The Determinants of Venture Capital: A Panel Data Analysis of 16 OECD Countries

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Abstract: The objective of this paper is to identify the main determinants of venture capital (VC). We develop a theoretical model where three main types of factors affect the demand and supply of VC. These factors are related to macroeconomic conditions, research efforts and technological opportunity, and the entrepreneurial environment. The model is evaluated econometrically with a panel dataset of 16 major OECD countries over the period 1990-1998. The estimates confirm that VC intensity is highly pro-cyclical - it reacts positively and significantly to GDP growth. Short-term (one-year) interest rates have a positive impact on VC intensity, which means that they affect more the demand side of VC (entrepreneurs) than the supply side. 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. The factors associated with the entrepreneurial environment also explain a substantial part of cross-country variations in VC intensity. An increase in corporate income tax rate has a negative effect on VC intensity. Labour market rigidities reduce the impact of the GDP growth rate and of the stock of knowledge, whereas a minimum level of entrepreneurship is required in order to have a positive effect of the available stock of knowledge on VC intensity. One important policy implication emerges from these results. It is not by providing money for VC that public decision makers will stimulate VC, but by providing knowledge and improving the entrepreneurial environment.

Keywords: Venture Capital, Technological Opportunity, Entrepreneurship, Labour Market Rigidities

JEL: G24, O33, M13, C33

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1. Introduction

Venture capital (VC) is a financial intermediary that aims at fitting innovative start-up's needs, mainly because these firms are generally associated with large growth potentials and high levels of uncertainty. A growing number of scholars have documented the positive impact that venture funds have on the probability of success of start-ups, as well as on the growth of their sales and employees[1]. Most government bodies in industrialized countries now recognize the importance of VC as a factor of firm creation and sustainable growth.

Despite this wide recognition of venture funds as key players underlying a country's entrepreneurial performances, there are huge differences across industrialized countries in the relative amounts invested in VC. The level of VC intensity is relatively high in the USA and Canada for instance, whereas it is very low in Japan. The diversity of national financial systems is undoubtedly one important factor underlying these international differences. Other factors also play an important role, as shown by Jeng and Wells (2000) and Gompers and Lerner (1998). With a panel dataset of 21 countries Jeng and Wells show that labour market rigidities, the level of Initial Public Offerings (IPO), government programs for entrepreneurship, and bankruptcy procedures explain a significant share of cross country variations in VC intensity.

The objective of this paper is to contribute to this recent stream of research in three ways. We first develop a theoretical model which takes into account the factors that affect the demand and supply of VC. These factors include the growth of GDP, short-term and long-term interest rates, several indicators of technological opportunity, and of entrepreneurial environment. Second, we exploit a panel dataset composed of 16 countries over a nine years period. Third, we investigate to what extent the level of entrepreneurship and of labour market rigidities affect the impact of the GDP growth rate and the stock of available knowledge on VC intensity.

The results show that interest rates and the corporate income tax rate significantly influence VC intensity. The countries with lower labour market rigidities benefit from a higher impact of the GDP growth rate and the available stock of knowledge on the relative level of VC. Higher levels of entrepreneurship – i.e., the percentage of people being involved in a start-up – induce a positive and significant relation between the R&D capital stock and VC intensity.

The paper is structured as follows: The next section summarizes the main findings of the few existing evaluation of the determinants of venture capital. A theoretical model of demand and supply of venture capital and the econometric model are developed in section 3. The empirical results are presented and interpreted in section 4. Section 5 concludes.

2. Literature review

Few articles have so far focused on the determinants of VC. To the best of our knowledge, only two articles attempted to evaluate quantitatively the macroeconomic determinants of VC. Jeng and Wells (2000) develop a model aiming at identify the determinants of VC and test it on a cross-section of 21 countries over a period of 10 years. Gompers and Lerner (1998) focus on the US economy over the period 1969-1994. The main results are summarised in Table 1.

[1] See Engel (2002), Hellmann and Puri (2002), Kortum and Lerner (2000), Romain and van Pottelsberghe (2003) for empirical evidence on the economic impact of VC.

Table 1: Potential determinants of VC

	Jeng and Wells (2000)	**Gompers and Lerner (1998)**
	21 countries, 1986-1995	US, 1972-1994
Potential Determinants		
Initial Public Offering	**+** Except for early stage funds	No effect at aggregate level
Gross Domestic Product	Not significant	+
Stock Market Opportunities[1]	Not significant	**+**
Finance reporting standards	-	/
Labour market rigidities	Not significant for total VC investment but - for early stage funds	n.a.
Private pension funds	(Level and growth of pension funds) + Over time but not across countries	(Dummy for changes in ERISA's prudent man rule) +
Corporate Gains Tax Rate	Not significant	-
Level of interest rate	n.a.	+ At aggregate level and – at state level
Industrial and academic R&D expenditures	n.a.	+ At the state level VC activity

[1.] This variable is proxied by an indicator of market capitalization growth by Jeng and Wells (not significant, but probably correlated with GDP and IPO) and by an indicator of equity market return by Gompers and Lerner (positive and significant).

Initial Public Offering is considered as being a very important determinant of VC. It is the strongest driver of VC according to Jeng and Wells (2000) because it reflects the potential return to VC funds. Gompers and Lerner (1998) take it as a proxy for fund performance but cannot find any significant effect in their multivariate regressions. It seems that the IPO variable is strongly correlated with the expected return on alternative investments and the Gross Domestic Product (GDP), which also proxy exit opportunities. GDP and Market Capitalization Growth (MCG) are part of the impact of IPOs and therefore turn out to be not significant for Jeng and Wells (2000). However the reverse is true for Gompers and Lerner who find a positive and significant impact of Equity Market Return and GDP on VC but no impact of IPO. Higher GDP growth implies higher attractive opportunities for entrepreneurs, which lead to a higher need for venture funds.

For Jeng and Wells (2000), getting the basic legal and tax structures into place appears to be an important factor influencing VC. Gompers and Lerner (1998) also recognize the importance of government decisions on the private equity funds. The labour market legislation is typically put in place to protect employees from arbitrary, unfair or discriminatory actions by employers. Some authors argue that venture financing can suffer from the rigidity of the labour market in Europe. Jeng and Wells (2000) show that it does not significantly influence total VC but affects negatively the early stage of VC investment.

It has been widely accepted in the literature that VC investments in the US have been positively influenced by the clarification of the Employee Retirement Income Security Act (ERISA) "prudent man" rule of 1979. As a result pension funds started to invest substantial amounts of money into VC funds. In 1978 pension funds accounted for 15% of VC funds in the US and in the middle of the 80's, the share had risen to more than 50 %. Jeng and Wells (2000) find that the level of investment by private pension funds in VC is a significant determinant of VC over time but not across countries. Gompers and Lerner (1998) use a proxy for

the amendment of the "prudent man" rule to show the impact of pension regulation and came to the same conclusion. After 1979, the additional capital provided by pension funds led to a dramatic shift in commitments to VC.

Concerning the impact of the Corporate Gains Tax Rate (CGTR) on VC activity, Gompers and Lerner (1998) reach the conclusion that a decrease in CGTR has a positive and important impact on commitment to new VC funds. In fact, they confirm the result of Poterba (1989) who built a model of decision to become an entrepreneur. He found that decreases in CGTR might increase the raising of VC funds not through stimulation on the supply side (i.e., the potential fund providers) but rather on the demand side. Indeed, decreases in CGTR often encourage entrepreneurship and thus the desire of people to create their own firm and to engage in R&D activities. Anand (1996, cited by Gomper and Lerner) also highlights the fact that the level and composition of investments appear to be negatively affected by increases in the CGTR but investments in one industry may be affected by myriad of other factors like technology shifts, tastes, etc.

Both industrial and academic R&D expenditures are significantly related to venture capital activity at the State level in the model of Gompers and Lerner (1998). For them, the growth VC fundraising in the mid-1990s may be due to increases in technological opportunities.

Interest rates might also be an important factor influencing VC. Although Jeng and Wells (2000) do not take this factor into account into their cross country investigation, Gompers and Lerner (1998) show that it affects positively the demand for VC funds in the US. Economic theory would suggest a reverse relationship: if interest rates rise, the level of investment should fall. The positive impact estimated by Gompers and Lerner is probably due to the fact that they use a short-term interest rate. If short-term interest rates increase, the attractiveness of venture financing versus credit through usual financial institutions increases from the entrepreneur's viewpoint.

Some scholars have also focused on the micro determinants of VC. Gompers and Lerner (1998) show that the individual firm performance and reputation computed by firm age and size, positively impact the capacity to raise larger funds. Hellmann and Puri (2000) use a probit model to show that the strategy of a company is one of the determinants of VC investment when controlling for the age of the company and its industrial sector. If the strategy is an innovative one (the company is the first to introduce a new product or service on the market), it has a higher probability to benefit from VC compared to companies that follow an imitation strategy (the company uses existing technologies to develop and improve products and processes). They also find that innovating companies are able to raise VC earlier in their life cycle than companies with a strategy of imitation. In other words, their analysis suggests that VC is stimulated by technological opportunities. However there is less evidence of such a relationship at the aggregate macroeconomic level.

In a nutshell, there are several potential determinants of VC. Some of them can be measured qualitatively or quantitatively at the macro level whereas others like the fund reputation and the strategy of the venture funded firms are microeconomic factors. In the next section we develop a theoretical model that takes into account the macroeconomic factors that might affect the demand and supply of VC.

3. Modelling the amount of venture capital

As Poterba (1989) and Gompers and Lerner (1998), we argue that changes in the level of VC funds come from changes either in the supply or the demand of VC. The demand comes from the entrepreneurs interested in setting up an innovative start-up. The supply of VC corresponds to the share of risk capital provided by private investors, pension funds and banks. The actual amount of VC invested represents the equilibrium between the demand and the supply of VC.

The demand and supply of VC can be modelled through equations (1) and (2) that characterize the demand price of VC, P^d, and the supply price of VC, P^s, respectively. The supply price of VC is assumed to be a positive function of the available VC funds, the interest rate (r) and the corporate tax rate (TAX). The more VC is available on the market, the higher will be the supply price of VC, due to increasing marginal costs ($a_{vc}>0$). If interest rates increase we can expect the fund providers to increase their return requirement ($a_r>0$; otherwise they would opt for alternative investments opportunities). Similarly, an increase in the corporate gains tax rate would increase the return requirements ($a_{tax}>0$).

$$P^{s}_{VC} = a_C + a_{vc} VC + a_{tax} TAX + a_r r \tag{1}$$

$$P^{d}_{VC} = b_C + b_{vc} VC + b_{\hat{Y}} \hat{Y} + b_{to} TO + b_{en} EN + b_{tax} TAX + b_r r \tag{2}$$

The equation of the demand price of VC reflects the entrepreneurs' viewpoint. Decreasing marginal returns to VC is assumed (the projects with the largest expected returns are selected first). The more VC is available the lower is the demand price of VC ($b_{vc}<0$). The other factors that are assumed to influence the demand of VC are the GDP growth (Y), technological opportunities (TO), entrepreneurial culture (EN), level of corporate gains tax rate (TAX) and interest rates (r). The countries with a high GDP growth, large technological opportunities and a strong entrepreneurial culture are more likely to be associated with a strong demand for VC (and hence positive effects on the demand price of VC: $b_Y>0$; $b_{TO}>0$; $b_{EN}>0$). The general level of taxation will probably reduce the rate of entrepreneurship (the demand for VC and therefore $b_{tax}<0$). Concerning interest rates, we consider that innovative start-up's need important amounts of money in the short-term. Therefore if the cost of capital increases entrepreneurs are more likely to switch from the banking sector to the venture fund providers ($b_r>0$).

Equations (3) and (4) show the equilibrium level of VC that equalizes the supply and demand of VC.

$$(a_{vc} - b_{vc}) VC = (b_C - a_C) + b_{\hat{Y}} \hat{Y} + b_{to} TO + b_{en} EN + (b_{tax} - a_{tax}) TAX_{it} + (b_r - a_r) r \tag{3}$$

$$\text{where} \begin{cases} a_{vc} > 0 \rightarrow & \text{increasing marginal cost of VC Investment} \\ b_{vc} < 0 \rightarrow & \text{decreasing marginal return} \\ (a_{vc} - b_{vc}) \rightarrow & \text{always positive} \end{cases}$$

$$VC = \left[\frac{(b_C - a_C)}{(a_{vc} - b_{vc})}\right] + \left[\frac{b_{\hat{Y}}}{(a_{vc} - b_{vc})}\right] \hat{Y} + \left[\frac{b_{to}}{(a_{vc} - b_{vc})}\right] TO + \left[\frac{b_{en}}{(a_{vc} - b_{vc})}\right] EN + \left[\frac{(b_{tax} - a_{tax})}{(a_{vc} - b_{vc})}\right] TAX + \left[\frac{(b_r - a_r)}{(a_{vc} - b_{vc})}\right] r \tag{4}$$

Since the denominator is always positive, the numerator provides the expected sign of the parameters between brackets. All the right-hand side variables, except the level of taxation and the interest rate, are

expected to have a positive impact on VC. For interest rate (r), the impact is either negative or positive depending on the difference between the demand price effect and the supply price effect. If the demand price effect of a high interest rate is larger than its supply price effect, then the overall impact of interest rates on VC should be positive. The effect of the level of corporate gains tax rate on the equilibrium level of VC will always be negative since ($b_{tax} - a_{tax}$) is always negative.

The empirical implementation of equation (4) is presented in equations (5) and (6). The growth rate of GDP allows testing the cyclicality of VC. Regarding interest rate we suspect that short-term and long-term interest rates could affect differently the venture fund providers and the 'high-tech' entrepreneurs. We therefore plan to use a short-term (one year, r^{ST}) and a long-term (ten years, r^{LT}) interest rate in the empirical model. Technological opportunity is proxied by three variables, the growth rate of business R&D outlays, the business R&D capital stock and the number of triadic patents. The growth rate of business R&D expenditures represents the research dynamics of a country. The business R&D capital stock is an indicator of the available stock of knowledge (or of the cumulated innovative efforts). The number of triadic patents is an indicator of innovative output. It measures the number of highly valuable inventions invented in each country (it is counted by country of inventor and by priority year). The entrepreneurial environment can be measured with three variables: level of taxation, entrepreneurial activity and labour market rigidity. The level of taxation is measured with the corporate income tax rate (CITR).

The measures of entrepreneurial activity (TEA) and labour market rigidity (RIG) are indices that are only available for one year. We therefore introduce them in interaction with other variables. For instance, it is possible to test whether RIG would affect the impact of GDP growth rate on the intensity of VC. This is equivalent to test whether the impact of GDP growth rate on VC intensity is composed of a fixed component ($\beta^{c}{}_{\Delta\, gdp}$) and a component that varies across countries according to the level of labour market rigidities (i.e., $\beta_{\Delta\, gdp} = \beta^{c}{}_{\Delta\, gdp} + \beta_{rig}\, \Delta$ GDP). Similarly, the level of entrepreneurship (TEA) could affect the impact of the available stock of knowledge, SBRD. These interactions are illustrated in equation (6).

Model with no interaction

$$VC_{it} = \beta_{\Delta gdp}\, \Delta GDP_{it} + \beta_{\Delta brd}\, \Delta BRD_{it-1} + \beta_{sbrd}\, SBRD_{it-1} + \beta_{pat}\, PAT_{it} + \beta_{citr}\, CITR_{it} + \beta_{r}\, r_{it} + \sigma_{G}\, G + \phi_{i} + \varphi_{t} + \mu_{it} \quad (5)$$

Model with interactions with TEA and RIG

$$VC_{it} = \beta^{c}_{\Delta gdp}\, \Delta GDP_{it} + \beta_{\Delta brd}\, \Delta BRD_{it-1} + \beta^{c}_{sbrd}\, SBRD_{it-1} + \beta_{pat}\, PAT_{it} + \beta_{tea}\, (SBRD_{it-1} * TEA_{i}) + \beta_{citr}\, CITR_{it} + \beta_{rig}\, (\Delta GDP_{it} * RIG_{i}) + \beta_{r}\, r_{it} + \sigma_{G}\, G + \phi_{i} + \varphi_{t} + \mu_{it} \quad (6)$$

where Δ represents the first logarithmic difference. 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 (the expected signs are presented between parentheses):

$\beta_{\Delta\, gdp}$ The impact of GDP growth (+).
$\beta_{\Delta\, brd}$ The impact of business R&D expenditures growth rate (+).
β_{sbrd} The impact of the level of business R&D capital stock (+).
β_{pat} The impact of the number of triadic patents (+).
β_{tea} The impact of the level of entrepreneurship on β_{sbrd} (+).
β_{citr} The impact of the CITR (-).
β_{rig} The impact of labour market rigidities on $\beta_{\Delta\, gdp}$ (-).
β_{r} The impact of interest rate (?).

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

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.

ϕ_i are country dummies which take into account country-specific framework conditions that might affect VC intensity.

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

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

VC is the venture capital intensity, i.e. the VC funds[2] divided by GDP (Sources: EVCA and OECD).

GDP is the gross domestic product (Source: OECD, Main Science and Technology Indicators).

BRD is the business R&D expenditures (Source: OECD, Main Science and Technology Indicators).

SBRD is the 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 1). The depreciation rate is 15%. Sensitivity analysis show that the results of the regressions do not change significantly with the chosen depreciation rate (Guellec and van Pottelsberghe, 2002) (Source: OECD Main Science and Technology Indicators).

PAT is the number of Triadic patents (Source: OECD). These patents have been applied at the USPTO, the Japanese Patent Office and the European Patent Office. We can therefore assume that they reflect patents with a very high value.

CITR is the corporate income tax rate (Source: OECD).

RIG is the employment protection index drawn up by the OECD (1994a) and based on the strength of the legal framework governing hiring and firing of employees. It is a measure of labour market rigidities. The countries are ranked from 1 to 20 with 20 being the most strictly regulated. Since the indicator is fixed over time, it is introduced in interaction with GDP.

TEA is the Total Entrepreneurship Activity (TEA)-index computed by adding the proportion of adults involved in the creation of nascent firms and the proportion involved in new firms (Source: The Global Entrepreneurship Monitor 2001). The variable is a ranking from 1 to 20. This measure of entrepreneurial activity can be meaningfully used for international comparisons.

r is the one-year national deposit rate (Source: IMF) or the long-term national interest rate (10 years, Source: OECD).

The estimates are performed with a panel data set of 16 OECD countries over the period 1990-1998. 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 period can vary across countries based on availability of information. Descriptive statistics of all the variables are presented in Table 2. The average value of the dependent variable (VC intensity) varies from 0.01 percent in Denmark to 0.16 percent in Canada, as shown in the last column.

[2] The European definition of VC is not exactly the same as the US one. For example, in Europe, the European Venture Capital Association included management buy-outs (MBOs) and management buy-ins (MBIs) in the definition of the VC. The management and the composition of the funds also differ in each country.

Table 2: Descriptive statistics (%)

Country	Period	GDP	Business R&D investment	Business R&D capital stock	Number of Patent	One-year Interest rate	Long-Term Interest rate	Corporate Income Tax Rate	Level of entrepre-neurship	Labour market rigidities	VC Intensity (GDP)
		Growth rates (%)						Average			% Shares
AU	1995-98	3.47	-4.64	5.79	6.87	-13.95	-15.67	0.47	15.2	4	0.09
BE	1990-98	1.68	5.28	3.72	6.77	-8.51	-9.09	0.45	4.5	17	0.06
CA	1995-98	3.14	4.00	4.95	10.47	-11.06	-13.14	0.40	12.2	3	0.16
DK	1990-98	2.53	7.06	7.18	7.11	-11.15	-8.91	0.47	7.6	5	0.01
FI	1990-98	1.55	8.58	7.33	12.36	-14.21	-11.89	0.49	12.5	10	0.04
FR	1990-98	1.42	0.70	2.80	0.89	-4.13	-9.08	0.46	5.0	14	0.04
GE	1990-98	2.94	-0.05	1.43	4.23	-10.62	-7.71	0.63	6.9	15	0.04
IR	1990-97	7.03	17.37	15.49	4.60	-31.18	-6.84	0.10	9.1	12	0.05
IT	1990-98	1.28	-0.65	2.34	1.20	-9.13	-11.97	0.43	8.1	20	0.03
JP	1994-98	0.94	4.86	3.55	5.83	-36.87	-22.91	0.55	5.7	8	0.02
NL	1990-98	2.55	2.17	1.78	3.63	-0.82	-7.87	0.45	6.4	9	0.10
NO	1990-97	3.64	3.81	3.23	11.14	-13.07	-8.15	0.51	10.9	11	0.06
SP	1990-98	2.19	1.06	4.07	4.83	-14.93	-12.90	0.34	6.6	19	0.03
SW	1990-97	0.95	8.19	5.75	12.00	-17.88	-9.36	0.52	6.6	13	0.03
UK	1990-98	2.15	-0.85	0.79	2.99	-12.07	-9.06	0.44	6.9	7	0.08
US	1990-98	3.07	3.25	2.72	3.05	-4.86	-5.88	0.43	16.7	1	0.08

Sources: OECD, MSTI, EVCA and own calculations

4. Empirical results

Each variable of equation (5) has first been included separately in the empirical model. The estimated parameters are presented in Table 3. All variables have the expected impact as far as their sign and significance is concerned. Results concerning the growth rate of GDP (Table 3, column 1) are in line with those of Gompers and Lerner (1998) for the US but do not confirm the non-significant impact obtained by Jeng and Wells (2000). Several tests have been carried out in order to determine whether a time lag is necessary. However, only the contemporaneous GDP growth rate has a significant impact on VC intensity.

Both one-year and ten-year interest rates have a positive and significant impact, suggesting that the demand effect of interest rates is stronger than the supply effect. Since entrepreneurs must have a shorter vision of financial constraints (or return) than fund providers, we would have expected a negative impact of the long-term interest rate. However, the adjusted R-squared is the smallest with the ten-year interest rate. Column 4 of Table 3 reports a variable representing the difference between the long-term and short-term interest rates. The negative and significant impact suggests a stronger supply-side effect. What matters is not only the level of the long-term interest rate but also the difference between the long-term and short-term rates. The larger this difference, the less venture fund providers would be attracted towards risky investment.

The three variables representing technological opportunity and research efforts play a significant role in determining VC intensity. The strong and positive impact of the growth rate of business R&D expenditures, the Business R&D capital stock and the number of triadic patents show that the demand of VC is sensitive to

the dynamics of research activities, to the available stock of knowledge and to the level of innovation output, as proxied by the number of high value patents.

It is worth noticing that the three variables that yield the highest adjusted R-squared are the short-term interest rate, the growth of business R&D investment and the difference between the long-term and short-term interest rates. Then come the GDP growth rate, the stock of knowledge and the number of triadic patents. The short-term cost of money and technological opportunity seem to be the strongest drivers of VC. High taxation of income reduces the relative level of VC probably due to an induced lower entrepreneurial will.

Table 4 presents the results of the estimates with several variables introduced simultaneously in the model. The sign and significance of the impact of all these variables remain unchanged when they are introduced simultaneously in the model. Columns 1 to 3 present the basic model described in equation (5), with different indicators for the interest rates.

The short-term interest rate (column 1) is still highly significant, whereas the long-term interest rate is no more significant (column 2), probably due to the simultaneous introduction of GDP growth in the model. However, the difference between short-term and long-term interest rates has a significant and negative impact (column 3). It seems therefore that the short-term cost of capital and its difference with the long-term cost play a more important role in explaining the intensity of VC. These results witness a stronger influence of the short-term cost of capital on the demand side (entrepreneurs) than on the supply side (investors). However, the larger the difference between long-term and short-term interest rates, the lower the VC intensity.

As predicted, corporate income tax rate has a negative impact on the VC intensity and the parameters associated with the three variables of technological opportunity and research efforts (the growth rate of business R&D expenditures, the business R&D capital stock and the number of triadic patents) are positive and significant. This result about triadic patents is consistent with the results of Kortum and Lerner (1998) who show that a surge of patents may increase the VC fundraising. In other words, the property of highly valued intellectual assets (triadic patents are associated with a much higher value than the patents applied only in one country or region) seems to stimulate the demand for VC.

The remaining columns test other specifications described in equation (6), with two interaction variables representing a country's entrepreneurial environment. The index of labour market rigidities is first interacted with the GDP growth rate variable (see column 4). Results show that the impact of GDP growth rate on the VC intensity is composed of a fixed and significant component (0.0067) and a country specific component that depends on labour market rigidities (-0.00047). The positive impact of GDP on the VC intensity is therefore reduced in countries with high labour market rigidities. Jeng and Wells (2000) obtain a similar result but only for early stage funding. Over the threshold of 14.2 in the index of labour market rigidities, the impact of GDP growth becomes negative.

The level of entrepreneurship is interacted in a similar way with the stock of available knowledge (the R&D capital stock, in column 5). Estimates indicate that the impact of the R&D capital stock on the VC intensity is composed of a fixed negative component and a country specific component that depends on the relative level of entrepreneurship (TEA): the higher the level of entrepreneurship, the stronger the impact of the business R&D capital stock on VC intensity. In order to have a positive impact of the available stock of knowledge on VC performances, a minimum level of entrepreneurship is required. The estimated parameters suggest that the impact of the business R&D capital stock on the VC intensity becomes positive and significant above a threshold of 12.8 in the TEA index (level of entrepreneurship).

Table 3: Estimation results of the VC intensity, single explanatory variables

		Dependent variable: VC intensity (VC/GDP)							
		GLS	*GLS*	*GLS*	*GLS*	*GLS*	*GLS*	*GLS*	*GLS*
Regressions		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Economic variables									
GDP growth rate	ΔGDP_{it}	0.003*** *(3.32)*							
One-year Interest rate	r_{it}		0.00004*** *(3.26)*						
Long-Term Interest rate (10 years)	r_{it}			0.00004** *(2.18)*					
Log [r10/r1]	r_{it}				-0.0001*** *(-3.05)*				
Technological opportunity									
Business R&D investment growth rate (t-1)	ΔBRD_{it-1}					0.001*** *(4.19)*			
Business R&D capital stock (t-1)	$SBRD_{it-1}$						$7*10^{-15}$*** *(5.15)*		
Log Number of triadic Patents	PAT_{it}							0.0003*** (2.67)	
Entrepreneurial environment									
Corporate Income Tax Rate	$CITR_{it}$								-0.002*** *(-3.20)*
Control variables									
German reunification dummy (t)		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific intercept		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared		0.726	0.755	0.628	0.737	0.742	0.713	0.682	0.669

Note: Panel data, 16 OECD countries, 1990-98, 130 observations. * Indicates the parameters that are significant at a 10% probability threshold, ** 5% probability threshold and *** 1% probability threshold. All equations include country dummies (within estimates), time dummies, and a dummy variable for the German reunification. The econometric method is GLS.

Table 4: Estimation results of the VC intensity, complete model and interactions

Dependent variable: VC intensity (VC/GDP), GLS estimates								
Regressions	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Economic variables								
GDP growth rate ΔGDP_{it}	0.001*	0.001	0.001*	0.007***	0.001*	0.007***	0.007***	0.007***
	(1.69)	(1.37)	(1.76)	(2.98)	(1.86)	(3.77)	(3.55)	(3.17)
One-year Interest rate r_{it}	0.00003***			0.00003**	0.00003***	0.00003***		0.00002 $^{\nabla}$
	(2.70)			(2.45)	(2.96)	(2.72)		(1.55)
Long-Term Interest rate (10 years) r_{it}		0.00002						
		(0.96)						
Log [r10/r1] r_{it}			-0.0001***				-0.0001**	-0.00004
			(-3.35)				(-2.23)	(-0.67)
Technological opportunities								
Business R&D investment growth rate (t-1) ΔBRD_{it-1}	0.001**	0.001**	0.001***	0.001**	0.001***	0.001**	0.001***	0.001***
	(2.25)	(2.46)	(2.52)	(2.19)	(2.62)	(2.46)	(2.67)	(2.56)
Business R&D capital stock (t-1) $SBRD_{it-1}$	$6*10^{-15}$***	$6*10^{-15}$***	$6*10^{-15}$***	$4*10^{-15}$***	$-2*10^{-14}$***	$-1.5*10^{-14}$***	$-1.1*10^{-14}$***	$-1.4*10^{-14}$***
	(4.44)	(4.90)	(4.66)	(2.91)	(-5.14)	(-5.25)	(-2.76)	(-3.17)
Log Number of triadic patents PAT_{it}	0.0004***	0.0003**	0.0004***	0.0003**	0.0003**	0.0003*	0.0002*	0.0003*
	(2.72)	(2.24)	(2.67)	(2.28)	(2.19)	(1.91)	(1.72)	(1.91)
Entrepreneurial environment								
Corporate Income Tax Rate $CITR_{it}$	-0.001**	-0.001*	-0.001**	-0.001*	-0.001**	-0.001*	-0.001*	-0.001*
	(-2.23)	(-1.67)	(-2.17)	(-1.76)	(-2.29)	(-1.82)	(-1.78)	(-1.77)
Labour Market Rigidities $\Delta GDP_{it} * RIG_i$				-0.0005***		-0.0005***	-0.0006***	-0.0005***
				(-2.55)		(-3.07)	(-3.26)	(-2.94)
Level of entrepreneurship $SBRD_{it-1} * TEA_i$					$1.4*10^{-15}$***	$1.1*10^{-15}$***	$1*10^{-15}$***	$1*10^{-15}$***
					(6.49)	(5.92)	(3.55)	(3.90)
Control variables								
German reunification dummy (t)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific intercept	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.833	0.805	0.821	0.820	0.833	0.860	0.827	0.830

Note: Panel data, 16 OECD countries, 1990-98, 130 observations. $^{\nabla}$ Indicates the parameters that are significant at a 15% probability threshold, * 10% probability threshold, ** 5% probability threshold and *** 1% probability threshold. All equations include country dummies (within estimates), time dummies, and a dummy variable for the German reunification. The econometric method is GLS.

The estimated parameters associated with the interaction between the two country-specific variables representing the entrepreneurial environment are stable in the subsequent models. Columns 6 to 8 show that the simultaneous introduction of the two indicators (RIG and TEA), and the use of short-term and long-term interest rates do not affect the results. The last column introduces simultaneously the short-term interest rate and the difference between the long-term and short-term interest rates. The non significant impact of the difference indicator suggests that what matters more is the short-term interest rate influence on the demand-side of VC.

Table 5a: Estimation results of the VC intensity, interactions with RIG

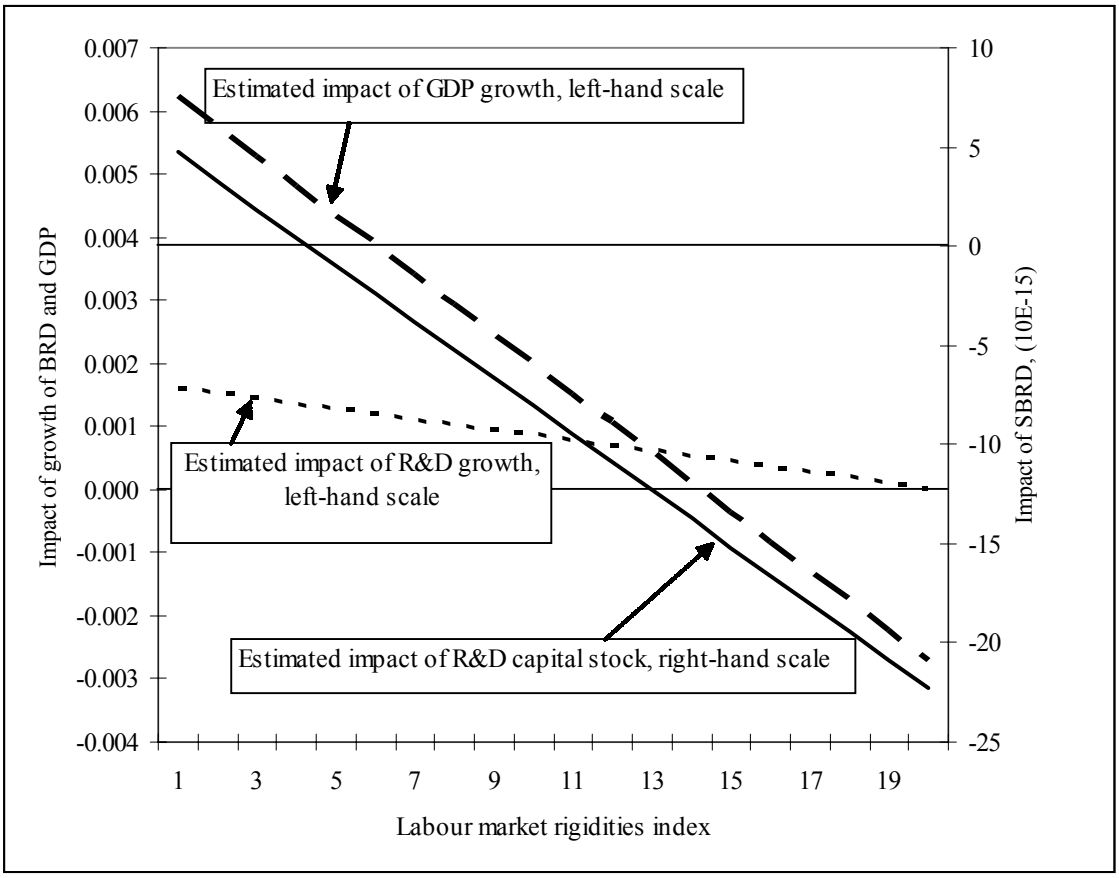
Dependent variable: VC intensity (VC/GDP)					
		GLS	*GLS*	*GLS*	*GLS*
Regressions		*1*	*2*	*3*	*4*
Economic variables					
GDP growth rate	ΔGDP_{it}	0.007***	0.001$^{\nabla}$	0.001	0.001
		(2.98)	(1.45)	(1.06)	(1.03)
One-year Interest rate	r_{it}	0.00003**	0.00003**	0.00003***	0.00002**
		(2.45)	(2.33)	(3.00)	(2.02)
Technological opportunities					
Business R&D investment growth rate (t-1)	ΔBRD_{it-1}	0.001**	0.002***	0.001**	0.001***
		(2.19)	(2.75)	(2.06)	(2.61)
Business R&D capital stock (t-1)	$SBRD_{it-1}$	$4*10^{-15}$***	$5*10^{-15}$***	$6*10^{-15}$***	$5*10^{-15}$***
		(2.91)	(4.30)	(4.66)	(3.58)
Log Number of triadic patents	PAT_{it}	0.0003**	0.0004***	0.0003*	0.001***
		(2.27)	(3.02)	(1.76)	(2.78)
Entrepreneurial environment					
Corporate Income Tax Rate	$CITR_{it}$	-0.001*	-0.001**	-0.001**	-0.001**
		(-1.76)	(-2.38)	(-1.99)	(-2.29)
Labour Market Rigidities 1	$\Delta GDP_{it} * RIG_i$	-0.0005***			
		(-2.55)			
Labour Market Rigidities 2	$\Delta BRD_{it-1} * RIG_i$		-0.0001*		
			(-1.93)		
Labour Market Rigidities 3	$SBRD_{it-1} * RIG_i$			$-1*10^{-15}$***	
				(-3.92)	
Labour Market Rigidities 4	$PAT_{it} * RIG_i$				0.00003$^{\nabla}$
					(-1.57)
Control variables					
German reunification dummy (t)		Yes	Yes	Yes	Yes
Country-specific intercept		Yes	Yes	Yes	Yes
Time dummies		Yes	Yes	Yes	Yes
Adjusted R-squared		0.820	0.840	0.814	0.844

Note: Panel data, 16 OECD countries, 1990-98, 130 observations. $^{\nabla}$ Indicates the parameters that are significant at a 15% probability threshold, * 10% probability threshold, ** 5% probability threshold and *** 1% probability threshold. All equations include country dummies (within estimates), time dummies, and a dummy variable for the German reunification. The econometric method is GLS.

We investigate more thoroughly the role of the two country-specific variables representing the entrepreneurial environment in tables 5a and 5b. The two indexes have been interacted with the GDP growth rate and each of the three variables of technological opportunity and research efforts. Table 5a presents the estimated parameters related to the interaction between labour market rigidities and the four variables. There is a negative and significant effect of RIG on the impact of the GDP growth rate, the growth rate of R&D outlays and the stock of business R&D. The impact of triadic patents is not really affected by labour market rigidities.

Figure 1 illustrates the results of the estimates presented in table 5a. It shows how the level of labour market rigidities affects the impact of three determinants of VC. For instance, the impact of the growth rate of R&D expenses is always positive but declining as RIG increases. The effect of these rigidities on the stock of knowledge (SBRD) and on the GDP growth rate is steeper, as they become negative over a threshold of about 13 to 14 in the index of labour market rigidities.

Figure 1: The indirect effect of labour market rigidities on VC



Note: Estimated impact of the growth rate of GDP, the growth rate of business R&D expenditure and the stock of knowledge on VC intensity, according to the level of labour market rigidities. See table 5a, columns 1 to 3.

Table 5b presents the estimated parameters related to the interaction between the level of entrepreneurship (TEA) and the four variables. The interaction term is positive and significant with the R&D growth rate and the business R&D capital stock (see columns 2 and 3). With the lower level of entrepreneurship, the growth rate of business R&D expenditures would have no impact on the VC intensity. The larger the level of

entrepreneurship is, the larger the impact of business R&D expenditures. In other words, there must be a minimum level of entrepreneurship in order to spur the demand for VC. The business R&D capital stock has a significant impact on VC intensity only above a threshold of about 12 in the index of entrepreneurship.

Table 5b: Estimation results of the VC intensity, interactions with TEA

Dependent variable: VC intensity (VC/GDP)					
		GLS	*GLS*	*GLS*	*GLS*
Regressions		*1*	*2*	*3*	*4*
Economic variables					
GDP growth rate	ΔGDP_{it}	-0.001 (-0.54)	0.001 (1.41)	0.001* (1.86)	0.001 (0.86)
One-year Interest rate	r_{it}	0.00003*** (2.57)	0.00003*** (2.60)	0.00003*** (2.96)	0.00002** (2.15)
Technological opportunities					
Business R&D investment growth rate (t-1)	ΔBRD_{it-1}	0.001** (2.14)	-0.0004 (-0.56)	0.001*** (2.62)	0.001** (2.47)
Business R&D capital stock (t-1)	$SBRD_{it-1}$	$5*10^{-15}$*** (3.51)	$5*10^{-15}$*** (4.16)	$-2*10^{-14}$*** (-5.14)	$5*10^{-15}$*** (3.60)
Log Number of triadic patents	PAT_{it}	0.0003** (2.42)	0.0004*** (2.96)	0.0003** (2.19)	-0.00002 (-0.07)
Entrepreneurial environment					
Corporate Income Tax Rate	$CITR_{it}$	-0.001** (-2.24)	-0.001** (-2.18)	-0.001** (-2.29)	-0.001** (-2.06)
Level of entrepreneurship 1	$\Delta GDP_{it} * TEA_i$	0.0003 (1.15)			
Level of entrepreneurship 2	$\Delta BRD_{it-1} * TEA_i$		0.0001* (1.62)		
Level of entrepreneurship 3	$SBRD_{it-1} * TEA_i$			$1*10^{-15}$*** (6.49)	
Level of entrepreneurship 4	$PAT_{it} * TEA_i$				0.00004 (1.34)
Control variables					
German reunification dummy (t)		Yes	Yes	Yes	Yes
Country-specific intercept		Yes	Yes	Yes	Yes
Time dummies		Yes	Yes	Yes	Yes
Adjusted R-squared		0.837	0.837	0.833	0.834

Note: Panel data, 16 OECD countries, 1990-98, 130 observations. $^{\nabla}$ Indicates the parameters that are significant at a 15% probability threshold, * 10% probability threshold, ** 5% probability threshold and *** 1% probability threshold. All equations include country dummies (within estimates), time dummies, and a dummy variable for the German reunification. The econometric method is GLS.

Table 6 summarizes the main findings of our empirical investigation and compares them with the results obtained by Jeng and Wells (2000) and Gompers and Lerner (1998). The cyclicality of VC with respect to GDP growth confirms both our expectation and the results of Gompers and Lerner (1998). Jeng and Wells (2000) did not find any significant effect partly because of the structure of their dataset (cross section of countries) and partly because of the use of the IPO variable.

Concerning the cost of capital, we confirm the positive impact of the short-term interest rate obtained by Gompers and Lerner (1998) at the aggregate level. We also show that the difference between the long-term interest rate and the short-term interest rate has a negative and significant impact on the VC intensity.

Labour market rigidities and the corporate income tax rate are two factors that reduce the intensity of VC. On the other hand, a strong entrepreneurial culture and more intense technological opportunities and research efforts improve the positive effect of the stock of knowledge and GDP growth on the VC intensity.

Table 6: Comparison of our results with the state of the art

	Jeng and Wells (2000), 21 countries, Panel data and cross section	Gompers and Lerner (1998) US industry aggregate data	Our analysis 16 countries, panel data
Macroeconomic conditions			
Gross domestic Product	0	+	+
Interest rate 1 year		+ at aggregate level and – at state level	+
Interest rate 10 years			0
Difference between 10 years and 1 year Interest rate			-
Private Pension Funds	+ Over time 0 Across countries	+ Over time	
Entrepreneurial environment			
Corporate income tax rate	0	-	-
Labour market rigidities	- at the early stage 0 at expansion stage		- reduces the impact of GDP and R&D on VC
Initial Public Offering	0 at early stage across countries + at expansion stage	0	
Stock Market Opportunities	(Market Capitalization Growth) 0	(Equity Market Return). +	
Level of entrepreneurship			+ Increases the impact of R&D on VC
Technological opportunity			
Number of Triadic Patents			+
Business R&D growth		+	+
Stock of knowledge		+	+

5. Concluding Remarks

This paper aims at contributing to the literature on the determinants of VC. Our contribution consists in (1) developing a theoretical model that takes into account the supply-side and demand-side variables to explain VC intensity; and (2) introducing simultaneously traditional determinants of VC and new potential determinants like the cost of capital, the level of entrepreneurship, and novel proxies aiming at measuring technological opportunity. Empirical results can be summarized as follows.

Interest rates have a significant impact on VC intensity. Whereas short-term interest rates influence positively the relative level of VC via a strong demand-side effect, the difference between long-term and short-term interest rates has the opposite impact, via a stronger supply-side effect. Long term interest rates do not affect significantly the equilibrium level of VC.

We show that the impact of corporate income tax rates on VC investment is negative. In other words, high corporate income tax rates reduce the relative level of VC investment across countries and over time.

VC is highly cyclical. It follows a similar evolution than GDP growth rate. In periods of high growth, the flow of venture capital outperforms the GDP growth rate, and *vice versa*. This cyclicality is reduced by the degree of labour market rigidities. A high level of labour market rigidity reduces the positive impact of GDP growth on VC intensity, as well as the positive impact of the knowledge capital stock and of the growth in business R&D.

We also show that indicators of technological opportunity, such as the growth rate of R&D investment, the available stock of knowledge and the number of high value patents (triadic patents), influence significantly a country's investment in VC. The positive impact of the stock of knowledge is strongly reinforced in the countries were the rate of entrepreneurship is very high.

One important policy implication that emerges from these results is that in order to stimulate VC in a country, demand-side factors have to be taken into account. The most important factors affecting the demand of VC are the stock of knowledge, innovative outputs, business R&D, the corporate income tax rate and short-term interest rates. In addition, labour market rigidities and the level of entrepreneurship do play an important role. Changing these factors would require adjustment in structural policies (labour market and education), whose impact can only appear in the long term.

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APPENDIX 1: Calculation of the variables

Business 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:

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

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

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

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

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

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 .

This formula has been used to calculate the business R&D capital stock (SBRD).