_G} \qquad (1)$$

The variables (for country *i* and time *t*) are defined as follows:

MFP[2] is an index of multi (total) factor productivity (*MFP)* and has been computed in the usual way (OECD, 2001), as the ratio of the domestic product of industry on the weighted sum of the quantity of labour and fixed capital stock, the weights being the annual labour cost share and the capital cost share respectively (under assumptions of perfect competition and constant return to scale). (Source: OECD National Accounts database).

SVC is the stock of domestic venture capital. It has been computed using the perpetual inventory method from venture expenditures, in constant 1990 GDP prices and US Purchasing Power Parity-PPP (see appendix 2). The European Venture Capital Association definition of VC is not exactly the same as the US one. It includes management buy-outs (MBOs) and management buy-ins (MBIs). In the present analysis, and in order to have an homogenous definition of VC, the venture expenditures include only seed, start-up and early stage capital and do not include replacement capital and buyout. Since VC is a highly risky investment and concerns

[2] It must be noticed that Ueda and Hirukawa (2003) use MFP index as a proxy for innovation. In this paper, we investigate to what extent various sources of knowledge, including VC, contribute to this index of technical change.

more development than basic research, we rely on a high depreciation rate to compute the stock of VC. The annual depreciation rate is 30%.[3] (Sources: EVCA and OECD).

SBRD is the domestic business R&D capital stock. It has been computed using the perpetual inventory method from total intramural business R&D expenditures, in constant 1990 GDP prices and US PPPs (see appendix 2). The depreciation rate is 15%. Sensitivity analyses show that the results of the regressions do not change significantly with the chosen depreciation rate (Guellec and van Pottelsberghe, 2001 and 2004). (Source: OECD Main Science and Technology Indicators).

SPRD is the public R&D capital stock (see appendix 2), which comprises R&D expenditures performed in the higher education sector and in the government sector (public laboratories). The depreciation rate is 15%. Again, sensitivity analysis show that the results of the regressions do not change significantly with the chosen depreciation rate (Guellec and van Pottelsberghe, 2001 and 2004). Since these R&D activities are not performed by the business sectors, we expect a longer delay before they affect business productivity and therefore include them in the model with a two-year lag. (Source: OECD Main Science and Technology Indicators).

A range of control variables is included in all the regressions.

U is intended to capture the business cycle effect: it is equal to 1 minus the unemployment rate. This should be a better proxy than the usually applied rate of utilisation of capital, which applies to manufacturing industries only (which account for about 20% of GDP in OECD countries). In the context of this study, it is also better than the output gap, as the OECD calculation of the output gap relies on certain assumptions on *MFP* growth: by using it, we would be faced with simultaneity problems (if *MFP* is the same on both sides of the equation) or inconsistency (if two different *MFP*s are used on the two sides of the equation).

G is a dummy equal to 1 for Germany in 1991, and 0 otherwise; in order to take into account the exogenous shock of the German unification.

[3] Sensitivity analyses are shown in Table AIII of Appendix 1. The results of the regressions do not change significantly with the chosen depreciation rate.

ϕ_i are country dummies which allow country-specific framework conditions that might affect long-term growth.

φ_t are time dummies which take into account exogenous technical change and exogenous shocks that are common to several countries, such as changes in exchange rates.

The basic equation we estimate is adapted from equation (1). It is a long-term stationary form of the model expressed in logarithm:

$$LMFP_{it} = \beta_{svc} LSVC_{it-1} + \beta_{sbrd} LSBRD_{it-1} + \beta_{sprd} LSPRD_{it-2} + \sigma_U \Delta U_{it} + \sigma_G G + \phi_i + \varphi_t + \mu_{it} \quad (2)$$

where Δ represents the first logarithmic difference and *L* the natural logarithm. In this equation, the parameters that are to be estimated are assumed to be constant across countries and over time; they are defined as follows:

β_{svc} The elasticity of *MFP* with respect to VC.

β_{sbrd} The elasticity of *MFP* with respect to domestic business R&D.

β_{sprd} The elasticity of *MFP* with respect to public R&D.

σ_U The elasticity of *MFP* with respect to the capacity utilisation growth rate.

σ_G The impact of the German unification on *MFP* in Germany.

The interpretation of these elasticities must take into account the fact that the explained variable is not GDP but *MFP*. That means that we capture mainly the spillover effects of R&D and VC, not the total effect on output growth (which includes also the direct effect on private return). This concerns especially business R&D and VC as part of the private resources devoted to R&D and/or financed by VC (labour and capital) are already reflected in the calculation of *MFP* (they are included in the economy's stock of capital and pool of labour). A positive elasticity would therefore signal the existence of spillovers and a risk premium. A further caveat is that the assumptions used for calculating *MFP* may not hold totally: increasing returns to scale and imperfect competition are often associated with R&D (*e.g.* Romer, 1990). If that is the case, the *MFP* index that we explain might be subject to some measurement errors.[4]

The estimates are performed with a panel data set of 16 OECD countries over the period 1990-2001. These 16 countries are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, Norway, Spain, Sweden, United Kingdom and United States. The choice of the sample has been made with caution to the availability of the data. The period varies slightly across countries according to the availability of information.

Country-specific descriptive statistics of all the variables for the 1990-2001 period (or the longest available period) are presented in Table I and Table A II in Appendix 1. The *MFP* growth ranges from -0.46 % a year in Germany to 3.62 % in Ireland. This weak rate for Germany is mainly due to the unification process. Most countries, however, are very close to 1 % a year. The *MFP* growth is high for Ireland, as this country has been catching up over the period. Business R&D (capital stock) growth ranges from 0.97 % (United Kingdom) to 8.33 % (Finland) and an outstanding performance of 14.37 % for Ireland. Most countries are between 3.5 and 7 %. The growth of publicly performed R&D was much lower than that of business R&D over the same time period. It ranges from 1.02 % (Canada) to 5.47 % (Ireland), with most countries reporting between 3 % and 5 %. The major reasons for this lower growth rate of public R&D are the end of the cold war (reduced defence spending) and strained budgetary conditions in many countries.

VC investment is much more volatile, ranging from -3.65 % in Australia to 38.14 % in Canada with the United States and Finland above 28 %. Note that we only have data from 1995 to 1999 for Canada and from 1995-1998 for Australia, which can explain these high values. The descriptive statistics for the VC stock with 15, 30, 45 and 60 % of depreciation are in Appendix 1, Table AII. Despite a higher volatility, the average growth rates of VC investment and VC stock have been much higher than the growth rate of business R&D capital stock, except for a few countries.

The R&D intensity (R&D investment divided by the domestic product of industry) varies between 1.2 % and 2.1 % for 9 countries. Sweden, Japan, Finland, and

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[4] See Guellec and van Pottelsberghe (2004) for a discussion on this issue.

the USA are the best performers in terms of relative effort in R&D. Regarding the VC intensity (VC investment divided by the domestic product of industry) the best performers are not necessarily the countries that have a high R&D intensity or high MFP growth rates. Japan is the least intensive in VC. Australia, Ireland, the Netherlands, the United-Kingdom and the United States are above 0.11 % and Canada is at the top with 0.22 %. In other words, some countries with relatively low effort in research turn out to be very active in terms of VC.

The correlations between the average annual growth rates of each variable are reported in Table II. The *MFP* is quite highly correlated with the business R&D capital stock, witnessing a positive long-term relationship. This long-term impact of R&D on growth could be expected from the evidence available in the existing literature. The *MFP* is also positively correlated, though to a lower extent than business R&D, with public R&D. With regard to the VC stock there is no apparent relationship with *MFP,* and neither with public nor business R&D. These non-significant parameters show that VC has had different growth profiles across countries.

Based on the equation in log-levels (2), our aim is to identify simple, long-term static relationships between *MFP* and its determinants. Panel co-integration tests are not performed because of the short period considered. These tests have been performed on similar data (MFP, SBRD and SPRD) by van Pottelsberghe and Lichtenberg (2001) for the same sample of countries but for a longer time period. They find that the combination of the time series satisfy the required statistical properties needed for meaningful estimations.

The econometric results are reported in Table III. The variables of business R&D capital stock and VC stock that represent stocks of knowledge have been introduced with a one-year lag (or the stock at the beginning of the year), and two-years lag for the public R&D capital stock. Since R&D performed by universities largely concerns basic research, a longer time lag is justified, as it takes time until basic R&D affects industrial productivity. [5]

The results for different specifications are reported in order to test the stability of our estimates. The control variable 'business cycle', as proxied by the growth of employment rate, is associated with an expected large and positive parameter. This confirms previous findings that the measure of productivity is substantially affected by the capacity utilization rate.

The progressive introduction of the other sources of knowledge significantly improves the overall fit of the model. The estimates suggest that the accumulation of VC significantly contributes to total factor productivity growth.[6] The estimated parameters remain stable (columns 5 and 6) after the withdrawal of the control variables and/or time dummies, witnessing the robustness of the estimated parameters.

The most appropriate estimates are displayed in column 3. These results include the three sources of knowledge, the two control variables, and country and time dummies. The elasticities of output with respect to the stocks of VC, business R&D and public R&D are 0.9 %, 19.9 %, and 13.6 %, respectively. In other words, the output elasticity of business R&D is higher than the output elasticity of public R&D and nearly 20 times as high as the output elasticity of VC.

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5 See Guellec and van Pottelsberghe (2001) for a more in depth analysis of the lag structure associated with the R&D capital stocks. As far as the direct impact of VC on *MFP* is concerned we start by estimating separately the effect of each variable. The results are reported in Table AI (in Appendix 1). All variables have the expected signs and are highly significant. Our estimates are based on the GLS econometric technique.

6 The objective of this paper is not to provide evidence on the causality issue between VC and economic performance but to perform an evaluation of the macroeconomic impact of VC. In order to avoid the potential effect of causality we have used a one year lagged stock of VC (as opposed to VC yearly flows). In addition, table 2 shows that there is little evidence of cross-country correlation between MFP growth and the VC intensity: the countries with the highest MFP growth rates are not those with the highest VC intensity ratio. In a previous paper we have investigated the determinants of VC intensity for 16 OECD countries (see Romain and van Pottelsberghe, 2003) and we have found that indicators of technological opportunity, such as the growth rate of R&D investment, the stock of knowledge and the number of triadic patents affect positively and significantly the relative level of VC.

As the direct impact of R&D and VC on output is at least partly accounted for in *MFP*, the positive parameters must mainly capture spillovers and possibly a premium (coming in addition to normal remuneration of capital and labour) arising from R&D and VC. In addition, these estimates are elasticities: relative increase in output due to a relative increase in the stock of knowledge. For instance, a one % variation in the business R&D capital stock would yield a 0.2 % variation in output. In order to quantify these estimates in terms of EURO, one must compute the marginal impacts of these sources of knowledge.

Table IV shows the marginal impacts, or social rates of return, of the three types of knowledge stocks. They correspond to the elasticities presented in column 3 of Table III. The rates of return are calculated as the elasticities divided by the average intensity of the knowledge stock. For instance, the marginal impact of business R&D is 0.199/(0.0998) = 1.99. The marginal impacts of public R&D and VC are respectively 2.69 and 3.33. In other words, an increase of one EURO in the business R&D capital stock would yield an increase of 1.99 EURO in output growth. The rate of return to public R&D is slightly higher. What is striking is the social rate of return to VC, which is significantly higher than the social rate of return to business R&D. This is probably due to the high risk-premium of VC and its induced spillover effects on the economy. Indeed, by definition, venture capitalists invest in highly risky projects such as the introduction of highly innovative products and processes on the market. In large firms, development activities also concern more incremental innovations (product and process improvement) that yield lower returns than a successful introduction of a breakthrough innovation.

The second potential effect of VC on economic performances is an indirect one. Since VC activities can be compared to an intensive learning process, it is assumed that it would improve and speed up the absorptive capacity of firms. The potential mechanism is similar to the one emphasized by Griffith *et al.* (2004) and Guellec and van Pottelsberghe (2001 and 2004) with R&D outlays. The authors show that the countries with a higher R&D intensity have a higher impact of their business R&D capital stock, thanks to an improved absorptive capacity of existing knowledge (inside and outside the firm's boundaries).

In order to test the hypothesis of an absorptive capacity associated with both R&D investment and VC, we estimate a model similar to equation (2), but where VC intensity and business R&D intensity (i.e. the ratio of business R&D expenses on DPI, the Domestic Product of Industry) interact with the various knowledge capital stocks. The results are presented in Table V.

A country's business R&D intensity has a positive effect on the elasticity of the business R&D capital stock as shown in column 1 of Table V. This finding confirms to some extent the existence of increasing returns to investment in research activities. Increasing returns to scale is the basic assumption of the theory of endogenous technical change (see Romer, 1990). By spending more on R&D, firms are able to reap internal economies of scale, to set up networks, to benefit from each other's discoveries. It also denotes an improved ability to absorb the knowledge generated by other firms and/or industries. The intensity of VC funding has also a positive effect on the elasticity of the business R&D capital stock (column 2).

When we introduce simultaneously the product of the business R&D capital stock with the R&D intensity and the VC intensity (column 3), we observe that the positive impact of business research is much higher in countries were the R&D intensity and the VC intensity is higher. The elasticity of public research is also higher when the business R&D intensity is higher. This shows the importance of the business sector being able to seize opportunities raised by public research (column 4). Therefore, part of the effect of public research on productivity is indirect, flowing through the use of its discoveries by the business sector research activities. Stronger links between public and private research, which governments in most OECD countries are trying to build, should enhance this effect. The intensity of VC investment also positively affects the impact of public R&D (columns 5 and 6). More VC allows absorbing more outside knowledge increasing therefore the innovative performances of firms and the aggregate impact of business and public R&D activities.

4. Concluding remarks

This paper provides an attempt to evaluate the economic impact of VC. The starting point of our investigation is that VC can be considered in several respects to be similar to experimental development performed by large firms. The econometric results confirm our assumption that VC contributes to growth through two main channels. The first one is the introduction of new products and processes on the market. The second one is the development of an improved absorptive capacity of the knowledge generated by private and public research institutions.

The social return to VC is much larger than the return to business or public R&D, probably due to a high risk premium and large potential spillovers or knowledge externalities – large firms devote the bulk of their research activities to product or process improvement which is associated with lower risks and lower expected returns. A high VC intensity further allows to improve the economic impact of private and public R&D capital stocks. In other words, VC improves the "crystallisation" of knowledge into new products and processes.

According to our estimates, VC must be considered as an additional "link" explaining variations in economic performances. In the line of Audretsch and Keilbach (2002)'s empirical results, we confirm Baumol's conjecture that entrepreneurial activity may account for a significant part of the "unexplained" residual in the traditional production function. These results therefore call for innovative policy instruments that would stimulate the participation of private VC funds available in the market.

Table I: Descriptive statistics (%)

Country	Period	Business R&D capital stock	Public R&D capital stock	Multi-Factor Productivity	VC Investment	Business R&D Intensity	VC Intensity
		Yearly average growth rates				% Shares	
Australia	1995-1998	5.79%	4.23%	2.09%	-3.65%	0.81%	0.11%
Belgium	1990-1997	3.57%	3.34%	0.78%	14.51%	1.51%	0.07%
Canada	1995-1999	4.93%	1.02%	1.18%	38.14%	1.23%	0.22%
Denmark	1990-1999	7.18%	4.09%	1.46%	23.51%	1.75%	0.03%
Finland	1990-2000	8.33%	4.17%	3.22%	28.31%	2.40%	0.09%
France	1990-2001	2.67%	1.80%	0.88%	6.91%	1.89%	0.09%
Germany	1990-1999	1.52%	2.35%	-0.46%	20.52%	2.09%	0.06%
Ireland	1990-2000	14.37%	5.47%	3.62%	19.87%	1.28%	0.10%
Italy	1990-2000	2.35%	2.07%	0.75%	23.36%	0.86%	0.05%
Japan	1994-1998	3.55%	3.72%	0.11%	8.46%	2.26%	0.03%
Netherlands	1990-2000	2.26%	3.18%	0.85%	23.27%	1.50%	0.20%
Norway	1990-1999	3.31%	3.90%	1.63%	13.54%	1.48%	0.09%
Spain	1990-1999	4.16%	1.21%	0.69%	26.23%	0.70%	0.04%
Sweden	1990-2000	6.33%	1.96%	1.69%	27.15%	4.18%	0.09%
United Kingdom	1990-2000	0.97%	1.65%	0.91%	19.82%	1.79%	0.15%
United States	1990-1999	2.96%	1.56%	1.24%	30.85%	2.22%	0.16%

Sources: OECD, MSTI, EVCA and own calculations

Table II: Correlation matrix between average annual growth rates for 16 OECD countries, 1990-2001

	Public R&D capital stock	Multi-Factor Productivity	VC Investment	Venture capital stock δ = 15%	Venture capital stock δ = 30%	Venture capital stock δ = 45%	Venture capital stock δ = 60%
Business R&D capital stock	0.643*	0.848*	0.085	0.043	0.120	0.117	0.111
Venture capital stock δ = 60%	-0.342	0.081	0.932*	0.894*	0.946*	0.987*	
Venture capital stock δ = 45%	-0.277	0.092	0.866*	0.916*	0.985*		
Venture capital stock δ = 30%	-0.196	0.105	0.775*	0.916*			
Venture capital stock δ = 15%	-0.204	0.027	0.758*				
VC Investment	-0.438	0.060					
Multi-Factor Productivity (MFP)	0.585*						

Sources: Table I and AII; * indicates the significance of the correlation at the 5% probability threshold.

Table III: Multifactor productivity estimation results in log-levels

			Dependent variable: Log MFP					
Regressions (GLS)			*1*	*2*	*3*	*4*	*5*	*6*
Log Venture capital stock (t-1)	$\delta = 30\%$	*LSVC*	0.014***	0.012***	0.009***	0.047***	0.006***	0.007**
			(4.88)	*(4.17)*	*(2.92)*	*(9.59)*	*(2.53)*	*(2.40)*
Log Business R&D capital stock (t-1)		*LSBRD*		0.214***	0.199***		0.197***	0.214***
				(14.98)	*(12.18)*		*(12.91)*	*(15.83)*
Log Public R&D capital stock (t-2)		*LSPRD*			0.136***		0.135***	0.142***
					(2.92)		*(5.52)*	*(5.67)*
Control variables								
Employment rate growth (t)			0.809***	0.519***	0.629***	1.60***	0.828***	
			(4.42)	*(3.07)*	*(3.57)*	*(7.89)*	*(6.62)*	
German reunification dummy (t)			-0.0002	-0.014	-0.012	-0.036	-0.017	
			(-0.003)	*(-0.40)*	*(-0.34)*	*(-0.87)*	*(-0.45)*	
Country-specific intercept			Yes	Yes	Yes	Yes	Yes	Yes
Time dummies			Yes	Yes	Yes	No	No	No
Adjusted R-squared			0.941	0.953	0.971	0.753	0.989	0.974

Note: Panel data, 16 OECD countries, 1990-2001, 148 observations. * Indicates the parameters that are significant at a 10% probability threshold, ** 5% probability threshold and *** 1% probability threshold.

Table IV: Long-term elasticity of Multi-Factor Productivity

		B	Intensity	ρ
Venture capital stock	*δ = 30%*	0.009	0.0027	3.33
Business R&D capital stock		0.199	0.0998	1.99
Public R&D capital stock		0.136	0.0505	2.69

Sources: own calculations, with the parameters presented in Table III, column 3.

Table V: Multifactor productivity estimation results in log-levels: VC and R&D as factors of absorptive capabilities

			Dependent variable: Log MFP					
Regressions (GLS)			*1*	*2*	*3*	*4*	5	6
Log Business R&D capital stock (t-1)	$\delta = 30\%$	*LSBRD*	0.175***	0.204***	0.188***	0.176***	0.204***	0.189***
			(9.75)	*(12.68)*	*(10.28)*	*(9.85)*	*(12.69)*	*(10.36)*
LBRD (t-1) * R&D intensity			0.093***		0.065**			
			(3.01)		*(1.99)*			
LBRD (t-1) * VC intensity				0.387***	0.362***			
				(4.02)	*(3.44)*			
Log Public R&D capital stock (t-2)		*LSPRD*	0.204***	0.168***	0.202***	0.203***	0.166***	0.201***
			(4.54)	*(3.83)*	*(4.63)*	*(4.51)*	*(3.79)*	*(4.59)*
LPRD (t-2) * R&D intensity						0.098***		0.069**
						(3.06)		*(2.05)*
LPRD (t-2) * VC intensity							0.401***	0.373***
							(4.00)	*(3.41)*
Control variables								
Employment rate growth (t)			0.554***	0.599***	0.572***	0.554***	0.598***	0.571***
			(3.36)	*(3.82)*	*(3.72)*	*(3.35)*	*(3.81)*	*(3.71)*
German reunification dummy (t)			-0.016	-0.015	-0.015	-0.016	-0.015	-0.015
			(-0.53)	*(-0.44)*	*(-0.49)*	*(-0.53)*	*(-0.44)*	*(-0.49)*
Country-specific intercept			Yes	Yes	Yes	Yes	Yes	Yes
Time dummies			Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared			0.970	0.977	0.973	0.970	0.977	0.973

Note: Panel data, 16 countries, 1990-2001, 148 observations. * Indicates the parameters that are significant at a 10% probability threshold, ** 5% probability threshold and *** 1% probability threshold.

5. APPENDIX 1: Other specifications of the models

Table AI: Multifactor productivity estimation results in log-levels

Dependent variable: Log MFP					
Regressions (GLS)		1	2	3	4
Log Venture capital stock (t-1) δ = 30%	LSVC	0.014*** (4.88)			
Log Business R&D capital stock (t-1)	LSBRD		0.213*** (15.31)		0.195*** (12.09)
Log Public R&D capital stock (t-2)	LSPRD			0.392*** (9.29)	0.161*** (3.66)
Control variables					
Employment rate growth (t)		0.809*** (4.42)	0.435*** (2.72)	1.021*** (5.76)	0.651*** (3.85)
German reunification dummy (t)		-0.0002 (-0.003)	-0.017 (-0.55)	-0.001 (-0.02)	-0.015 (-0.43)
Country-specific intercept		Yes	Yes	Yes	Yes
Time dummies		Yes	Yes	Yes	Yes
Adjusted R-squared		0.941	0.976	0.990	0.986

Note: Panel data, 16 OECD countries, 1990-2001, 148 observations. * Indicates the parameters that are significant at a 10% probability threshold, ** 5% probability threshold and *** 1% probability threshold.

Table AII: Descriptive statistics for VC

Country	Period	VC investment	Venture capital stock δ = 15 %	Venture capital stock δ = 30 %	Venture capital stock δ = 45%	Venture capital stock δ = 60%
		Growth rates				
Australia	1995-1998	-3.65%	-36.14%	-4.84%	-4.90%	-4.66%
Belgium	1990-1997	14.51%	8.35%	8.36%	9.22%	10.50%
Canada	1995-1999	38.14%	33.51%	38.66%	38.42%	38.13%
Denmark	1990-1999	23.51%	12.82%	15.10%	17.24%	19.16%
Finland	1990-2000	28.31%	30.81%	30.29%	29.80%	29.32%
France	1990-2001	6.91%	7.54%	9.25%	10.03%	10.04%
Germany	1990-1999	20.52%	22.62%	21.85%	21.46%	21.20%
Ireland	1990-2000	19.87%	14.73%	16.50%	17.74%	18.62%
Italy	1990-2000	23.36%	9.76%	12.84%	15.59%	17.99%
Japan	1994-1998	8.46%	2.25%	13.55%	13.34%	12.39%
Netherlands	1990-2000	23.27%	20.08%	21.15%	21.94%	22.51%
Norway	1990-1999	13.54%	29.66%	25.07%	21.52%	18.71%
Spain	1990-1999	26.23%	13.57%	16.02%	18.33%	20.54%
Sweden	1990-2000	27.15%	19.84%	22.25%	23.94%	25.20%
United Kingdom	1990-2000	19.82%	5.84%	9.66%	12.67%	15.04%
United States	1990-1999	30.85%	13.26%	16.83%	20.11%	23.11%

Sources: OECD, MSTI, EVCA and own calculations

Table AIII: Multifactor productivity estimation results in log-levels (with different depreciation rates of VC stock)

		Dependent variable Log MFP							
		$\delta = 15\%$		$\delta = 30\%$		$\delta = 45\%$		$\delta = 60\%$	
Regressions (GLS)		1	2	3	4	5	6	7	8
Log Venture capital stock (t-1)	*LSVC*	0.011***	0.006**	0.014***	0.009***	0.013***	0.008***	0.013***	0.008***
		(4.66)	*(2.21)*	*(488)*	*(2.92)*	*(4.96)*	*(2.90)*	*(4.84)*	*(2.85)*
Log Business R&D capital stock (t-1)	*LSBRD*		0.200***		0.199***		0.199***		0.198***
			(12.30)		*(12.18)*		*(12.27)*		*(12.39)*
Log Public R&D capital stock (t-2)	*LSPRD*		0.128***		0.136***		0.141***		0.145***
			(2.69)		*(2.92)*		*(3.07)*		*(3.19)*
Control variables									
Employment rate growth (t)		0.831***	0.595***	0.809***	0.629***	0.827***	0.629***	0.839***	0.625***
		(4.41)	*(3.36)*	*(4.42)*	*(3.57)*	*(4.45)*	*(3.59)*	*(4.42)*	*(3.58)*
German reunification dummy (t)		0.001	-0.013	-0.0002	-0.012	-0.001	-0.013	-0.002	-0.014
		(0.01)	*(-0.35)*	*(-0.003)*	*(-0.34)*	*(-0.03)*	*(-0.35)*	*(-0.05)*	*(-0.37)*
Country-specific intercept		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared		0.941	0.963	0.941	0.971	0.943	0.971	0.945	0.971

Note: Panel data, 16 countries, 1990-2001, 148 observations. * Indicates the parameters that are significant at a 10% probability threshold, ** 5% probability threshold and *** 1% probability threshold.

6. APPENDIX 2: Calculation of the variables

6.1 Business R&D capital stocks, Public R&D capital stocks

R&D capital stocks are calculated following the perpetual inventory method. The stock at time *t* is equal to the new investment at time *t* plus the stock at time *t-1* minus depreciation:

$$SR_t = r_t + (1-\delta)SR_{t-1} \quad \text{(A1.1)}$$

$$SR_t = r_t + (1-\delta)r_{t-1} + (1-\delta)^2 r_{t-2} + (1-\delta)^3 r_{t-3} + \ldots \quad \text{(A1.2)}$$

To construct the initial stock we assume a constant annual rate of growth of the past investments,

$$SR_t = r_t + (1-\delta)\lambda r_t + (1-\delta)^2 \lambda^2 r_t + (1-\delta)^3 \lambda^3 r_t + \ldots \quad \text{(A1.3)}$$

$$SR_t = \frac{r_t}{1-\lambda(1-\delta)} \quad \text{(A1.4)}$$

where SR_t = R&D capital stock at time *t*.

r_t = R&D investment at time *t*.

δ = Depreciation rate (constant over time).

$\lambda = \frac{1}{1+\eta}$ and η is the mean annual rate of growth of r_t .

The same formula has been used to calculate the Business R&D Capital Stock (SBRD), the Public R&D Capital Stock (SPRD).

6.2 Venture capital stocks

VC stocks are calculated following the perpetual inventory method as for R&D capital stocks.

$$SVC_t = \frac{vc_t}{1-\lambda(1-\delta)} \quad \text{(A1.4')}$$

where SVC_t = VC capital stock at time *t*.

vc_t = VC investment at time *t*.

δ = Depreciation rate (constant over time).

$\lambda = \frac{1}{1+\eta}$ and η is the mean annual rate of growth of vc_t .

In the following table, you will find the multiplicator λ that we have calculated for each depreciation rate.

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