European Venture Capital vs. Patents: Are Patents a Venture Capital output or input?[&]

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Abstract

This paper examines the direction of causality between Venture Capital (VC) and Patents in Europe. We test whether causality runs from Patents to VC by applying the Generalized Method of Moments on a linear dynamic panel model and from VC to Patents using a panel count model namely, the Linear Feedback Model. We conclude that the causality runs from Patents to VC and that patenting activity should thus be considered an input rather than an output of the VC investment process.

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Introduction

Venture Capital (henceforth VC) is equity investment aiming at the development of young, dynamic and innovative firms. VC, along with R&D, are the main investment types whose consequence is, or should be technological progress and innovation. According to Gompers and Lerner (2001) and Kenney (2000), some of the most famous high-tech companies in the US have been developed due to VC assistance (Amazon.com, America Online, Amgen, Compaq, DEC, Federal Express, Intel, Lotus, Oracle, Seagate, 3Com, Yahoo, Apple Computer, Cicko Systems, Genentech, Microsoft, Netscape, Sun Microsystems and others). Other researchers have also stressed the role of US VC in fostering innovation (Timmons and Bygrave, 1986, Hellman and Puri, 2000, Kortum and Lerner, 2000, Lerner, 2002). Regarding Europe, Bottazi and Da Rin (2002) find that VC's contribution to the development of innovative companies listed in Euro.nm new stock market is substantial, although the European VC market lags behind the US counterpart.

Although the VC role to technological evolution is in general appreciated, it hasn't been thoroughly investigated by empirical researchers, unlike R&D investments whose contribution has been examined extensively by numerous papers. Most of them approximate technological development by the patent applications or grants each year. Pakes and Griliches (1980) were among the first to approach the issue and found a significant contemporaneous relation between R&D and patents. A series of related papers have found similar results. Namely, Hausmann et al (1984), Hall et al (1986), Cincera et al, (1997), Crepon and Duquet (1997) and Blundell et al (2002) find a rather strong contemporaneous effect of R&D to patents with varying elasticities. Regarding Venture Capital, Kortum and Lerner (2000) are the only to investigate the VC-patent relation. Using US microdata, they find a significant effect of VC and R&D to patents and conclude that a VC dollar has a three times higher probability to end up in a patent compared to a normal dollar.

The main idea of all the above papers is that patents are an output rather than an input of the R&D process (see for example Hall et al., 1986). In this paper we challenge this view regarding VC investments and investigate the direction of the causality of the patent-VC relation using a panel data set of VC investments and European patent applications for 15 European countries for the period 1995-2004. We use the term causality in the Granger (1969) sense, that is, whether in the presence of lags of the dependent variable among the regressors, including lags of a second regressor improves our prediction of the dependent variable. In order to test whether patents cause VC and also take into account the individual heterogeneity or fixed effect of the cross section units (the relatively constant over time characteristics of the cross section units which might be correlated with the regressors) we use a first differenced linear dynamic distributed lag model which we estimate with the Generalized Method of Moments (GMM) as the proper method for dynamic panel data models (see Holtz-Eakin et al.1988, 1989; Arellano and Bond, 1991; Ahn and Schmidt, 1995, 1997; Arellano and Bover, 1995 and Blundell and Bond, 1998). In order to test the reverse causality, we apply a different model. Being positive integers (counts), patents have to be handled with specially designed models that take into account the nature of the patent data. We choose the Linear Feedback Model (Blundell et al. 1995; Cincera, 1997; Blundell et al. 2002; Uchida and Cook, 2007) which allows for dynamics by including lags of the dependent count variable among the regressors in a linear manner and takes into account the individual heterogeneity of the cross section units. The results indicate that the causality runs from patents to VC and not vice versa implying that entrepreneurial projects tied with a probable patent grant precede VC financing. It seems that VC investments are directed to investees whose potential patent signals good prospects of the investment.

The paper is structured as follows. First we compare VC and R&D investments and then we explain our data set and the methodology. Finally we present our results and we end up with the conclusions.

Venture Capital vs R&D

Venture Capital works in a somewhat different manner compared to R&D conducted within businesses. Venture Capitalists (henceforth VCsts) are a type of financial intermediaries who collect funds from various external investors such as banks, pension funds and individuals, and invest them in risky equity. VC investment thus, refers to equity-linked financing of firms at various stages of their development (Sahlman, 1990) where VCsts become co-owners of the investee firm aiming in capital gains. R&D on the other hand doesn't necessarily follow a similar fashion. Business R&D investments can be financed from the firm's own resources or they can be derived from an external source with or without equity reward. However, part of the VC financing can be directed to R&D style expenses and thus, there might be an overlap between the two investment types.

Both R&D and VC can be staged. The literature suggests discreet stages of the VC process. Particularly, Bottazi and Da Rin (2002) distinguish between seed, start-up, expansion and later stage whereas, Sahlman (1990) makes a more detailed distinction and mentions eight VC stages. European Venture Capital Association's (EVCA) terminology split VC into three stages namely, seed, start-up and expansion stage finance. EVCA defines seed investments as financing intended for new firms in order to evaluate their initial concept, start-up as financing aiming at the development of the firm's product before the firm has sold any products, and expansion investments as financing aiming to assist the growth and expansion of the firm. R&D can similarly be staged. Badri et al (1997) distinguish among several R&D stages each of which is associated with a respective cost. Table 1 depicts European VC, Business R&D and patenting activity in 2004.

Table 1
VC, business R&D and patenting activity in 2004

	Total VC* in 2004 (percentage over total investments)	Business R&D investment in 2004 (percentage over total investments)	Patent applications at the EPO** (by priority year) in 2004
Austria	0,24%	7,05%	1348
Belgium	0,31%	6,33%	1405
Denmark	0,73%	8,53%	1082
Finland	0,35%	12,87%	1154
France	0,48%	6,84%	7984
Germany	0,26%	10,24%	23261
Greece	0,01%	0,75%	75
Italy	0,17%	2,52%	4581
Netherlands	0,42%	5,40%	3956

Norway	0,48%	4,38%	287
Portugal	0,47%	1,15%	61
Spain	0,53%	2,05%	1209
Sweden	1,34%	n.a.	2172
Switzerland	0,20%	n.a.	3087
UK	1,18%	6,19%	5869

*VC includes seed, start-up and expansion investments
**European Patents Office

Both R&D and early stage VC can be considered as irreversible investments. Early stage VC is clearly a sunk cost since it refers to firms with no production and no secondary market for their assets. R&D is also irreversible since it is firm or industry-specific and might have the lemons problem (Pindyck, 1991). Expansion VC investments however, are likely to be less irreversible since expansion stage firms are more mature, probably entering or expanding their production process.

Information asymmetry issues like moral hazard and adverse selection arise both in VC and R&D. The VC information asymmetry problems have been pointed out by many researchers (Sahlman, 1990, Schertler, 2000, Barry, 1994, Wright and Robbie, 1998). The external investors have to distinguish between "good" and "bad" VCsts to manage their funds and make sure that they will gain what they had been promised. Similarly, the VCsts have to select an investee entrepreneur out of a heterogeneous population and ensure that the provided financing will be properly managed. Similar problems appear in R&D investments between the investor and inventor (Hall, 2002).

Data

We use annual VC data obtained from the European Venture Capital Association (EVCA) for 15 European countries. The countries are Austria, Belgium Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and UK.

Regarding patent data, we employ patent applications to the European Patents Office (EPO) obtained from the Eurostat Database. We choose patent applications rather than patent grants since there might be a significant time lag between filing an application and receiving a grant (Hall et al, 2001). Thus, we believe that patent applications are more appropriate patent statistic proxying a country's innovation activity at a given year. Table 2 presents some descriptive statistics of our data set.

Table 2
Descriptive statistics

	Total VC*	Patent applications
Mean	565439,8	3201,387
Median	223850	1332,500
Maximum	6099578	23261
Minimum	844	14
Std. Dev.	856426,4	4875,836
Skewness	3,179	2,788
Kurtosis	16,129	10,450
Sum	84815964	480208
Observations	150	150

*In thousand Euros

Our EPO statistics on patent applications are classified by "priority date" that is, by the year of first filling in any national or regional patent organization (OECD patent glossary) prior to EPO. Ahead of applying to EPO, one might have applied to another national or regional office reserving thus, priority to a subsequent application to a second patents office (EPO for example) for the same patent within a given period of time. The European Patent Convention (EPC) restricts this period to one year (Article 87(1)).

Methodology

Patents cause VC

The initial equation to be estimated for causality is

$$y_{it} = \sum_{k=1}^{h} b_k y_{i,t-k} + \sum_{k=1}^{m} c_k x_{i,t-k} + e_{it} \qquad (1)$$

with $e_{it} = a_i + u_{it}$

where i and t denotes the cross section and time dimension respectively, u_{it} is the usual disturbance and a_i is the individual or fixed effect which we assume to be constant across time for each cross section unit but different across cross units and represents relatively constant over time characteristics of the countries which are possibly correlated with the regressors. Different countries might have time-invariant but different innovation networks or different mentality and attitude towards innovation which might affect both VC investments and patenting. The presence of a_i creates some complications, namely, both y_{it} and all lagged values $y_{i,t-k}$ are correlated with a_i and thus, with e_{it} which induces a bias in usual OLS estimators. Taking the first differences eliminates this individual effect and the respective bias.

$$y_{it} - y_{i,t-1} = \sum_{k=1}^{l} b_k \left(y_{i,t-k} - y_{i,t-k-1}\right) + \sum_{k=1}^{m} c_k \left(x_{i,t-k} - x_{i,t-k-1}\right) + u_{it} - u_{i,t-1} \qquad (2)$$

Since the right hand $y_{i,t-1}$ still depends on $u_{i,t-1}$, OLS is again not a proper method. In order to investigate whether patents Granger cause VC we follow the Arellano and Bond (1991) Generalized Method of Moments approach to estimate equation (2). We assume that past values of y and x are not correlated with the current error term and we use lagged values of Patents and VC as instruments such that the following orthogonality conditions are satisfied

$$E\left[y_{is}(u_{i,t} - u_{i,t-1})\right] = E\left[x_{is}(u_{i,t} - u_{i,t-1})\right] = 0, \text{ for all } s \le (t-2).$$

These orthogonality conditions that rely on the absence of second order serial correlation among the first-differenced residuals (Arellano and Bond, 1991) have also been proposed by Holtz-Eakin et al. (1988, 1989). For convenience we take $l = m$ and we use the Wald test to test the null hypothesis that all lagged coefficients of patents are not significant

$$H_0 : c_1 = c_2 = ... = c_m = 0$$

Rejection of the null hypothesis implies that patents cause VC. Due to our small sample size and the limited time series dimension we apply this test only for m=1, 2 and 3.

VC causes patents

Since patents are positive integers (counts) we have to apply models designed to facilitate the non-negativity and discreteness of patents when utilized as a dependent variable. Furthermore, since our data have a panel form, the individual heterogeneity of the cross section units has to be taken explicitly into account. The starting point is the assumption that our dependent count variable follows a Poisson process which implies the following exponential model:

$$E(y_{it} / x_{it}, \eta_i) = \exp(\beta x_{it} + \eta_i) \qquad (3)$$

where y_{it} is the dependent count variable, x_{it} the vector of regressors, η_i the individually specific characteristic. Equation (1) implies that the individual heterogeneity (fixed effect) enters the model multiplicatively, i.e.

$$E(y_{it} / x_{it}, \eta_i) = v_{it} h_i \qquad (4)$$

where $v_{it} = \exp(\beta x_{it})$ and $h_i = \exp(\eta_i)$ (5)

In order to eliminate the individual effect, the Chamberlain (1992) quasi-differencing transformation is used

$$\kappa_{it} = y_{it} \frac{v_{it-1}}{v_{it}} - y_{it-1} \qquad (6)$$

and the respective moment conditions for GMM estimation are

$$E(x_{is} k_{it}) = 0 \text{ for all } \quad s \leq t-1 \qquad (7)$$

where all lagged regressors are used as instruments. Since we are interested in adding dynamics, we apply a modified version of the above model namely, the Linear Feedback Model (LFM) introduced by Blundell et al, (2002) which in our purpose takes the following form

$$E(y_{it} / x_{it}, \eta_i) = \sum_{k=1}^{l} g_k y_{it-k} + v_{it} h_i \qquad (8)$$

where $v_{it} = \exp(\sum_{k=1}^{m} d_k x_{it-k})$

Equation (8) can be estimated with GMM using the quasi-differenced transformation (Blundell et al, 2002)

$$q_{it} = (y_{it} - \sum_{k=1}^{l} g_k y_{it-k}) \frac{v_{it-1}}{v_{it}} - (y_{it-1} - \sum_{k=1}^{l} g_k y_{it-k-1}) \quad (9)$$

And the respective instruments and moment conditions are

$$E(y_{il} q_{it}) = 0 \text{ for all } l \leq t-2 \quad (10)$$

$$\text{and } E(x_{is} q_{it}) = 0 \text{ for all } s \leq t-1 \quad (11)$$

In order to examine whether VC Granger causes patents we assume that $l = m$ and test the null hypothesis that all coefficients of lagged VC investments are jointly zero, that is

$$H_0 : d_1 = d_2 = ... = d_m$$

We test this hypothesis with the Wald test for m=1, 2 and 3.

Results

Table 3 presents the results of patents to VC causality test. The Wald test for two and three lags estimation indicate that patents do cause VC. Though, for one lag estimation the coefficient of patents isn't significant.

Table 3
Patents cause VC

Wald test (χ^2)	VC coefficients			Patent coefficients		
	b_1	b_2	b_3	c_1	c_2	c_3
-	0.091 (0.133)	-	-	1.238 (0.697)	-	-
30.637* [0.000]	0.301** (0.127)	-0.295** (0.126)	-	0.673 (1.353)	2.092** (0.828)	-
26.224* [0.000]	0.419** (0.174)	-0.395** (0.192)	-0.079 (0.160)	-0.106 (2.131)	5.910* (1.998)	-2.561 (2.267)

Standard errors in parenthesis and p-values in square brackets. Standard errors are heteroscedasticity robust. The coefficients b_m and c_m correspond to VC and patents respectively where subscripts denote the number of lags. The test for second order serial correlation and the Sargan test are satisfied.
*Significant at 0,01
**Significant at 0,05

Regarding the VC to patents causality (table 4) our findings indicate that VC do not cause patents at least for two and three lags estimation. For only one lag, the coefficient of VC is significant, though with a negative sign.

Table 4
VC causes Patents

Wald test (χ^2)	Patent coefficients			VC coefficients		
	g_1	g_2	g_3	d_1	d_2	d_3
-	0.766* (0.035)	-	-	-0.094* (0.030)	-	-
4.385 [0.112]	0.453* (0.113)	0.349* (0.102)	-	0.017 (0.015)	-0.251** (0.123)	-
2.664 [0.446]	0.512 (0.420)	0.326** (0.152)	-0.024 (0.351)	0.019 (0.090)	-0.344 (0.302)	0.058 (0.197)

Standard errors in parenthesis and p-values in square brackets. Standard errors are heteroscedasticity robust. The coefficients g_m and d_m correspond to patents and VC respectively where subscripts denote the number of lags. The test for second order serial correlation and the Sargan test are satisfied.
*Significant at 0,01
**Significant at 0,05

Conclusion

In this paper we have conducted causality tests to investigate whether patenting is an input or an output to the VC process. The patents to VC causality was tested through a GMM estimation of a linear dynamic panel and the reverse causality was tested through the Linear Feedback Model due to the integer nature of patents. Our findings indicate that the causality runs from patents to VC and not the other way round. The usual argument that VC advances technological evolution and innovation has to be enriched. Venture Capital promotes technological progress in the sense that it helps with the marketability and the diffusion of the potential benefits of already existing ideas and not with the creation of new ones.

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