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Market Frictions in Entrepreneurial Innovation: Theory and Evidence*

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Abstract

This paper proposes a model of entrepreneurial innovation that explains its pronounced pattern of boom and bust. In the model, a successful entrepreneurial project is the result of a search and matching process between entrepreneurs looking for funds and capitalists looking for new ideas to finance. The resulting strategic complementarity between them gives rise to a multiplier effect, whereby any exogenous shock has a magnified effect on the process of innovation. Hand-collecting data on the venture capital market of 21 developed countries for the period 2004-2012, we show that, at the country level, a complementarity exists between the size of the venture capital sector and the number of innovative entrepreneurs. This evidence suggests the existence of a thick market externality in the financial market for innovation.

Keywords: Financing of innovation, search and matching, strategic complementarities, venture capital.

JEL Classification: 031, C78, L26.

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*This paper supersedes our previous work that circulated with the title "Animals Spirits in Entrepreneurial Innovation: Theory and Evidence". In this new version, the empirical section has been thouroughly revised, using a different dataset and a different econometric strategy.

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1 Introduction

Suppose you think you have a promising idea for a new business venture. However, you find it hard to finance your project from banks or other conventional sources of capital, because of its high degree of uncertainty and/or lack of good collateral. You might then want to turn to other agents, specialized in screening and evaluating innovative business projects exactly like yours. If they judge your project valuable, these agents decide to provide you with the necessary capital, as well as technical and managerial advice, in exchange for an equity stake in the project. In the standard economics terminology, you are referred to as the entrepreneur, and the specialized agents as the capitalists (such as venture capitalists or business angels). The whole process is usually described as one of *entrepreneurial innovation.*

A distinctive feature of entrepreneurial investments is their higher volatility over time. In Figure 1, we have depicted the volatility of "more traditional" investments, those in fixed capital and in R&D, for the period 1995-2013 in both the US and Europe.[1,2]

INSERT FIGURE 1 HERE

The pronounced volatility in Figure 1 almost disappears when we compare it with the one observed on the investments provided by venture capitalists (VCs) and private equity (PE) funds devoted to seed and start-ups, as shown in Figure 2 for both the US and Europe in the same period. A look at Figure 2 clearly suggests a pattern of boom and bust of entrepreneurial investments. In particular, both the dotcom bubble (and the subsequent bubble burst), as well as the effect of the economic crisis initiated in 2007 are clearly visible from the figure.[3]

INSERT FIGURE 2 HERE

[1] Volatility is measured as percentage deviation of investment components from their Hodrick-Prescott trends with smoothing parameters set at 6.25 (see Ravn and Uhlig, 2002).

[2] In this and in the next figure, the aggregate "Europe" refers to EU15 plus Poland, Norway, Switzerland, Russia, Estonia, Czech Republic, Hungary, Slovakia, Slovenia.

[3] A less pronounced but similar pattern of boom and bust arises even when we restrict the attention to entrepreneurial investments provided by business angels.

In this paper, we propose a simple model of entrepreneurial innovation that may contribute to explain this volatility over time, and then we try to validate empirically its main theoretical claims against the available data on entrepreneurial innovation.

We use a dynamic, partial-equilibrium model where an entrepreneurial project (or an innovative, start-up firm) is the outcome of a process of *search and matching* between the two main actors of the innovative process: those who come up with new ideas, that we call entrepreneurs (or simply innovators); and those who screen and select the most valuable ideas deserving financing funds, that we call capitalists (or simply financiers). An innovation is the result of a successful matching between an entrepreneur and a capitalist.[4]

In our model, entrepreneurs are willing to spend their time and intellectual resources to discover a new idea only if they have a chance to meet a capitalist. On the other hand, capitalists are willing to spend their time and intellectual resources to evaluate the profitability of ideas only if they have the chance to meet valuable entrepreneurs. More generally, the return to becoming an entrepreneur (capitalist) is higher, the higher the number of capitalists (entrepreneurs) in the market. Hence, and as usual in the class of search and matching models (Diamond, 1982, Kiyotaki and Wright, 1993), a *thick market externality* characterizes the financial market of innovation.

The strategic complementarity between entrepreneurs and capitalists -that is, the fact that the number of entrepreneurs devoting to innovation is an increasing function in the number of capitalists, and *viceversa*- implies the existence of a multiplier effect in entrepreneurial innovation, whereby the effect of an exogenous shock on the pace of innovation is magnified by the self-reinforcing nature of the interaction between the two sides of the market for ideas.

In the second part of the paper, we test empirically the main theoretical claim of the model, that is, the mutual positive interaction between entrepreneurs and capitalists, for 21 developed countries (20 European countries plus the US) over the period 2004-2012. We gather data on the number of early-stage innovative entrepreneurs from the Global Entrepreneurship Monitor (GEM), and we hand-collect data on the total amount of venture capital funds available for investment from the European Venture Capital Association and from the National Venture Capital Association (for the US). We use 4 approaches to estimate the complementarity: fixed effects estimation (FE),

[4] The model is a simple extension of the classical *coconut model* by Diamond (1982) applied to the financial market of innovation. A more thorough justification of this modeling strategy is provided in Section 2.

two-stage least squares (2SLS), three-stage least squares (3SLS), and Arellano-Bover estimation (Arellano and Bover, 1995). The whole set of results confirm the existence of a statistically and economically significant complementarity between entrepreneurs and capitalists. In particular, we find that a one percentage point increase in the volume of venture capital managed funds (as percentage of GDP) increases the number of innovative entrepreneurs (as a percentage of adult population) by between 1.2 and 1.7 percentage points. Conversely, a one percentage point increase in the number of innovative entrepreneurs (as a percentage of adult population) increases the volume of venture capital managed funds (as percentage of GDP) by between 0.03 and 0.04. Based on these estimates, we finally carry out a simple quantitative exercise and obtain a value of the multiplier between 1.03 (from the Arellano-Bover estimation) and 1.08 (from the pure FE model). This number tells us that a shock to either side of the market produces a final effect on the market equilibrium values of entrepreneurs and capitalists which is between 3% and 8% higher than it would have produced in the absence of strategic complementarity. Although clearly not exhaustive, this multiplier effect may contribute to explain the pronounced volatility of entrepreneurial investments that we have documented in Figure 2.

The goal of this paper is that of modeling and documenting empirically the market frictions characterizing the financial market of innovation. In the words of Phelps (2009, p. 50), "the classical supply-and-demand apparatus does not apply to the core market of capitalist economies - the capital market, particularly the market for capital going to entrepreneurs' innovative projects". In this paper, we provide some evidence in favor of this statement. In other words, while in a standard frictionless market, demand and supply are independently determined, in this paper we claim theoretically, and verify empirically, the existence of a mutual positive interaction (a "strategic complementarity") between demand and supply in the financial market of innovation.

The rest of the paper is organized as follows. Section 2 discusses the related literature. Section 3 introduces the theoretical framework. Section 4 characterizes the stationary equilibrium, proves the strategic complementarity between entrepreneurs and capitalists and derives the multiplier effect. Section 5 carries out the empirical analysis. Section 6 concludes the paper. Proofs are relegated to a technical appendix at the end of the manuscript.

2 Related Literature

This paper is related to the literature, initiated by Arrow (1962), on the market failures associated with the process of innovation, and more particularly, with the process of innovation financing. Both microeconomic theory and empirical evidence have long recognized the existence of binding financial constraints in the innovation process (for a review of the literature see, for instance, Hall and Lerner, 2010). Theoretical arguments, proposed to explain financial market imperfections in this sector, range from transaction costs to agency problems due to informational asymmetries between the innovator (agent) and the financier (principal).[5]

We capture financial market imperfections via search theory. This modeling strategy is inspired by the following observations. Entrepreneurs and capitalists are heterogeneous in terms of skills, location, beliefs, information etc. It then takes time and resources for an entrepreneur to find and convince a financier about the profitability of her business venture; and it takes time and resources for a financier to select the innovative project that she believes is worth financing. As a result, entrepreneurial finance can be depicted as a decentralized market where heterogeneous entrepreneurs and financiers meet bilaterally according to a matching technology. In the words of Phelps (2009, p. 52), "the capital market is a sort of matching process that matches a financier to an entrepreneur who the former sees as having a model compatible with his own model". Search theory is then a convenient modeling tool to capture succintly the frictions characterizing the financial market for innovation.

The idea of modeling entrepreneurial innovation as a process of search and matching is not new in the entrepreneurial finance literature.[6] A few papers explore the microeconomic foundations of the market frictions in the financing of innovation (Silveira and Wright, 2007, Silveira and Wright, 2010, Chiu, Meh and Wright, 2011). Others emphisize the contractual content of the relationship between entrepreneurs and capitalists (Boadway et al., 2005, Keuschnigg, 2003, Jovanovic and Szentes, 2013). Neither of these papers, however, identify and empirically test the complementary nature of this relationship, nor do they explore whether this complementarity can contribute to shed

[5] While these aspects are common to any financing relationship, a number of additional elements suggest that financing problems can be even more severe for innovative investments: innovations are unique events, and the process aimed at producing them is an uncertain and largely unpredictable economic activity.

[6] Prior to finance, search theory has been extensively applied to several fields in economics, such as labor economics, monetary theory, and the theory of marriage.

light on the stylized fact highlighted above. Three other contributions deserve special mention inside this stream of literature. The first is the work by Inderst and Muller (2004), who construct a search and matching model of entrepreneurial innovation that may generate a pattern of boom and bust of entrepreneurial investments. Their theory, however, does not rely on the strategic complementarity across the two sides of the market of innovation:[7] ups and downs are instead due to a self-reinforcing relationship between the profitability of entrepreneurial investments, the entry of venture capitalists and the market valuation of start-ups. The second contribution is the one by Michelacci and Suarez (2004), who analyze the relationship between entrepreneurial finance and the stock market development in the framework of an endogenous growth model. Interestingly, the model may generate multiple Pareto-rankable equilibria as a result of a complementarity across the "going public" decisions of start-up firms. The third is Giordani (2015), who analyzes the *welfare* consequences of search frictions in the financing of innovation in a general equilibrium context of an endogenous R&D-driven growth model.

3 The Model

The world is populated by a measure E of entrepreneurs and a measure K of capitalists who must decide whether to participate or not in a *fair of ideas*.[8] Time is continuous, and new ideas arrive randomly to the entrepreneurs according to a Poisson process with (exogenous) instantaneous probability σ. In order for these raw entrepreneurial ideas to become marketable innovations however, entrepreneurs need the (financial and managerial) support of capitalists.

Once an entrepreneur has come up with a new idea, she has to decide whether to pursue it by participating in the fair, or abandon it and wait for the next idea. To pursue it, each entrepreneur has to pay a cost c_E, representing the cost of developing and submitting the project to the financiers. This cost is idiosyncratically drawn from a (twice continuously differentiable) cumulative distribution function $F(c_E)$ in the support $[0, \overline{c_E}]$. If the entrepreneur pays her own c_E, she acquires the right to participate in the fair and hence, as we will see, the chance of matching the "right"

[7] Indeed in their model, due to the hypothesis of a constant flow of new ideas over each unit of time, entrepreneurs and capitalists are inversely related.

[8] The theoretical framework that we present here resembles Diamond's (1982) coconut model, the main difference being that ours is a *two-sided* search model.

capitalist and implement her project. Cost c_E can also be interpreted as an (inverse) measure of the quality of the entrepreneur's project.

On the other hand, each capitalist sustains an entry cost c_K to participate in the fair of ideas (the cost of screening, evaluating and selecting the entrepreneurial projects). This cost is distributed across capitalists according to a (twice continuously differentiable) cumulative distribution function $G(c_K)$ in the support $[0, \overline{c_K}]$. c_K can be thought of as an (inverse) measure of each capitalist's talent and, thus, differently from c_E, is assumed time-invariant.[9]

To analyze the entry decisions of entrepreneurs and capitalists in the fair of ideas, we now need to specify the potential benefits that accrue to them if they pay the entry fee. Let $L_E \leq E$ and $L_K \leq K$ denote, respectively, the endogenous stock of entrepreneurs and capitalists participating in the fair at each instant of time, that is, those that have paid their respective entry cost.[10] An entrepreneurial venture is the result of a process of successful search and matching between an entrepreneur and a capitalist both attending the fair. We capture this production process of new ideas via the following aggregate matching function:

$$M = M(L_E, L_K), \tag{1}$$

with $\partial M/\partial L_j > 0$ and $\partial^2 M/\partial L_j^2 < 0$ for $j = E, K$, implying positive and decreasing marginal returns to both inputs. We also impose $M(L_E, 0) = M(0, L_K) = 0$ (that is, the absence of entrepreneurs or capitalists implies zero successful matches) and homogeneity of degree 1 of the matching function (which ensures equilibrium uniqueness[11]).

The instantaneous probability of matching for, respectively, entrepreneurs and capitalists attending the fair, is then given by

$$\alpha_E = \frac{M}{L_E} \text{ and } \alpha_K = \frac{M}{L_K}. \tag{2}$$

The standard assumptions on the first two derivatives of the matching function imply that $\partial \alpha_j/\partial L_j < 0$ and $\partial \alpha_j/\partial L_{-j} > 0$ for $j = E, K$. That is to say, the match-

[9] One might alternatively interpret c_E and c_K as outside options, that is, as the opportunity costs of devoting to entrepreneurial innovation. The opportunity cost of capitalists is constant over time, that of entrepreneurs varies with the idea.

[10] Given that our focus will be on the stationary equilibrium of this economy, we drop time subscripts to ease notation.

[11] In a related paper, Cipollone and Giordani (2015) confirm the empirical plausibility of equilibrium uniqueness by explicitly estimating the scale elasticity of the matching function using data from the business angel market.

ing probability for an entrepreneur decreases with the number of entrepreneurs and increases with the number of capitalists (and the same holds for capitalists).

Without loss of generality, entrepreneurs and capitalists are assumed risk neutral and to discount the future via the exogenous riskless interest rate r. At any point in time, entrepreneurs and capitalists can be in two states: either outside or inside the fair of ideas. In order to determine the expected benefits from entry, we need to define the values of both states for both agents. Let us start with entrepreneurs.

For an entrepreneur, the value of being outside the fair (and thus of waiting for a new idea) is denoted by V_E^0 and defined by the following asset equation:

$$rV_E^0 = \sigma \int_0^{c_E^*} \left(V_E^1 - V_E^0 - c_E\right) dF\left(c_E\right), \tag{3}$$

where c_E^* is the highest cost for which there is still entry (to be determined at equilibrium), and V_E^1 represents the value of being inside the fair (that is, the expected payoff associated with the entrepreneurial venture for an entrepreneur attending the fair). This latter value is defined by

$$rV_E^1 = \alpha_E \theta \pi + V_E^0 - V_E^1, \tag{4}$$

where π represents total instantaneous profits originating from the innovation, and $\theta \in (0,1)$ is the entrepreneurs' fraction of these profits. These asset equations have the usual interpretations. Equation (3) tells us that, for an entrepreneur, the flow of utility from waiting for a new idea is equal to the instantanous probability of a new idea times the corresponding payoff, which is given by the capital gain associated with participating in the fair minus the entry cost. Equation (4) says that the flow of utility from venturing into innovation is equal to the probability of a successful matching with a capitalist times the payoff associated with this chance, plus the capital gain (or loss) deriving from exiting from the fair. Note that, in the two expressions above, we have decided to focus directly on the steady state, as we have imposed $\dot{V}_E^h = 0$ for $h = 0, 1$.

Two implicit assumptions in (4) are worth noticing. First, every match becomes a successful innovation, that is to say, every venture-backed firm raises positive profits. Indeed, observation suggests that only a small fraction of funded projects reaches that stage (anecdotal evidence suggests that this fraction is below 20%). The second assumption is that, whether or not a successful matching has occurred, all entrepreneurs go back to the initial "inventive" stage (say, by selling their idea -or patent- to a firm which will start production in case of successful matching, or coming up with a new, better idea in case of failure).[12] This endless circular process is meant to represent the so called *venture capital cycle* described by Gompers and Lerner (1999). None of these assumptions is necessary for any of our results.

Let us now turn to capitalists. The expected payoff associated with being a capitalist outside the fair is denoted by V_K^0 and defined by the following asset equation:

$$rV_K^0 = V_K^1 - V_K^0 - c_K, \tag{5}$$

for all $c_K \geq c_K^*$, and where V_K^1 represents the expected value from participating in the fair of ideas. This value is defined by[13]

$$rV_K^1 = \alpha_K (1-\theta)\pi + V_K^0 - V_K^1, \tag{6}$$

where $(1-\theta)\pi$ is the capitalists' fraction of the profits prevailing in the market (again, along the steady state it is $\dot{V}_K^h = 0$ for $h = 0, 1$).

Here again, two issues are worth remarking. First, the allocation of the innovation profits across entrepreneurs and capitalists, as captured by the parameter θ, is here taken as exogenous. This is not because we believe the contractual arrangement between entrepreneurs and capitalists is uninteresting but simply because our focus is different.[14] Secondly, in expression (6) we have implicitly supposed that the cost of financing the entrepreneurial project is null (so that the capitalists' contribution to the venture is technical and/or managerial but not financial). This is only to economize on parameters and simplify calculations.

We are now ready to characterize the expected benefit of participating into the fair of ideas for both entrepreneurs and capitalists. By entering into the fair, an entrepreneur loses V_E^0 and gains V_E^1. As a result, her net expected benefit is measured by the difference $V_E^1 - V_E^0$. Subtracting (3) from (4), and solving the resulting equation for $V_E^1 - V_E^0$, we obtain

[12] In the business literature, an individual with such characteristics is sometimes referred to as a serial entrepreneur. We prefer to portray him/her as a Schumpeterian entrepreneur, given that he/she dedicates exclusively to innovation.

[13] The implicit assumption here is that each capitalist can enter into one and only one project at a time, and that each entrepreneur needs one and only one capitalist.

[14] An extensive literature has focused on optimal contracts between capitalists and entrepreneurs (for instance in the presence of moral hazard and adverse selection): see, among others, Keuschnigg (2003), Inderst and Muller (2004), Michelacci and Suarez (2004), Silveira and Wright (2007).

$$V_E^1 - V_E^0 = \frac{\alpha_E \theta \pi + \sigma \int_0^{c_E^*} c_E dF(c_E)}{1 + r + \sigma F(c_E^*)}. \tag{7}$$

It is immediate to prove that the expression above is increasing in α_E, and thus in L_K.[15] The intuition is straightforward: the higher the number of capitalists, the higher the matching probability for an entrepreneur, and hence the higher her return from participating in the innovation process.

The same argument holds for capitalists. Their expected benefit from fair attendance is measured by the difference $V_K^1 - V_K^0$. Again, solving the system made up of (5) and (6) for $V_K^1 - V_K^0$, we obtain

$$V_K^1 - V_K^0 = \frac{\alpha_K (1-\theta)\pi + c_K}{2 + r}, \tag{8}$$

which is increasing in α_K, and thus in L_E.

In the next section we characterize the optimal entry decisions for both entrepreneurs and capitalists as well as the stationary equilibrium resulting from their optimal choice behavior.

4 Complementarities in the Financial Market of Innovation

At each point in time, the choice of the $E - L_E$ entrepreneurs who are outside the fair, as to whether to pursue their project or abandon it, depends on the relative costs and benefits of the project. The cost c_E is distributed according to $F(c_E)$, while the benefit is measured by the difference $V_E^1 - V_E^0$. There exists an *inframarginal* entrepreneur for

[15] Differentiating (7) with respect to L_K, we obtain

$$\frac{d\left(V_E^1 - V_E^0\right)}{dL_K} = \frac{\partial\left(V_E^1 - V_E^0\right)}{\partial \alpha_E} \cdot \frac{\partial \alpha_E}{\partial L_K} = \frac{\theta \pi}{1 + r + \sigma F(c_E^*)} \cdot \frac{1}{L_E} \frac{\partial M}{\partial L_K},$$

which is always strictly positive, given that the marginal productivity of capitalists is strictly positive ($\partial M / \partial L_K > 0$).

whom $c_E^* = V_E^1 - V_E^0$. Substituting for the expression given in (7), we obtain

$$c_E^* = \frac{\alpha_E \theta \pi + \sigma \int\limits_0^{c_E^*} c_E dF(c_E)}{1 + r + \sigma F(c_E^*)}. \tag{9}$$

All entrepreneurs whose entry cost is lower than c_E^* find it profitable to participate in the fair. The expression above links the threshold cost c_E^* to the probability of successful matching for entrepreneurs α_E, and hence to the number of entrepreneurs and capitalists attending the fair, L_E, L_K: it is easy to prove that a higher L_K and/or a lower L_E lead to an increase in the probability of a successful matching with a capitalist (α_E), which in turn causes an increase in the cutoff value of the entry cost c_E^*.[16]

In analogy to the previous case, the chance of a successful matching with an entrepreneur is worth $V_K^1 - V_K^0$ to a capitalist. Given that the cost of this chance c_K is distributed according to $G(c_K)$, there exists an inframarginal capitalist for whom $c_K^* = V_K^1 - V_K^0$. Substituting for the expression given in (8), we obtain

$$c_K^* = \frac{\alpha_K (1 - \theta) \pi}{1 + r}. \tag{10}$$

All capitalists whose entry cost is lower than c_K^* find it profitable to participate in the fair. This expression captures the positive relationship between α_K and c_K^*.

Finally remind that, for both entrepreneurs and capitalists, the inflows into the fair of innovation must be equal to the outflows along the steady state, that is

$$\dot{L}_E = \sigma (E - L_E) F(c_E^*) - L_E = 0, \tag{11}$$

and

$$\dot{L}_K = (K - L_K) G(c_K^*) - L_K = 0. \tag{12}$$

Equation (11) captures the evolution of entrepreneurs over time. Along the steady state, the number of entrepreneurs deciding to participate in the fair ($\sigma (E - L_E) F(c_E^*)$) must equalize the number of entrepreneurs who exit from the fair (whether successfully

[16] Define

$$Z(c_E^*, \alpha_E) = \frac{\alpha_E \theta \pi + \sigma \int\limits_0^{c_E^*} c_E dF(c_E)}{1 + r + \sigma F(c_E^*)} - c_E^*$$

as the implicit function of c_E^* with respect to α_E. It is immediate to prove, via the implicit function theorem, that $dc_E^*/d\alpha_E > 0$.

or not) and return to the waiting stage (L_E). An analogous interpretation can be given to (12).

Equation (11) can be interpreted as a positive relationship between L_E and c_E^*.[17] A higher value of c_E^* implies greater entry in the market of innovation. To maintain the steady state, the number of exits must correspondingly increase. Hence, a higher value of L_E is required for equation (11) to hold. The same is true, *mutatis mutandis*, for equation (12) capturing L_K as a positive function of c_K^*.

Before defining a stationary equilibrium for this economy, let us characterize the type of interdependence between entrepreneurs and capitalists that is implied by this model. The number of entrepreneurs venturing in innovative projects depends on the number of capitalists deciding to back these projects, as this affects the chance of a successful matching. This relationship is captured by a best-response function for entrepreneurs, $L_E = f_E(L_K)$, that is implicitly defined by the system made up of (9) and (11). On the other hand, the number of capitalists devoting their time and resources to screening and evaluating innovative projects depends on the chances of encountering good potential entrepreneurs. This relationship is given by the capitalists' best-response function, $L_K = f_K(L_E)$, defined by the system made up of (10) and (12). We now prove that these two best-response functions are positively sloped.

Theorem 1 *Entrepreneurs and capitalists are strategic complements, in that the number of entrepreneurs attending the fair of ideas is an increasing function of the number of capitalists attending the fair, and viceversa:* $df_j/dL_{-j} > 0\ \forall j = E, K$.

Intuitively, a higher number of capitalists participating in the fair raises the chance of a successful matching for an entrepreneur, it makes her participation to the fair more profitable, and thus it brings about an increase in the number of entrepreneurs (and viceversa). This complementarity is *strategic*, as it is the result of endogenous and interdependent entry choices of the two types of agents. Its existence will be verified empirically in the next section. We are ready for the following

Definition. *A stationary equilibrium for this economy is any 4-tuple* (L_E, L_K, c_E^*, c_K^*) *that solves the four equations (9), (10), (11) and (12).*

As recalled above, the hypothesis of homogeneity of degree 1 of the matching function ensures that, if an equilibrium exists, it is unique (see footnote 11). The presence

[17] This will be explicitly shown in the proof of Theorem 1.

of strategic complementarities between the two sides of the market, however, makes this equilibrium highly sensitive to disturbances. For illustrative purposes, say that a negative macroeconomic shock hits this economy so that, for instance, $\Delta\pi < 0$ (say, a negative business cycle hurting corporate profts). This negative shock directly reduces the payoff to both entrepreneurial and capitalistic activities. This, however, is not the end of the story. The lower number of entrepreneurs weakens the incentive to become capitalist, which in turn further lowers the incentive to entrepreneurship (and viceversa). This process continues *ad infinitum*, describing a vicious circle whereby the aggregate response to the shock is stronger than the initial partial response. In other words, the strategic complementarity across the two main actors of the innovation process magnifies the initial effect of the shock and gives rise to what is usually referred to as a *multiplier effect*.

More formally, define $L_j = f_j\left(L_{-j}, \rho\right)$ as the (positively sloped) reaction function of agents of type j with respect to the agents of type $-j$ (for $j = E, K$), parameterized by ρ capturing any feature that affects L_j other than changes in L_{-j}. We are now ready to state the following

Theorem 2 *A multiplier effect characterizes the process of entrepreneurial finance, in that the total equilibrium response of entrepreneurs and capitalists to an exogenous shock is greater than the partial response:*

$$\left|\frac{dL_j^*}{d\rho}\right| = \left|\frac{\partial f_j}{\partial \rho}\right|_{\left(L_E^*, L_K^*\right)} + \left|\frac{\partial f_j}{\partial L_{-j}}\right|_{\left(L_E^*, L_K^*\right)} \left|\frac{dL_{-j}^*}{d\rho}\right| > \left|\frac{\partial f_j}{\partial \rho}\right| \ \forall j = E, K.$$

As a result of this multiplier effect, any factor that affects the entrepreneurs' or the capitalists' payoff may have a big impact on the level of innovative activity. This mutual, self-reinforcing, interaction between entrepreneurs and capitalists contributes to explain the high volatility of entrepreneurial investments that we have documented in Figure 2. To use a phrase from Summers (1988), our entrepreneurial equilibrium is *fragile*, in the sense that it is potentially subject to large fluctuations in the level of activity. In the next section we give an empirical estimate of the multiplier effect for the venture capital market.

5 Empirical Evidence from the Venture Capital Market

This section is devoted to the empirical validation of the model's findings. We introduce the dataset (subsection 5.1), describe the empirical strategy (subsection 5.2), present the findings (subsection 5.3), and carry out a simple quantitative exercise on the multiplier effect (subsection 5.4).

5.1 Data

The dataset is an unbalanced panel data of 21 developed countries (all EU-15 countries except Luxembourg, plus Czech Republic, Hungary, Norway, Poland, Romania, Switzerland and the US) observed over the period 2004-2012 and measured along our two variables of interest (plus a number of controls): the number of potential innovative entrepreneurs and the size of the potential financing market of innovation. A key challenge of our analysis is the search of suitable data to measure these two variables.

The number of potential innovative entrepreneurs. The number of potential entrepreneurs poses a serious measurement challenge as we usually observe the number of *actual* entrepreneurs, which is a proper subset of the group of those who are willing to become entrepreneurs but may or may have not been financed yet. To construct our proxy for this variable, we gather information from the Global Entrepreneurship Monitor (GEM), which is an annual survey of the entrepreneurial aspirations, attitudes and activities of individuals across a wide range of countries. We classify an individual as early stage innovative entrepreneur when this individual meets simultaneously the two following conditions: (i) being a nascent entrepreneur or owner-manager of a new business, (ii) indicating that their product or service is new to at least some customers. We now provide some details aboout these two requirements.

From the GEM data base, we extract the early-stage entrepreneurial activity indicator, which gives the percentage of 18-64 population who are either nascent entrepreneur or owner-manager of a new business and is available for the years 2002-2013 in an unbalanced form.[18,19] This indicator adopts a broad definition of potential entrepreneurs (for instance, considering as entrepreneurs also those who are about to open retail store businesses). To restrict our focus is on innovative entrepreneurs only, we then combine it with the new product early-stage entrepreneurial activity indicator, comprising those entrepreneurs who declare that their product or service is new to at least some customers (see Appendix B for details about the exact questions we select).

Matching these data with the size of the working-age population by year and country extracted from the Eurostat database, we finally obtain the share of potential innovative entrepreneurs as the percentage of working age individuals (between 18 and 64 years old) involved in "innovative early-stage entrepreneurial activity", that is, those who are either nascent entrepreneurs or owner-managers of a new business *and* indicate that their product or service is new to at least some customers. A summary description of this variable across our sample of countries over the period 2004-2012 (which is the time window we consider in our estimation due to the presence of missing values in several control variables for the years 2002, 2003 and 2013) is provided in Table 1.

INSERT TABLE 1 HERE

On average, throughout 2004-2012, the percentage of potential entrepreneurs is estimated at 2.7%, with relevant cross-country differences. In particular, United States, Poland and Czech Republic are characterized by a significantly higher percentage compared to the mean (above 4%), followed by Ireland, Greece, Denmark and Norway (all around 3%). At the other extreme, the countries with the lowest rate of innovative entrepreneurship are Belgium, Hungary and Sweden (below 2%). During the period of interest, the rate of innovative entrepreneurship has been roughly stable until 2010 and starts increasing from 2011 (especially in such countries as the US, the UK, Spain, Romania, the Netherlands).

The size of the potential financing market. Our goal is to measure the size of the potential financing market through the total amount of financial funds managed by

[18] To be qualified as nascent entrepreneur, one must be actively involved in setting up a business they will own or co-own (this business has not paid salaries, wages, or any other payments to the owners for more than three months); instead, those who are currently owning and managing a running business that has paid salaries, wages, or any other payments to the owners for more than three months (but not more than 42 months) are qualified as owner-managers of a new business.

[19] For example, data for Austria are only available for 2005, 2007 and 2012, those for Czech Republic for 2006 and 2011, those for Portugal as of 2010. Finally, data for Poland are missing from 2005 to 2010.

venture capital firms, defined as the total amount of funds available to fund managers for future start-up investments, plus the amount of funds already invested (at cost) and not yet divested.

Unfortunately, this figure is readily available only for the US for our period of interest (from the National Venture Capital Association (NVCA)). For the remaining countries instead, the amount of funds managed by venture capital firms is only available for 2013 (from the European Venture Capital Association (EVCA)). To derive the same figure for the remaining years 2004-2012, we then proceed in two steps. In the first step, we hand-collect yearly *flow* data on the fundraising, investing and disinvesting activities of both European private equity (PE) and venture capital (VC) firms for the period 2004-2013. These data allow us to find recursively the stock values for all years back to 2004 using the following difference equation (Appendix B contains a few more details of the iterative process that we apply): $Total\ managed\ funds_t = Total\ managed\ funds_{t-1} + Total\ raised\ funds_t - Total\ divestments_t$, with $Total\ managed\ funds_t$, $Total\ raised\ funds_t$, and $Total\ divestments_t$ respectively denoting the amount of funds managed, raised and divested by PE and VC firms at time t. Given that flow data are only available at the aggregate level (that is, as the sum of private equity and venture capital components), this backwards iterative exercise, however, only allows us to infer the aggregate stock of funds managed by both PE and VC firms for each year ($Total\ managed\ funds_t$).

In the second step then, we try to disentangle the sole component ascribed to VC firms ($VC\ managed\ funds_t$) by exploiting the two following pieces of information. On the one hand, we know with certainty the share of funds managed by VC firms over the total amount of managed funds in 2013 ($VC\ funds\ ratio_{2013}$). On the other hand, aggregate evidence on the European continent and the US (available from the yearly PREQUIN reports on "Global Private Equity & Venture Capital") for the period 2005-2013 suggests that this share -which is a stock value, not to be confounded with the flow value of the annual investments- does not vary significantly over the years. We then assume that this share does not vary over the period 2004-2013 and use the following formula to gain an estimate of VC managed funds for all previous years: ($VC\ managed\ funds_t$) = ($VC funds ratio_{2013}$) $\times$ ($Total\ managed\ funds_t$) (again, Appendix B works out the details of this procedure).

A summary description of the constructed variable $VC\ managed\ funds$ (as a percentage of GDP) across our sample of countries over the period 2004-2012 is provided in Table 2.

INSERT TABLE 2 HERE

In our sample, VC managed funds represent a small percentage of GDP, e.g. often less than 0.5%. Notable exceptions are, in descending order, United States, Denmark and Switzerland where this percentage stands above 1%. Looking at the dynamics of the variable throughout 2004-2012, notice that, after a first period of slow progressive increase (+0.1 percentage points between 2004 and 2010), the trend has reversed in 2010 and the amount of venture capital managed funds (as a percentage of GDP) has turned back to 0.45% in 2012. In the United States, the trend correction is observed earlier: after a peak in 2004 (when our indicator has reached 2.1%), the amount of venture capital managed funds (as a percentage of GDP) has started falling, reaching 1.2% in 2012.

Control variables. Variables potentially affecting either capitalists or innovative entrepreneurs (or both) are classified into five categories: (i) entrepreneurial attitudes: the number of *non-innovative* early-stage entrepreneurs (as percentage of 18-64 population, from GEM); (ii) entrepreneurial incentives: the amount of incentives to startups (as a percentage of GDP, from Eurostat); (iii) attitudes towards innovation: the number of scientific and technical published articles (from The World Bank) as a percentage of the number of scientific graduates,[20] the percentage of 18-64 population graduating in science and math disciplines (from OECD statistics), and the number of patent applications from residents (from The World Bank) per $100,000$ population aged 18-64; (iv) macroeconomic indicators: the amount of domestic credit to private sector provided by banks or, more generally, by the financial sector (both as a percentage of GDP, from The World Bank) and their ratio, the degree of capital market capitalization (as a percentage of GDP, from The World Bank), the GDP growth (from Eurostat), the interest rate (from Eurostat), a trend variable and country dummies; (v) two measures of information transparency in the credit market: namely, the two World Bank indicators of "credit bureau coverage" and "credit registry coverage", which report the number of individuals and firms listed in their respective database (by a private credit bureau or in a public credit registry, respectively) with information on their borrowing history, unpaid debts, or credit outstanding during the previous 5 years (both numbers are expressed as a percentage of the adult population).[21] Further details on the control variables can be found in the summary statistics provided in Tables A1 and A2.

[20] Articles are classified by year of publication and assigned to country on the basis of the institutional address(es) appearing on them.

[21] A credit bureau is a private firm or nonprofit organization that maintains a database on the

5.2 The Estimation Strategy

As a first step, we estimate the following pair of equations using a fixed effects method:

$$(l_E)_{i,t} = \alpha_i + \alpha_K (l_K)_{i,t} + \boldsymbol{\alpha}_{\mathbf{x}} \mathbf{x}_{i,t}^E + \varepsilon_{i,t} \tag{13}$$

$$(l_K)_{i,t} = \beta_i + \beta_E (l_E)_{i,t} + \boldsymbol{\beta}_{\mathbf{x}} \mathbf{x}_{i,t}^K + \eta_{i,t}, \tag{14}$$

where $(l_E)_{it}$ and $(l_K)_{it}$ are our proxies for the number of potential innovative entrepreneurs (as a % of 18-64 population) and the size of the potential financing market (as a % of GDP) in country i at time t; $\mathbf{x}_{it}^E$ and $\mathbf{x}_{it}^K$ are two vectors of controls including country and year dummies; $\varepsilon_{i,t}$ and $\eta_{i,t}$ are disturbance terms. In particular, vector $\mathbf{x}_{it}^E$ includes all variables capturing entrepreneurial attitudes, attitudes towards innovation, entrepreneurial incentives, and the macroeconomic indicators. Vector $\mathbf{x}_{it}^K$ includes the macroeconomic indicators, the two measures of information transparency in the credit market, entrepreneurial attitudes, plus the number of patent applications from residents as a percentage of 18-64 population. There are several reasons for including entrepreneurial attitudes and the number of patent applications among the determinants of venture capital market. On the one hand, venture capital firms are themselves often sponsored and led by (ex) innovative entrepreneurs; on the other hand, patents might act as a signal for markets with the highest rate of start-ups quality (see, among the others, Conti et Al., 2013a,b). Hence, entrepreneurial attitudes and the number of patent applications might have a direct effect on the degree of development of the venture capital market.

The two key parameters of our analysis are α_K and β_E. α_K measures the impact of the share of potential innovative entrepreneurs on the venture capital market size; conversely, β_E measures the impact of the venture capital market size on the share of potential innovative entrepreneurs. We expect both significantly positive (Theorem 1).

Equations (13), (14) are correctly and consistently estimated via pure fixed effects only if the explanatory variables are distributed independently of the disturbance term. If not, these estimators are likely to be biased. In this respect, our theoretical framework helps us identify the main source of endogeneity, which is the fact that

creditworthiness of borrowers (individuals or firms) in the financial system and facilitates the exchange of credit information among creditors. A credit registry is a database managed by the public sector, usually by the central bank or the superintendent of banks, that primarily assists banking supervision and facilitates the exchange of information among creditors.

the explanatory variables are partially determined as a function of each other (reverse causality). Given that the number of potential innovative entrepreneurs is a function of the venture capital market size and *viceversa*, l_K and ε are correlated in equation (13) and l_E and η are correlated in equation (14), making l_K and l_E endogenous. To address these issues, we employ three related instrumental variables (IV) techniques to correct for potential endogeneity bias.

Our first IV procedure is the two-stage least squares (2SLS) with fixed effects in two versions which employ the same set of instruments for the endogenous variables but differ with respect to the sets of exogenous regressors. In particular, in both models, as instruments for the financing market size, we employ the lagged size of the potential financing market ($(l_K)_{i,t-1}$, as a % of GDP) and the two measures of credit information transparency. The rationale behind the choice of these last two variables as instruments is that, as measures of information transparency in the financial market, they are likely to be positively correlated with the size of the potential financing market and uncorrelated with ε. Indeed, a credit bureau or a public registry are databases which collect information on the creditworthiness of borrowers (individuals or firms) in the financial system in order to facilitate the exchange of credit information among creditors. Hence, they are likely to affect entrepreneurship via the supply of funds, that is, by influencing the financiers' willingness to lend. As instruments for the number of potential innovative entrepreneurs, we employ the lagged number of potential innovative entrepreneurs ($(l_E)_{i,t-1}$, as a % of 18-64 population), the number of scientific and technical published articles (as a percentage of the number of scientific graduates) and the number of scientific graduates as a percentage of graduates in all fields, and finally the current and the lagged amounts of incentives to startups (as a % of GDP). We include the second and the third variable among the set of instruments for $(l_E)_{i,t}$ because they are thought to affect directly the *demand* side of the financial market of innovation only, the reason being that innovative entrepreneurial ideas are disproportionately concentrated in such sectors as ICT, biotechnology, energy and environmental technology. As a result, the higher the number of scientific articles and graduates, the higher the demand of venture capital funds. Finally, the rationale behind the choice of the amount of incentives to startups (as a % of GDP) is that, as direct subsidies to innovative entrepreneurship, startup incentives are likely to affect the size of the venture capital market only through their positive effect on innovative entrepreneurs (i.e. only once supported start-ups are seeking broad funds and expansion capital). We add the amount of incentives to startups also in its lagged form since we cannot exclude that our aspiring entrepreneurs gained access to business grants in the previous year.

As anticipated, the two versions of the 2SLS model with FE differ with respect to the choice of the second stage exogenous regressors. In the first version, the second stage equation replicates the pure FE model (equations (13), (14)). The second version, instead, adds lagged variables among the set of second stage exogenous regressors, by employing also the lagged size of the potential financing market ($(l_K)_{i,t-1}$, as a % of GDP) in the estimation model for the size of venture capital funds, and the lagged number of potential innovative entrepreneurs ($(l_E)_{i,t-1}$, as a % of 18-64 population) and the lagged amount of incentives to startups in the estimation model for the number of potential entrepreneurs over adult population. To sum up, our second (dynamic) 2SLS model with FE can be written as follows:

$$\begin{aligned} (l_E)_{i,t} &= \alpha_i + \alpha_K (l_K)_{i,t} + \alpha_{E-1} (l_E)_{i,t-1} + \boldsymbol{\alpha}_{\mathbf{x}} \mathbf{x}^E_{i,t} + \varepsilon_{i,t} \\ (l_K)_{i,t} &= \beta_i + \beta_E (l_E)_{i,t} + \beta_{K-1} (l_K)_{i,t-1} + \boldsymbol{\beta}_{\mathbf{x}} \mathbf{x}^K_{i,t} + \eta_{i,t}, \end{aligned} \tag{15}$$

where vectors $\mathbf{x}^E_{it}$, $\mathbf{x}^K_{it}$ denote the same set of control variables as in equations (13), (14) (notice that the vector $\mathbf{x}^E_{i,t}$ now also includes the 1-year lagged amount of incentives to startups).

Our second IV procedure is the pooled three-stage least squares (3SLS) over the dynamic 2SLS model (15). This technique has the advantage of incorporating information from the cross-correlations of the error terms in the equations (13), (14). The 3SLS estimator is consistent and, in general, asymptotically more efficient than the 2SLS estimator. If the disturbances in the different structural equations are uncorrelated, so that the contemporaneous variance-covariance matrix of the disturbances of the structural equations is diagonal, 3SLS reduces to 2SLS.

As a third approach, we finally perform an Arellano-Bover estimation. Since lags of the dependent variables are necessarily correlated with the idiosyncratic errors ($(l_E)_{i,t-1}$ with $\varepsilon_{i,s}$ and $(l_K)_{i,t-1}$ with $\eta_{i,s}$, for $s < t$), traditional static panel data model estimators of the dynamic equations in (15) are not consistent in panels with a short time dimension (Wooldridge, 2002, Ch. 11). We tackle this problem by using the methodology proposed by Arellano and Bover (1995) over the two equations of (15). The Arellano-Bover estimator, which employs an instrumental variable technique on the orthogonal deviations model (an alternative to first-differencing proposed by Arellano and Bond, 1991) by using appropriate lags of the dependent variables as instruments, leads to consistent parameter estimates. The orthogonal deviations transformation of the variables in equations (15) subtracts the average of all available future observations rather than subtracting the previous observation and, since we deal with a panel with gaps, this transformation helps preserve the sample size. The instruments set for the Arellano-Bover estimation of the first equation in system (15) include the orthogonal deviations of the exogenous variables (that is the variables included in vector $\mathbf{x}_{i,t}^{E}$), plus the lagged values of l_K between order 1 and order 8 and the lagged values of l_E between order 2 and order 8. Similarly, the instruments set for the Arellano-Bover estimation of the second equation of system (15) include the orthogonal deviations of the exogenous variables (that is, the variables included in vector $\mathbf{x}_{i,t}^{K}$), plus the lagged values of l_E between order 1 and order 8 and the lagged values of l_K between order 2 and order 8.

We are now ready to comment the results of our empirical analysis.

5.3 Findings

Our findings, summarized in Table 3, confirm the theoretical prediction contained in Theorem 1. The positive effect of innovative entrepreneurs on the size of VC funds, as well as the positive effect of the size of VC funds on the share of innovative entrepreneurs, are statistically significant and robust across all alternative model specifications.

The estimated coefficients of the control variables have the expected sign. In particular, and throughout the different specifications, (i) the share of innovative entrepreneurs is positively autocorrelated and positively affected by the share of non-innovative early stage entrepreneurs over working age population; (ii) the amount of VC funds over GDP is positively autocorrelated though decreasing over time.

INSERT TABLE 3 HERE

According to the FE estimates (columns 1-2), a one percentage point increase in the ratio between venture capital funds and GDP is associated with 1.762 percentage points increase in the share of innovative entrepreneurs over working age population ($\alpha_K = 1.762$). At the same time, a one percentage point increase in the share of innovative entrepreneurs over working age population is associated with 0.042 percentage points increase in the ratio between venture capital funds and GDP ($\beta_E = 0.042$). Among the other determinants of the share of innovative entrepreneurs (column 1), only the share of startup incentives (over GDP) and the share of non-innovative early stage entrepreneurs (over 18-64 population) are found to be significant (and positive). Conversely, among the remaining determinants of the VC funds size (column 2), the amount of VC funds is found to be negatively affected by the prevalence of the traditional bank credit lending models and by the number of patent applications.[22]

Moving to the estimates of the first 2SLS model (columns 3-4), the coefficients of the two endogenous variables slightly decrease: in particular, α_K becomes equal to 1.375 while β_E to 0.040. The estimated coefficients of the remaining regressors are very close to their pure FE results. Our goodness-of-fit measures indicate that the model fits the data well. In particular, the F statistics for joint significance of the instruments in first-stage regressions reject the null hypotheses of weak instruments, since they are higher than the first-stage F value provided by the Staiger–Stock (1997) rule of thumb ($F = 10$). Our underidentification tests -based on the Kleibergen-Paap rk Wald statistics for estimates with heteroskedasticity-robust and clustered standard errors- reject the null hypothesis that the equations are underidentified (that is, the matrix of reduced form coefficients on the excluded instruments are full column rank); the Hansen statistics do not reject the null hypothesis that the instruments are valid instruments (that is, that they are uncorrelated with the error term), and hence the excluded instruments are correctly excluded from the estimated equations.

The dynamic 2SLS model performs even better (columns 5-6). The p-values of our overidentification tests improve as well as the weak identification and underidentification test statistics. Compared to the first 2SLS model, the estimated complementarities between the size of venture capital funds and the share of innovative entrepreneurs slightly decrease in magnitude, α_K moving to 1.172 and β_E to 0.036. Moreover, both endogenous variables turn to be significantly and positively autocorrelated. In the equation for the share of innovative entrepreneurs, notice that (i) the amount of incentives to startups becomes significant only in its lagged form; (ii) the coefficient of number of scientific articles (per 100 scientific graduates) becomes significantly negative;[23] (iii)

[22] The reader might wonder why patents have a consistently negative effect on the size of VC funds. We conjecture the following explanation. On the one hand, more patents imply more new ideas around in search of financial funds, and thus foster the raising of new VC funds. On the other hand, it is well known that patents (and IPRs more generally) may also harm the innovation process, as innovative firms engage in ever more costly patent wars. Given that the first positive effect is already captured by our main variable "innovative early stage entrepreneurs", we conjecture that this negative coefficient might be capturing the "dark side" of patents.

[23] This negative relation may be due to the particular quantitative measure of scientific articles (per 100 scientific graduates) that we use here, which counts the number of articles from journals classified by the Institute for Scientific Information's Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) and thus reflect a significant bias toward English-language journals (The World

the ratio between bank and financial credit becomes significantly positive. In the equation for the size of VC funds instead, notice that the credit bureau coverage becomes significantly positive, while the GDP growth and the trend variable become significantly negative (the last variable indicating a negative impact of the recent financial crisis with the amount of VC funds declining by around 0.02 percentage points year after year).

When estimating the system (15) by 3SLS (columns 7-8), the estimated coefficients are very close to those obtained from the dynamic 2SLS model. Again, our diagnostic testing procedures suggest that our estimates are statistically valid: (i) the F statistics for joint significance of the instruments in first-stage regressions reject the null hypotheses of weak instruments, (ii) our underidentification tests reject the null hypothesis that the equation is underidentified, (iii) the Hansen statistics do not reject null hypothesis that the instruments are valid instruments.

Finally, the Arellano-Bover estimation results (columns 9-10) - which are consistent to possible correlation between the error term and any lag of the dependent variable - also confirm our theoretical predictions. We find that one percentage point increase in the share of venture capital funds over GDP induces 1.250 percentage points increase in the share of innovative entrepreneurs over working age population, and a one percentage point increase in the share of innovative entrepreneurs over working age population induces 0.027 percentage points increase in the share of venture capital funds over GDP. Compared to the previous IV-style estimates, among the determinants of the share of innovative entrepreneurs, the ratio between bank and financial credit turns insignificant; among the determinants of the size of VC funds, the degree of market capitalization and the interest rate are found to positively affect the venture capital market development, while the coefficient for the number of patent applications becomes insignificant. For the Arellano-Bover estimator to be consistent, the errors need to be serially uncorrelated. This is indeed the case. According to the Arellano-Bover test for zero autocorrelation in first-difference errors, the null hypothesis of serial uncorrelation is rejected at order 1 but not at higher orders, thus implying that lag order 2 (or higher) variables are valid instruments. Finally, the null hypothesis that the population moment conditions are correct is not rejected by the Hansen test.

Bank databank metadata). Hence, the measure is likely to be overestimated for Anglosaxon countries (US and UK) and underestimated for countries with a still relatively high percentage of innovative entrepreneurs over adult population (such as Czech Republic, Denmark, Greece, Ireland, Poland, Switzerland).

5.4 The Multiplier Effect in the Venture Capital Market

Using the coefficients reported in the previous subsection, we can easily produce a quantitative measure of the multiplier. This number is useful to gain a rough idea of the "additional" volatility generated by the thick market externality documented above. More formally, solving the linear system composed of (13) and (14) by the two endogenous variables l_e,l_k, we find the usual expression for the multiplier as[24]

$$m = \frac{1}{1 - \alpha_K \beta_E}. \qquad (16)$$

Plugging the results from our estimates of α_K and β_E into this formula, we obtain a value of m between 1.03 and 1.08 (see the last row of Table 3). These numbers tell us that a shock to *either* side of the market - such as an increase in start-up incentives for entrepreneurs, or an improvement in the credit information transparency for the capitalists - produces an impact on the equilibrium values of innovative entrepreneurs and of VC funds which is between 3% and 8% higher than it would have produced in the absence of strategic complementarity. Although not exhaustive, this argument may contribute to explain the pronounced volatility that we observe in the market for entrepreneurial finance.

6 Concluding Remarks

This paper has built a model of the market for innovation that focuses on the relationship between innovators and financiers. An innovation is the outcome of a search and matching process between an innovator with a new project and a financier backing that project. The model has investigated the choice of innovators and financiers as to whether or not to participate in a fair of innovation and has determined the equilibrium number of innovators and financiers contributing to the innovation process along the steady state. The main purpose of the modeling strategy that we have followed has been the one of representing the venture capital cycle described in the literature on entrepreneurial finance (Gompers and Lerner, 1999).

[24] The one discussed here is a particular case of that considered in Proposition 2 for two reasons. First, that model is generally non-linear. Secondly, there the shock can, more generally, hit both sides of the market at the same time (in fact, the expression for the multiplier contained in (17) in the Proof of Proposition 2 collapses to (16) if $\partial f_K / \partial \rho = 0$, that is, if the shock hits only one side of the market).

We have shown that a strategic complementarity exists between innovators and financiers, in that an increase in participation of the former induces an increase in participation of the latter (and *viceversa*). This complementarity is at the root of a multiplier effect in the process of financing innovation, which magnifies the effects of any exogenous shock on the innovative performance of the system.

The second part of the paper has been devoted to the empirical validation of the main theoretical result of the model. Our findings confirm the existence of a significant complementarity between the demand and the supply side of the venture capital market and thus signal the presence of a thick market externality. Our estimation has also allowed us to obtain a quantitative measure of the multiplier effect in this market which can, at least in part, rationalize the volatility documented in the Introduction.

Let us close the paper hinting at a different line of interpretation of our findings. A salient and well known empirical characteristic of the process of entrepreneurial innovation is its high degree of geographic *clusterization*.[25] Several explanations to this phenomenon have been proposed in the literature, which are based on the existence of network externalities, such as input sharing, labor market pooling or knowledge spillovers (see, for instance, Jaffe et al., 1993; Audretsch and Feldman, 1996; Chen et al., 2009). In this paper, we document the existence of a different positive network externality, the one between innovators and financiers. This externality might be an additional reason for the observed concentration in space (and not only in time). Pursuing further this line of reasoning and comparing it with alternative, and more consolidated, explanations to the formation of entrepreneurial clusters (as in Guiso and Schivardi, 2011) transcend the scope of this paper but might be an interesting future research avenue.

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A Proofs

Proof of Theorem 1. The entrepreneurs' reaction function with respect to capitalists, $f_E(L_K)$, is implicitly defined by the steady state condition

$$H(L_E, L_K) \equiv \sigma(E - L_E) F(c_E^*(L_E, L_K)) - L_E = 0$$

where $c_E^*(L_E, L_K)$ is itself implicitly defined in (9). It is

$$\frac{dH}{dL_K} = \sigma(E - L_E) F' \frac{dc_E^*}{d\alpha_E} \frac{d\alpha_E}{dL_K},$$

which is strictly positive given that $dc_E^*/d\alpha_E > 0$, and that $d\alpha_E/dL_K = (1/L_E)(\partial M/\partial L_K) > 0$. On the other hand, it is

$$\frac{dH}{dL_E} = -\sigma F + \sigma(E - L_E) F' \frac{dc_E^*}{d\alpha_E} \frac{d\alpha_E}{dL_E} - 1,$$

which is strictly negative given that $dc_E^*/d\alpha_E > 0$ and that

$$\frac{d\alpha_E}{dL_E} = \frac{1}{L_E}\left(\frac{\partial M}{\partial L_E} - \frac{M}{L_E}\right) < 0.$$

Hence, by the implicit function theorem, we have

$$\frac{df_E}{dL_K} = -\frac{\frac{dH}{dL_K}}{\frac{dH}{dL_E}} > 0$$

To prove that $df_K/dL_E > 0$, a totally symmetric argument can be developed starting from the total differentiation of (12) with respect to L_E.

Proof of Theorem 2. Define $L_j = f_j(L_{-j}, \rho)$ as the reaction function of L_j to L_{-j}, for $j = E, K$ and where ρ captures all the model's parameters. By convention, suppose that $\partial f_j/\partial \rho > 0$. Then it is

$$\frac{dL_E^*}{d\rho} = \frac{\partial f_E}{\partial \rho} + \frac{\partial f_E}{\partial L_K} \frac{dL_K^*}{d\rho}.$$

On the other hand,

$$\frac{dL_K^*}{d\rho} = \frac{\partial f_K}{\partial \rho} + \frac{\partial f_K}{\partial L_E}\frac{dL_E^*}{d\rho}.$$

Substituting the second expression into the first, we obtain

$$\frac{dL_E^*}{d\rho} = \frac{1}{1 - \frac{\partial f_E}{\partial L_K}\frac{\partial f_K}{\partial L_E}} \left(\frac{\partial f_E}{\partial \rho} + \frac{\partial f_E}{\partial L_K}\frac{\partial f_K}{\partial \rho} \right) > \frac{\partial f_E}{\partial \rho}, \tag{17}$$

given that $\partial f_K / \partial \rho > 0$ and that -as ensured in Theorem 1- $\partial f_j / \partial L_{-j} > 0$ for $j = E, K$.

B Data

The number of potential innovative entrepreneurs. This data is obtained from the Global Entrepreneurship Monitor (GEM) data base. In particular, the GEM questions for early-stage entrepreneurs are the following: 1) Are you, alone or with others, currently trying to start a new business, including any self-employment or selling any goods or services to others? 2) Are you, alone or with others, currently trying to start a new business or a new venture for your employer as part of your normal work? In order for the individual to classified as an early-stage entrepreneur, it is also required that the individual has conducted any concrete activities over the past 12 months, that he/she be one of the owners, or the sole owner of the business-in-gestation. A positive answer to either of the following questions characterizes *innovative* early-stage entrepreneurs: 1) Will all, some, or none of your potential customers consider this product or service new and unfamiliar? 2) Right now, are there many, few, or no other businesses offering the same products or services to your potential customers? 3) Have the technologies or procedures required for this product or service been available for less than a year, or between one to five years, or longer than five years?

The size of the potential financing market. As already recalled in the main text, the first challenge encountered in the definition of this variable is that we do not have data on total managed funds prior to 2013 for most European countries. However, we do have data on the inflows and the outflows (divestments and fundrasing activity) for each year back to 2004, as well as on the stock value at the end of the period (that is, in year 2013). This allows us to induce backwards the values of all stocks over the remaining years, 2004-2012. The iterative exercise that we perform is captured by the following difference equation:

$$\text{Total Managed Funds}_t = \text{Total Managed Funds}_{t-1} + \text{Total Raised Funds}_t - \text{Total Divestments}_t$$

with "Total Managed Funds$_t$" being the amount of funds managed by private equity and venture capital firms at time t, "Total Raised Funds$_t$" being the amount of funds raised by private equity and venture capital firms at time t, and "Total Divestments$_t$" being the amount of funds divested by private equity and venture capital firms at time t. Applying this equation starting with $t = 2013$, we can easily find the values for the "Total Managed Funds" down to 2004.

The second challenge is that these "total managed funds" include funds of both venture capital and private equity firms, while we are interested in the funds managed by VC firms only (whose figure is only available in 2013). Given that we do not have flow data for VC firms only, in order to identify the sole component ascribed to VC firms, we first calculate the ratio of funds *managed* by VC firms over the total amount of managed funds in 2013, that is:

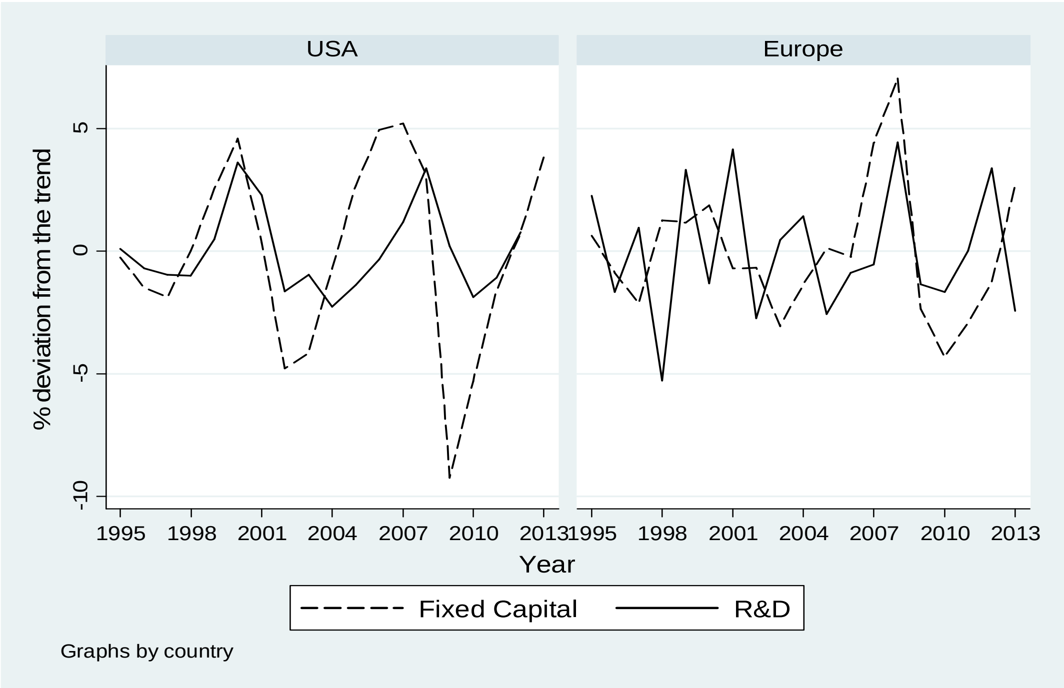
$$\text{VC Funds Ratio}_{2013} = \frac{\text{Venture Capital Managed Funds}_{2013}}{\text{Total Managed Funds}_{2013}}$$

Afterwards, under the hypothesis that this share remain constant over the period of interest, we impute it to the stock of managed funds, using this formula:

$$\text{Venture Capital Managed Funds}_t = \text{VC Funds Ratio}_{2013} \cdot \text{Total Managed Funds}_t.$$

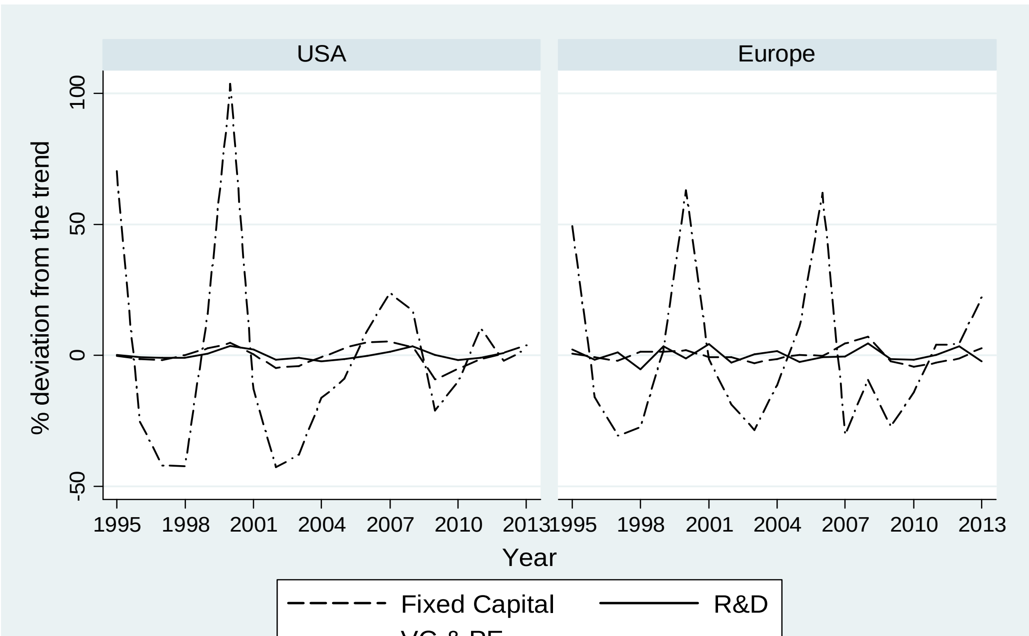
INSERT TABLE A1, A2 HERE

Figure 1. Volatility of investments in fixed capital and in R&D, years 1995-2013.



Note: The value of US investments in R&D for the year 2013 is missing from the OECD database.
Source: Own elaborations from OECD.Stat.

Figure 2. Volatility of investments in fixed capital and in R&D, and volatility of investments in seed-and start-ups provided by Venture Capitalists (VC) and Private Equity (PE) funds, years 1995-2013.



Note: The value of US investments in R&D for the year 2013 is missing from the OECD database.
Source: Own elaborations from OECD.Stat, MoneyTree Report, EBAN Annual Reports.

Table 1 - Total early-stage innovative entrepreneurs (as % 18-64 pop.)

country	2004	2005	2006	2007	2008	2009	2010	2011	2012
Austria		2.33		1.06					4.61
Belgium	1.33	1.37	1.03	1.52	1.25	1.47	1.52	1.94	2.76
Czech Republic			4.29					4.48	
Denmark	2.81	2.49	2.86	3.02	1.8	1.98	2.28	3.08	3.29
Finland	1.8	2.16	2.6	3.31	3.21	2.29	1.94	2.77	2.64
France	3.36	2.65	2.02	1.47	2.69	2.45	2.9	3.02	3.59
Germany	2.58	2.66	2.87	3.41	3.15	2.9	2.92	2.25	2.91
Greece	2.67	2.02	2.69	2.05	5.05	4.66	2.48	3.44	2.6
Hungary	1.38	0.42	1.32	0.9	1.06	2.82	1.92	2.96	3.31
Ireland	3.93	4.51	2.52	3.69	3.72		3.54	3.53	
Italy	2.45	1.52	1.82	2.5	1.89	1.33	0.96		3.4
Netherlands	1.73	1.29	2.21	2.08	2.13	2.95	2.59	4.26	4.33
Norway	3.04	3.64	4.09	1.61	3.65	4.17		2.42	1.9
Poland	3.78							6.75	6.77
Portugal	1.18			3.17			1.23	2.4	3.31
Romania				1.44	1.36	1.95	1.25	4.26	4.42
Spain	1.84	2.34	3.5	3.72	3.57	1.89	1.33	2.09	2.39
Sweden	1.33	1.16	1.67	1.26			2.06	2.38	2.3
Switzerland		2.52		3.02		3.54	2.5	2.97	2.54
United Kingdom	2.6	2.6	2.2	1.93	2.48	2.05	1.92	3.8	3.42
United States	4.18	4.84	3.9	4.7	4.32	2.96	2.43	5.54	6.02
Total	2.47	2.38	2.60	2.41	2.76	2.63	2.10	3.39	3.50

Source: Own elaborations from GEM database

Table 2 - VC managed funds as a percentage of GDP

country	2004	2005	2006	2007	2008	2009	2010	2011	2012
Austria	0.157	0.157	0.154	0.154	0.158	0.177	0.179	0.165	0.166
Belgium	0.536	0.514	0.506	0.462	0.465	0.476	0.478	0.459	0.431
Czech Republic	0.011	0.015	0.013	0.012	0.01	0.012	0.01	0.01	0.009
Denmark	1.304	1.381	1.403	1.422	1.396	1.479	1.411	1.405	1.315
Finland	0.394	0.429	0.405	0.475	0.543	0.614	0.609	0.589	0.604
France	0.315	0.344	0.366	0.366	0.39	0.405	0.398	0.387	0.386
Germany	0.472	0.478	0.47	0.467	0.465	0.484	0.45	0.415	0.396
Greece	0.001	0.001	0.021	0.051	0.054	0.073	0.078	0.083	0.089
Hungary	0.268	0.267	0.264	0.245	0.258	0.312	0.346	0.331	0.332
Ireland	0.481	0.457	0.415	0.45	0.493	0.573	0.602	0.585	0.576
Italy	0.048	0.048	0.048	0.049	0.05	0.056	0.056	0.055	0.054
Netherlands	0.234	0.247	0.256	0.268	0.274	0.293	0.297	0.308	0.315
Norway	0.476	0.441	0.533	0.576	0.671	0.762	0.683	0.72	0.663
Poland	0.092	0.074	0.101	0.117	0.123	0.148	0.132	0.136	0.143
Portugal	0.138	0.14	0.134	0.148	0.142	0.189	0.189	0.211	0.227
Romania	0.004	0.005	0.018	0.013	0.011	0.013	0.015	0.014	0.01
Spain	0.255	0.225	0.24	0.257	0.285	0.3	0.3	0.29	0.288
Sweden	0.502	0.506	0.687	0.732	0.889	1.02	0.853	0.847	0.793
Switzerland	0.743	0.91	1.088	1.292	1.588	1.643	1.513	1.369	1.325
United Kingdom	0.179	0.236	0.338	0.387	0.535	0.62	0.567	0.565	0.528
United States	2.088	2.009	1.99	1.901	1.567	1.321	1.244	1.359	1.209
Total	0.395	0.404	0.430	0.447	0.471	0.499	0.473	0.468	0.448

Source: Own elaborations from NVCA and EVCA databases

Table 3: Estimation results

VARIABLES	(1) FE - Entrepreneurs Clustered SE	(2) FE - VC funds Clustered SE	(3) 2SLS FE (1) - Entrepreneurs Clustered SE	(4) 2SLS FE (1) - VC funds Clustered SE	(5) 2SLS FE (2) - Entrepreneurs Clustered SE	(6) 2SLS FE (2) - VC funds Clustered SE	(7) 3SLS FE - Entrepreneurs Clustered SE	(8) 3SLS FE - VC funds Clustered SE	(9) AB - Entrepreneurs Clustered SE	(10) AB - VC funds Clustered SE
VC managed funds (as % of GDP)	1.762***		1.375**		1.172**		1.165**		1.250**	
	(0.482)		(0.556)		(0.523)		(0.488)		(0.638)	
innovative early stage entrepreneurs (as % of 18-64 pop.)		0.042*		0.040**		0.036**		0.036***		0.027**
		(0.023)		(0.019)		(0.018)		(0.013)		(0.014)
lag 1 innovative entrepreneurs (as % 18-64 pop.)					0.219*		0.213**		0.307*	
					(0.129)		(0.105)		(0.186)	
startup-incentives (as % GDP)	0.530***		0.540***		-0.271		-0.184		0.310	
	(0.175)		(0.155)		(0.191)		(0.209)		(0.246)	
lag 1 startup-incentives (as % GDP)					1.646***		1.587***		0.860***	
					(0.242)		(0.276)		(0.123)	
scientific graduates (as % 18-64 pop.)	-0.793		-0.473		-3.612		-2.379		-2.736	
	(4.682)		(4.387)		(3.797)		(4.585)		(4.034)	
number of scientific articles (as % of scientific graduates)	-0.004		-0.004		-0.007**		-0.007*		-0.006*	
	(0.004)		(0.004)		(0.003)		(0.004)		(0.003)	
lag 1 venture capital funds (as % GDP)						0.771***		0.771***		0.851***
						(0.100)		(0.082)		(0.089)
credit bureau coverage		0.002		0.002		0.001*		0.001*		0.000
		(0.002)		(0.002)		(0.001)		(0.001)		(0.001)
credit registry coverage		-0.001		-0.001		0.002		0.002*		0.000
		(0.002)		(0.002)		(0.001)		(0.001)		(0.000)
non-innovative early-stage entrepreneurs (as % 18-64 pop.)	0.210*	-0.000	0.213**	0.000	0.334***	-0.005	0.327***	-0.004	0.268***	-0.001
	(0.107)	(0.007)	(0.100)	(0.008)	(0.087)	(0.004)	(0.081)	(0.004)	(0.076)	(0.006)
patent applications from residents (per million people)	0.038	-0.013***	0.033	-0.013***	0.024	-0.007***	0.023	-0.007**	0.037	-0.002
	(0.027)	(0.002)	(0.025)	(0.002)	(0.024)	(0.002)	(0.018)	(0.003)	(0.026)	(0.002)
market capitalization (as % GDP)	0.002	-0.000	0.002	-0.000	0.001	0.000	0.001	0.000*	-0.000	0.001*
	(0.004)	(0.000)	(0.003)	(0.000)	(0.003)	(0.000)	(0.002)	(0.000)	(0.003)	(0.000)
domestic credit provided by banks (as % GDP)	-0.009	0.004**	-0.008	0.004***	-0.026	0.002	-0.025	0.002	0.002	0.001
	(0.038)	(0.001)	(0.035)	(0.001)	(0.024)	(0.003)	(0.022)	(0.004)	(0.027)	(0.002)
domestic credit provided by financial sector (as % GDP)	-0.002	-0.002	-0.003	-0.002	0.019	-0.000	0.019	-0.000	-0.007	0.000
	(0.037)	(0.002)	(0.034)	(0.002)	(0.022)	(0.003)	(0.022)	(0.004)	(0.026)	(0.002)
bank vs. financial credit	7.496	-0.991*	7.299	-0.983*	10.761**	-0.062	10.635**	-0.066	3.442	-0.105
	(7.526)	(0.562)	(6.994)	(0.512)	(5.032)	(0.647)	(4.801)	(0.574)	(5.269)	(0.359)
interest rate	0.038	0.001	0.041	0.002	0.011	0.006	0.015	0.006	0.016	0.004*
	(0.060)	(0.013)	(0.054)	(0.012)	(0.053)	(0.005)	(0.059)	(0.005)	(0.057)	(0.002)
GDP growth	0.011	-0.001	0.011	-0.001	0.019	-0.005**	0.018	-0.005**	0.025	-0.004
	(0.018)	(0.006)	(0.017)	(0.006)	(0.018)	(0.002)	(0.017)	(0.002)	(0.021)	(0.003)
trend	0.110	-0.005	0.110*	-0.005	0.070	-0.019*	0.065	-0.019***	0.061	-0.015***
	(0.072)	(0.016)	(0.066)	(0.014)	(0.055)	(0.011)	(0.049)	(0.006)	(0.050)	(0.005)
Country Dummies	YES	YES	YES	YES	YES	YES	YES	YES		
Observations	111	111	111	111	111	111	111	111	103	108
Overidentification Test			1.302	3.466	0.191	1.995	0.124	2.394	7.010	3.980
P-value			0.5215	0.4831	0.9091	0.7366	0.9396	0.6637	0.4280	0.8590
Weak Identification Test			15.81	25.703	17.77	25.41	17.77	25.41		
Underidentification Test			72.26	198.41	83.43	198.83	151.13			
P-value			0.0000	0.0000	0.0000	0.0000	0.0000			
Arellano-Bond test for zero autocorrelation in first-differenced errors										
Order 1									-2.27	-2.17
P-value									0.023	0.030
Order 2									0.67	-0.86
P-value									0.504	0.39
Multiplier Effect (m)	1.08		1.06		1.04		1.04		1.03	

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A1 - Control variables summary statistics by year

	Entrepreneurial Attitudes	Entrepreneurial Incentives	Attitudes towards Innovation			Macroeconomic Indicators						Access to Credit Information Indexes	
year	non-innovative early-stage entrepreneurs (as % 18-64 pop.)	startup-incentives (as % of million€ GDP)	patent applications from residents (per million people)	scientific graduates (as % 18-64 pop.)	number of scientific articles (as % of scientific graduates)	market capitalization (as % GDP)	domestic credit provided by banks (as % GDP)	domestic credit provided by financial sector (as % GDP)	domestic vs. financial credit	GDP growth	Interest rate	credit registry coverage	credit bureau coverage
2004	3.207	0.135	33.020	10.83%	99.28915	74.841	94.255	111.805	0.855	3.342	4.439	40.838	8.610
2005	3.506	0.121	32.308	11.25%	97.22427	78.086	101.946	119.359	0.866	2.968	3.650	42.824	8.862
2006	3.338	0.088	32.362	11.56%	95.81053	98.232	109.623	126.382	0.881	3.823	4.200	44.023	9.232
2007	3.430	0.097	32.743	11.60%	97.53168	104.777	120.538	137.781	0.885	3.489	4.630	45.632	9.786
2008	3.505	0.113	32.993	12.36%	95.9274	45.559	127.519	143.186	0.887	0.525	4.706	47.536	10.505
2009	3.339	0.102	32.806	11.24%	103.7011	66.414	132.914	152.814	0.865	-4.110	4.508	49.714	10.936
2010	3.138	0.174	33.008	11.81%	99.77631	70.409	131.738	154.843	0.849	1.820	4.252	52.736	11.323
2011	3.788	0.162	33.258	12.19%	93.29333	54.005	129.148	152.533	0.848	1.331	4.965	56.082	13.823
2012	3.863	0.116	32.695	12.15%		63.509	126.452	151.043	0.840	-0.392	4.418	55.418	14.909

Table A2 - Control variables summary statistics by country

	Entrepreneurial Attitudes	Entrepreneurial Incentives	Attitudes towards Innovation			Macroeconomic Indicators						Access to Credit Information Indexes	
country	non-innovative early-stage entrepreneurs (as % 18-64 pop.)	startup-incentives (as % of million€ GDP)	patent applications from residents (per million people)	scientific graduates (as % 18-64 pop.)	number of scientific articles (as % of scientific graduates)	market capitalization (as % GDP)	domestic credit provided by banks (as % GDP)	domestic credit provided by financial sector (as % GDP)	domestic vs. financial credit	GDP growth	Interest rate	credit registry coverage	credit bureau coverage
Austria	3.101	0.006	38.723	0.080	136.317	29.409	114.791	130.264	0.881	1.534	3.666	44.190	1.410
Belgium	2.195	0.004	7.982	0.096	109.898	63.064	85.155	111.646	0.761	1.256	3.808	0.000	65.120
Czech Republic	3.377	0.110	9.312	0.101	57.250	25.064	43.145	53.127	0.804	2.591	3.951	62.420	4.560
Denmark	2.131	0.000	44.181	0.120	134.382	63.936	189.500	192.073	0.983	0.551	3.488	7.550	0.000
Finland	3.031	0.018	50.946	0.114	137.750	86.518	81.491	85.345	0.955	1.349	3.537	16.260	0.000
France	2.233	0.028	33.838	0.180	44.660	76.791	102.536	119.673	0.856	0.975	3.638	0.000	28.510
Germany	1.984	0.093	84.186	0.091	106.168	43.245	109.827	132.209	0.831	1.071	3.320	96.090	0.750
Greece	4.033	0.041	6.956	0.110	61.080	43.800	91.536	117.055	0.775	-0.096	7.764	50.320	0.000
Hungary	4.424	1.618	10.061	0.054	79.649	23.300	56.755	69.609	0.808	1.443	7.392	15.690	0.000
Ireland	4.499	0.000	26.320	0.299	30.232	47.582	176.945	179.055	0.990	1.857	4.983	100.000	0.000
Italy	2.080	0.050	20.416	0.065	114.256	33.800	101.209	127.455	0.799	-0.146	4.496	78.920	14.820
Netherlands	3.800	0.000	20.368	0.064	224.425	86.773	179.409	190.455	0.941	0.879	3.528	79.620	0.000
Norway	4.753	0.018	35.807	0.094	145.261	55.500	79.280	82.480	0.961	1.482	4.018	100.000	0.000
Poland	3.199	0.176	9.965	0.145	20.102	30.445	40.509	50.327	0.797	3.827	5.744	61.020	0.000
Portugal	4.223	0.003	4.926	0.077	69.797	37.445	162.600	169.464	0.963	-0.069	5.526	14.970	77.410
Romania	3.869		7.219	0.081	11.675	16.136	28.536	35.100	0.846		7.309	23.940	7.270
Spain	3.390	0.108	10.092	0.104	66.022	85.100	170.391	188.046	0.903	1.187	4.425	9.530	47.690
Sweden	2.975	0.229	41.562	0.083	212.866	102.846	119.736	127.273	0.940	2.178	3.498	99.800	0.000
Switzerland	3.658	0.010	31.629	0.119	158.798	215.273	162.327	176.927	0.918	1.741	2.163	24.300	0.000
United Kingdom	3.862	0.000	42.144	0.247	49.296	124.018	173.827	183.627	0.952	1.468	3.963	92.310	0.000
United States	6.342	0.000	107.748	0.129	88.025	116.373	53.891	220.318	0.245	1.841	3.641	100.000	0.000
Total	3.489	0.123	30.289	0.115	99.832	71.387	113.509	132.828	0.858	1.391	4.375	49.401	11.355