Venture Capital and Innovation in Europe

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Abstract

This paper examines the direction of causality between Venture Capital (VC) and innovation (proxied by patents) in Europe. We test whether causality runs from patents to VC by estimating a linear dynamic panel model and causality from VC to patents by estimating a panel count model. Evidence from a European sample indicates that causality runs from patents to VC suggesting that, in Europe, innovation seems to create a demand for VC and not VC a supply of innovation. In this sense, innovative ideas seem to lack more than funds in Europe.

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Introduction

Venture Capital (henceforth VC) is financial investment channeled to the development of young, dynamic and innovative firms, and along with R&D, plays a major role in technological progress and innovation, most frequently proxied by the number of patent applications or grants at the appropriate level, firm, industry or country level. According to Gompers and Lerner (2001), some of the most renowned high-tech innovators in the US, such as Apple Computers, Cisco Systems, Genentech, Microsoft, Netscape, and Sun Microsystems, have developed thanks to VC assistance.

Research on the topic has also been abundant, most researchers stressing the role of VC in fostering innovation. Timmons and Bygrave (1986), Hellman and Puri (2000), Kortum and Lerner (2000) and Lerner (2002) have analyzed the US evidence, while Bottazi and Da Rin (2002) have found that, although the European VC market lags behind its US counterpart, European VC contributed substantially to the development of innovative companies listed in the Euro.nm stock market. The underlying idea in the literature above is the seemingly unquestionable assumption that VC generates innovation or, alternatively, that innovation is an output rather than an input of the VC process.

The widely accepted view of VC to innovation causality, let us call it the direct causation hypothesis, has been recently challenged by Ueda and Hirukawa (2003). On the basis of a US sample and assuming that Total Factor Productivity is a good proxy for technological progress and innovation, the authors have found that, at least at country level, causality runs from innovation to VC. However, when they examined the direct causation hypothesis at industry level, they found conflicting results. Reverse causation, according to the authors might well be the case when a substantial wave of innovation creates business opportunities and demand for VC finance.

In this paper we explore these contrasting views on the role of VC on technological progress and innovation and investigate the direction of causality in the innovation to VC relation. In other words we search for evidence in support of the direct/reverse causation based on a panel dataset of VC investments and European patent applications for 15 European countries for the period 1995-2004. To that we introduce causality in Granger's (1969) sense, that is, we test whether the inclusion of lagged values of the regressand in the right-hand side of the regression equation, including lags of the regressors improves predictability. The empirical method is based on standard panel data analysis.

In order to allow for heterogeneity (fixed effect) of the cross section units, when testing for direct causation, we use a linear dynamic distributed lag model in first differences. The model is estimated using a dynamic panel data methodology (Holtz-Eakin et al.; 1988 and Arellano and Bond; 1991). When we test for reverse causation, we apply a different method. Because the dependent variable, i.e. patents, consists in panel count data, the appropriate model is the Linear Feedback Model (Cincera, 1997; Blundell et al. 2002; Uchida and Cook, 2007) which includes lagged dependent counts among the regressors capturing eventually any heterogeneity of the cross section units.

Our evidence seems to run against the direct causation and in support of the reverse causation hypothesis, i.e. the VC to innovation causality. In our opinion, this possibly implies that innovative projects tied with a probable patent grant have an edge over their non-patent counterparts in signaling higher "quality" and attracting VC finance.

The paper is structured as follows. First, we discuss the issues involved in the role of VC in technological progress and innovation; next we present our dataset and in a subsequent section we lay down explicitly our methodology and present the results. Finally, we epitomize our research in a concluding section.

2. The Role of VC in Technological Progress

Schumpeter's initial claim was that dynamic entrepreneurs are the source of innovation, but in his later works he attributed innovation to large corporations (Nooteboom, 1983). Large firms have the edge over their smaller counterparts due to capital market imperfections and information asymmetries and their ability to fund independent R&D projects using their own resources. More recent studies examining the issue of the firm's size on the production of innovation appear to be inconclusive (Tether, 1998). However, the emergence of VC markets in modern economies has provided some support in Schumpeter's initial claim. Due to the lack of collateral, small innovative firms, mostly individual entrepreneurs, have limited access to capital markets in order to finance their projects and hence, external equity is the main alternative. Venture Capitalists (henceforth VCsts), the managers of VC funds, come to bridge this funding gap by providing equity to small, dynamic and innovative firms, becoming thus, co-owners of the investee's project.

Although the role of VC in technological progress is in general acknowledged, it has received less attention in empirical research, as opposed to R&D investments whose contribution has been examined extensively in numerous papers. Pakes and Griliches (1980) were among the first to suggest a significant relation between R&D and patents. A series of related papers have found similar results. Namely, Hall et al. (1986), Cincera et al., (1997), Crepon and Duquet (1997) and Blundell et al (2002) and others report a quite strong effect of R&D to patents at the firm level.

Kortum and Lerner (2000) are among the few to investigate the VC to patent relation. Using US industry level data, they have showed that VC and R&D have a significant effect on patents and estimated to that a VC dollar is three times more valuable in generating patents compared to a normal dollar. Narrowing the focus to VC, Hellman and Puri (2000) have presented evidence at the firm level indicating that companies "pursuing an innovator rather than an imitator strategy are more likely to obtain Venture Capital financing". Finally, Ueda and Hirukawa (2003) have presented country level evidence in support of the reverse hypothesis ("innovation comes first" in their terminology), using Total Factor Productivity as a proxy for innovation. In their view, "an arrival of new technology [resulting in increased numbers of patents] increases demands for VC capital by driving new firm start-ups".

In our opinion, reverse causation may also be explained in terms of information asymmetry considerations (Sahlman, 1990). VC might be deterred in the presence of severe adverse selection issues, due to the risk of venturing into an ex post unacceptably risky project. In this context, a patent can act as a signal, indicate the project's higher quality and, as a consequence, attract prospective VC investment.

On the other hand, VC, especially when funding the early stages of development [1], can be considered as irreversible investment and according to the irreversibility-delay hypothesis (Dixit and Pindyck, 1994) the decision to invest may be deterred in the presence of uncertainty over future cash flows. VC, especially early stage VC, is clearly a sunk cost since it refers mostly to firms with no production and no secondary market for their assets. Irreversibility might also make the cost of adverse selection more severe and thus the signaling effect of a patent more valuable.

Hence, we propose to test the following hypothesis.

Hypothesis: Because of information asymmetries and irreversibility considerations, innovation generates, rather than is generated by, VC activity.

3. Data description

Although the preceding analysis refers mostly to the firm level, the issues directly extend to any level of aggregation. In this paper we employ country level data, since we have no reason to believe that the aggregate behavior of firms should generate conflicting data on the VC to patent relation. We use annual VC data for 15 European countries obtained from the European Venture Capital Association (EVCA). The countries are Austria, Belgium Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and UK.

Patent data refer to the European Patents Office (EPO) and have been obtained from the Eurostat Database. We as well choose patent applications rather than patent grants, as is typically the case in existing research, since there might be a significant time lag between filing an application and receiving a grant (Hall et al, 2001). Thus, we believe that the number of patent applications is a better proxy for a country's innovation activity at a given year. On the other hand the signaling effect of a patent is more pronounced on the time of application rather than on the time of the patent grant. The same holds, in our opinion, for the irreversibility-delay effect: a patent application is more uncertain than a patent grant or a patent rejection.

Statistical parameters of our sample are depicted in Tables 1 and 2. Table 1 presents European VC, Business R&D and patenting activity in 2004 and Table 2 presents the descriptive statistics of our sample. The interested observer will note the great diversity across European countries both in terms of VC investment, R&D expenses but especially in the patent applications data with Germany showing the maximum patent count, almost seven times the average European count.

[INSERT TABLE 1 AND 2 AROUND HERE]

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)).

4. Methodology and Results

In order to test the Patents to VC causality, the initial equation to be estimated is:

$$VC_{it} = a + \sum_{k=1}^{h} b_k VC_{i,t-k} + \sum_{k=1}^{m} c_k P_{i,t-k} + e_{it} \tag{1}$$

with $e_{it} = \eta_i + u_{it}$

where all variables are expressed in logarithms, i and t denotes the cross section and time dimension respectively, u_{it} is the usual disturbance and η_i is the individual or fixed effect. We make the standard hypothesis that η_i represents constant over time characteristics of the cross section units which might be 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. All lagged values $VC_{i,t-k}$ are correlated with a_i and thus, with e_{it} which induces a bias in OLS. Taking the first differences eliminates this individual effect and the respective bias:

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

Since the right hand $VC_{i,t-1}$ still depends on $u_{i,t-1}$, and OLS is still not the proper method, we apply Arellano and Bond's (1991) Generalized Method of Moments. We assume that past values of VC and P 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:

$$E\left[VC_{is}(u_{i,t} - u_{i,t-1})\right] = E\left[P_{is}(u_{i,t} - u_{i,t-1})\right] = 0, \text{ for all } s \le (t-2) \tag{3}$$

The above orthogonality conditions, relying on the absence of second order serial correlation among the first-differenced residuals (Arellano and Bond, 1991), are also proposed by Holtz-Eakin et al. (1988). 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:

$$H_0 : c_1 = c_2 = ... = c_m = 0 \tag{4}$$

Rejection of the null hypothesis would imply 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. We also test for second order serial correlation among the first-differenced residuals (Arellano and Bond, 1991), since the correct specification of the model requires no residual time dependency; any second order residual serial correlation would invalidate the use of lagged $VC_{i,t-2}$ values as an instrument.

In order to test the reverse causality, i.e. from innovation to VC, an appropriate modeling is being called for. Since our data on patents are counts (positive integers) we have to apply models designed to facilitate the non-negativity and discreteness of patents. Furthermore, the panel form our data introduces individual heterogeneity of the cross section units which has to be taken explicitly into account.

Assuming that our count variable follows a Poisson process and adding lags of the count among the regressors, we end up with a variant of the Linear Feedback Model (LFM) as the one introduced by Blundell et al, (2002) which in our purpose takes the following form:

$$P_{it} = \sum_{k=1}^{l} g_k P_{it-k} + v_{it} h_i + u_{it} \tag{5}$$

$$\text{where } v_{it} = \exp(\sum_{k=1}^{m} d_k VC_{it-k}) \text{ and } h_i = \exp(\eta_i)$$

and η_i is the individually specific characteristic (fixed effect).

Except for the drawbacks mentioned earlier, individual heterogeneity may also generate data overdispersion, that is, a conditional data variance significantly greater (and not equal to) than the conditional data mean (as in the usual Poisson specification)

(Cincera, 1997). Since η_i enters the model multiplicatively, usual differencing doesn't eliminate it. We use instead the quasi-differenced Generalized Method of Moments (GMM) estimator proposed by Blundell et al. (2002) with the following orthogonality conditions:

$$E(P_{il} q_{it}) = 0 \text{ for all } \quad l \leq t-2 \tag{6}$$

$$\text{and } E(VC_{is} q_{it}) = 0 \text{ for all } \quad s \leq t-1 \tag{7}$$

$$\text{where} \quad q_{it} = (P_{it} - \sum_{k=1}^{l} g_k P_{it-k}) \frac{v_{it-1}}{v_{it}} - (P_{it-1} - \sum_{k=1}^{l} g_k P_{it-k-1})$$

In order thus to examine the significance of the VC to patents causality, we assume that $l = m$ and test the null hypothesis that all coefficients of lagged VC investments are jointly zero:

$$H_0 : d_1 = d_2 = ... = d_m = 0 \tag{8}$$

We test the reverse causation hypothesis with the Wald test for m=1, 2 and 3 and we check for second order serial correlation (Uchida and Cook, 2007).

Our estimates are presented in Tables 3 and 4. Table 3 presents the results of patents to VC causality test. The Wald tests for two and three lags indicate that the effect of lagged patents is jointly significant. At one lag, on the contrary, the coefficient of patents is not significant at acceptable probability levels.

[INSERT TABLE 3 AROUND HERE]

As to the VC to patents causality results depicted in Table 4, the Wald tests show that there is no joint significance of the VC coefficients for two and three lags. At one lag, the coefficient of VC is found to be significant but with a negative sign, which is in line with Ueda and Hirukawa's (2003) finding. However, their claim that this is a stock market overreaction correction caused by rapid VC investment seems not to fit our sample.

[INSERT TABLE 4 AROUND HERE]

As depicted in Table 4, the Wald tests indicate that VC does not cause patents in our sample, whereas the joint significance of the patent coefficients in Table 3 verifies the hypothesis that patents cause VC, that is, innovation precedes VC investments. Reverse causation is generated, in our opinion, by information asymmetries and irreversibility considerations. A small firm or an entrepreneur has to somehow indicate the quality of his project in order to be a good candidate for VC finance. Applying for a patent costs both money and time, thus a patent application signals high project quality and confers to the applicants cum investees an advantage over their non-applicant competitors. Moreover, given that VC investment is mostly irreversible, patent applicants cum investees will increase their edge even more. Hence, it seems that international differences in VC activity across countries are rather demand than supply side induced: ideas rather than funds are at shortage.

5. Conclusion

In this paper we have proposed a causality testing methodology in order to investigate whether patenting is an input or an output to the VC process, i.e. whether causation is direct, from innovation to VC, or reverse, from VC to innovation. The widely accepted patents to VC direct causation was tested by means of a GMM estimation of a linear dynamic panel in first differences, while reverse causation by means of a Linear Feedback Model due to the count nature of patents. Our findings indicate that causality in Europe runs from patents to VC and not the other way around. Adverse selection problems and irreversibility considerations may well explain the reason why innovation precedes rather that follows VC activity.

We also believe that, in the same line of argument, the low VC activity in some countries might also be attributable to the absence of value creating innovative ideas rather than the lack of available funds.

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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

R&D data were obtained from the Eurostat database
*VC includes seed, start-up and expansion investments
**European Patents Office

Table 2
Descriptive statistics

	Total VC*	Patent applications
Mean	565439.8	3201.387
Median	223850	1332.5
Maximum	6099578	23261
Minimum	844	14
Std. Dev.	856426.4	4875.836
Skewness	3.179	2.788
Kurtosis	16.129	10.45
Sum	84815964	480208
Observations	150	150

*In thousand Euros

Table 3
Patents cause VC

	VC coefficients			Patent coefficients		
Wald test of Patent Coefficients (χ^2)	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. 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

Table 4
VC causes Patents

Wald test of VC coefficients (χ^2)	Patent coefficients g_1	g_2	g_3	VC coefficients 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

Endnotes

[1] European Venture Capital Association's (EVCA) terminology split VC into three stages namely, seed finace (intended for new firms in order to evaluate their initial concept), start-up finance(aiming at the development of the firm's product before the firm has sold any products) and expansion finance (aiming to assist the growth and expansion of the firm)