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Public Policy and the Creation of Active Venture Capital Markets

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Abstract

We study how public policy can contribute to increase the share of early stage and high-tech venture capital investments, thus helping the development of active venture capital markets. A simple extension of the seminal model by Holmstrom and Tirole (1997) provides a theoretical base for our analysis. We then explore a unique panel of data for 14 European countries between 1988 and 2001. We have several novel findings. First, the opening of stock markets targeted at entrepreneurial companies positively affects the shares of early stage and high-tech venture capital investments; reductions in capital gains tax rates have a similar, albeit weaker, effect. Second, a reduction in labor regulation results in a higher share of high-tech investments. Finally, we find no evidence of a shortage of supply of venture capital funds in Europe, and no evidence of an effect of increased public R&D spending on the share of high-tech or early stage venture capital investments.

JEL Classification numbers: G20, G24. H20, O30.

Keywords: Venture Capital; Capital Gains Tax; Public R&D Expenditure; Barriers to Entrepreneurship; Stock Markets; Public Policy.

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1 Introduction

Venture capital is a form of intermediation particularly well suited to support the creation and growth of innovative, entrepreneurial companies (Hellmann and Puri (2000, 2002), Kortum and Lerner (2000)). It specializes in financing and nurturing companies at an early stage of development ('start-ups') that operate in high-tech industries. For these companies the expertise of the venture capitalist, its knowledge of markets and of the entrepreneurial process, and its network of contacts are most useful to help unfold their growth potential (Bottazzi, Da Rin and Hellmann (2004), Gompers (1995), Hellmann and Puri (2002), Lerner (1994, 1995), and Lindsey (2003)). By contrast, when venture capital is applied to companies at a later stage of their growth, or in companies which operate in technologically mature industries, it has less of an opportunity to 'make a difference' (Michelacci and Suarez (2004)). Economics thus points to the relevance of providing an adequate share of venture investments in high-tech and early stage companies.

The creation of 'active' venture capital markets, i.e. venture capital markets which provide strong support for early stage and high-tech ventures has received a high priority by economic policy, which appreciates its importance for achieving continued economic growth and job creation ((Bottazzi and Da Rin (2002a), European Commission (2003), OECD (2001)). As economies become ever more dependent on innovation and entrepreneurship for achieving sustained growth (Bottazzi, Da Rin, and Giavazzi (2003), Nelson and Romer (1996), OECD (2001)), governments around the world have been trying to replicate the diffusion and success that venture capital has achieved in the United States (Megginson (2004)). These attempts absorb large sums of public money. Yet, we still know very little about what policies can help create active venture capital markets, and our study contributes a first step towards filling this gap.

We start by providing a simple extension of the seminal model of Holmstrom and Tirole (1997) which helps us focus on the determinants of the distribution of financing between early and late stage, and between high-tech and low-tech, investments. We extend the model by Holmstrom and Tirole by allowing for the possibility of an excess supply of funds. As in the original model, firms are heterogeneous in their ability to pledge collateral against borrowing, but we also assume that this ability is higher for firms that possess more tangible assets, which are more easily accepted as collateral than intangible assets. As firms mature from start-ups to later stage ventures, they can rely more on tangible assets. Likewise, firms in high-tech industries make more use of intangible assets than those in traditional industries. This creates a 'pecking order' in firms' ability to pledge collateral against loans.

We use this framework to introduce the notion of 'innovation ratios,' defined to be the ratio of early stage (or high-tech) investments to total venture investments. These ratios provide a measure of the extent to which venture capital markets are active. They are useful for studying how policy can make venture capital markets not only larger but also focussed on those firms which can most benefit from the support of a venture capitalist.

While simple, this framework is rich enough to point to several potential drivers of active venture capital markets which are under the influence of policy-makers. The first is the sheer supply of funds available for investment, which could ease binding credit constraints. Second, there are factors which directly affect project's expected returns: the existence of exit markets for venture investments and the level of capital gains taxation, both of which affect the capital gains that investors and entrepreneurs can reap when they succeed; and the existence of good technology, which can be turned into commercially valuable ventures. Third, there are factors which affect expected returns by determining the cost of creating a new venture, namely barriers to entrepreneurship.

Starting with Gompers and Lerner (1998) several previous studies have looked at the development of venture capital markets and their determinants. Our approach allows us to advance the literature on several counts. First, we use a simple model to guide our empirical approach, which is based on ratios instead of levels of demand and supply—unlike previous analyses.

Our panel approach, based on data for 14 European countries over 1988 to 2001, is another innovation. Previous studies either lacked panel data or focussed on 'between' country estimators. Jeng and Wells (2000), for example, use a panel of OECD country-level data for 1986-95, and focus on cross-country analysis; their approach raises issues of unobserved heterogeneity, that our panel approach can address adequately. Based on our comprehensive set of policy variables, we choose to provide an answer to the question of what can governments do to increase the innovation ratios rather than understanding cross-country variation in the levels of the ratios; we thus focus on estimating 'within' country effects. Our choice is motivated also by the nature of our data, which come from a rather homogeneous set of developed economies.

One notable exception to pure cross-country comparisons is Gompers and Lerner (1998), who use a panel of U.S. state-level variables for examining the effect of variations in taxation during the 1976-94 period.[1] However, ours is the first study to analyze all policy variables with a panel dimension. Our results provide several novel insights.

First, we look at the opening of 'New' stock markets target at entrepreneurial companies, and find that it considerably increases both the early stage and high-tech innovation ratios. Our panel setting thus provides strong support for the importance of an exit option for venture capital, as suggested by Black and Gilson (1998) and Michelacci and Suarez (2004).

Second, we examine the taxation of capital gains, which has recently received considerable attention in theoretical studies of venture capital (e.g., Keuschingg and Nielsen (2003, 2004)). Previous empirical analyses looked at cross-sectional comparisons of taxation across OECD countries (e.g., Armour and Cummings (2003)). We extend them by collecting a panel of country-level data which goes back to 1988. We find that a reduction in capital gains taxation increases both the high-tech and early stage ratios, albeit the economic effect is not very large.

Third, we consider the effects of a reduction in barriers to entrepreneurship. Like in the case of taxation, we believe we are the first to introduce a panel dimension into the analysis. We consider several alternative measures of such barriers, and find that those related to labor regulations have a significantly negative effect on the share of high-tech

[1] See also Armour and Cumming (2003), who develop an original measure of the leniency of bankruptcy laws across 15 European and North American countries over 1990-2002.

investments.

These results are consistent with our model, which suggests that a higher expected rate of return makes more venture funds available for companies with lower collateral, such as those in high-tech and early stage, and thus results in an increase of the innovation ratios.

Finally, our data do not provide any evidence of a shortage of venture capital funds for European companies, contrary to what assumed by the prevailing policy approach. Nor we find evidence that public expenditure in research and development (R&D) favors the innovation ratios through the creation of better entrepreneurial opportunities.

Overall, the European experience we analyze thus suggests that the creation of active venture capital markets might depend crucially on providing investors and entrepreneurs with the possibility to reap the benefits of their efforts, rather than on providing them with more funds.

The rest of the paper is organized as follows. Section 2 briefly describes recent policy programmes for venture capital markets. Section 3 presents our model. Section 4 describes our data and empirical strategy. Section 5 reports our results, and is followed by a brief conclusion.

2 Public policy for active venture capital markets

To the extent that growth depends on innovation and creative destruction, and that innovative firms suffer from credit constraints because of asymmetric information, one could think of fostering productivity by channeling more funds into venture financing of technologically innovative companies. This reasoning has in fact held sweeping influence on policy. While venture capital was born in the U.S. out of private initiative (Gompers (1994)), its expansion benefited from the Small Business Innovation Research (SBIR) programme in the 1980s (Gans and Stern (2003), Lerner (1999)). Interestingly, the SBIR programme, which pioneered public policy towards venture capital by investing several billion dollars, was largely motivated by the fear that insufficient financing was available to innovative small firms.

The perceived need to overcome this market failure by increasing the supply of risk capital is probably the main motivation for public policy in favor of venture capital markets. Such an approach has also informed recent public policy initiatives, most notably in Israel and Europe. In Israel, the Yozma programme, started in 1992, provided 100 million dollars of public funding to attract private funds for over 150 millions (Avnimelech and Teubal (2002)). Yozma helped create ten private venture capital firms and to jump-start a successful and active venture capital market. In 2001, the European Commission transformed the European Investment Fund (EIF) into Europe's largest venture investor with an injection of more than 2 billion euros (EIF (2002)), making the increase of the supply of risk capital one priority of its policy towards innovation and capital markets (European Commission (1998, 2003)).

This approach is shared by many other large national programmes, from Germany's federal and regional schemes for innovative companies (German Federal Ministry for Economics and Technology (1999)), to the French 'Plan Innovation' (French Ministry of Industry (2003)), to the decision to turn the Danish Growth Fund into a public venture fund in 2001 (Danish Growth Fund (2003)), and to the creation of the UK High Technology Fund (HM Treausury (2003)). Public programmes aimed at increasing the supply of venture capital have also been implemented in several emerging economies, from Chile to India (Carter, Barger, and Kuczynski (1996), Gilson (2003), Lerner and Schoar (2004)).

The economics foundations for such policies are however still unchecked. While venture capital is widely thought to foster the creation of particularly innovative and dynamic companies, this does not imply that more funds would directly translate into a larger number of successful companies. Theory warns about the value-reducing effects of increasing the supply of funds to the venture capital industry when competition for good projects is high (Inderst and Müller (2004)). In such an environment, promoting innovation by increasing research and development (R&D) expenditure would be more effective than stimulating the funding of the venture capital industry.

Recent empirical work also casts doubts on the hope to increase investment into new ventures simply by increasing the supply of risk capital. Looking at U.S. sector-level data, Hirukawa and Ueda (2003) argue that, at the aggregate level, it may be innovation activity to lead the development of venture capital, and not *vice versa*. Also Gompers and Lerner (1998) emphasize the role of R&D expenditure in the development of the U.S. venture capital industry.

The view that factors other than the supply of funds may be important for the creation of active venture capital markets has also yielded influence over policy. For example, the increase in R&D expenditure is seen as one of the main factors lying behind the discovery of new technology, and thus to the arrival of new entrepreneurial opportunities. On these bases, the Barcelona European Council of March 2002 set the objective to increase the average investment in R&D in Europe from 1.9% to 3.0% by 2010, of which two thirds to be funded by the private sector (European Commission (2002)).

Three other factors have held influence over policies toward active venture capital markets. One is the need to offer an exit option to venture capital investors. The realization of a large capital gain when bringing a company public is arguably the greatest incentive to venture investing. Moreover, venture capital should benefit from the ability to exit from investments before the marginal value of their time and money starts to decrease. Michelacci and Suarez (2004) formalize this notion, and show that active stock markets induce the development of a vibrant venture capital industry. The Risk Capital Action Plan adopted by the European Commission in 1998, subscribed to this view and greatly influenced national policies in the late 1990s (European Commission (1998)). The recent demise of the Neuer Markt and other European 'new' markets, however, cast serious doubts on the positive effect of this approach (Bottazzi and Da Rin (2004)).

Second, the taxation of capital gains has long been pointed to as a driver of both entrepreneurship and venture capital investment (Poterba (1989a,b), Gompers and Lerner (1998)). Recent theories argue in favor of reductions of capital gains tax rates on the ground of incentive effects for the provision of effort by venture capitalists (Keuschnigg and Nielsen (2001) and Keuschnigg (2004)). Capital gains taxation has been recently reduced in several countries (EVCA (2003)). For example, investment vehicles with a favorable taxation have been introduced in 1995 in the UK ('Venture Capital Trust') and in 1997 in France ('Fonds Communs de Placement dans l'Innovation'–FCPI). Reforms aimed at lowering the effective taxation have also been enacted in Germany (1998 and 2000), the Netherlands (1996), Spain (1996 and 2001).

Finally, barriers to entrepreneurship—which range from the formalities needed to establish a corporation, to regulatory and administrative opacity and barriers to competition—are another important hindrance to the formation of new companies. The reduction of such barriers has thus been advocated as a major step towards the creation of entrepreneurial companies, and has been object of recent empirical analyses (see Alesina et al. (2003), Klapper, Laeven, and Rajan (2004) and Scarpetta et al. (2002) among others). One important finding which motivates our interest is the decrease in business regulations in several European countries over the 1990s, documented in a series of OECD studies reviewed in Nicoletti and Scarpetta (2003).

Which of these approaches, if any, receive support from the data is however unclear. This study provides new evidence in this respect.

3 A model of venture capital markets

In this section we provide a simple extension of the seminal double moral hazard model of financial intermediation by Holmstrom and Tirole (1997) to study the structure of venture capital investment.[2] We start by summarizing the key ingredients of the model, which formalizes the idea that the ability to pledge collateral determines both the amount and the type of financing that a firm can obtain. We refer the reader to the original article for further details. We then use the model to define the concept of innnovation ratio, and we extend the model to the case of excess supply of venture capital.

The model lasts two periods. In the first period financial contracts are signed and investments are implemented. In the second period uncertainty about project returns is resolved and payments are made. There is a continuum of firms—or, equivalently, entrepreneurs—which have access to a project that delivers a payoff equal to $R>0$ with probability p_H and to 0 otherwise. The cost of the investment is I. Firms need to borrow the amount $I - A > 0$, where A denotes a firm's own equity capital which is pledged as collateral. We denote by $G(A)$ the cumulative uniform density of collateral for all firms, which we assume to be continuous. Entrepreneurs are able to divert resources from the project and extract private benefits equal to $B > 0$, which reduces the probability of success to $p_L < p_H$.

Firms can borrow from arms' length ('uninformed') investors or from ('informed') financial intermediaries. Uninformed investors simply provide funds and require a return γ, which reflects their opportunity cost of funds. In addition to providing funds, financial intermediaries can also monitor, which reduces private benefits to $0 < b < B$ and mitigates the

[2] The double moral hazard model, where both the entrepreneur and the venture capitalist exert noncontractible effort, has become the workhorse of the theoretical venture capital literature (see Casamatta (2003), Inderst and Müller (2004), Repullo and Suarez (2004), Schindele (2004), and Schmidt (2003) among others).

entrepreneur's moral hazard problem. In our setting, we identify financial intermediaries with venture capital firms.

Finally, we assume that only the good project is economically viable, which we can write as: $p_H R - \gamma I > 0 > p_L R - \gamma I + B$.

3.1 Direct finance

It is easy to show that some firms with low equity capital will not be financed by uninformed investors, because their capital is not enough to generate the correct incentives for entrepreneurs to behave diligently. Let R_f be the share of the payoff retained by the firm, and $R_u = R - R_f$ the share paid out to uninformed investors. A necessary condition to obtain finance is that the entrepreneur prefers not to shirk, i.e. $p_H R_f \geq p_L R_f + B$.

A necessary and sufficient condition to obtain finance from uninformed investors is then:

$$\gamma(I - A) \leq p_H R_u = p_H \left[R - \left(\frac{B}{p_H - p_L}\right) \right]$$

which says that the market value of the loan (the left hand side) cannot exceed the firm's expected income (the right-hand side). Firms are then able to raise finance from uninformed investors if and only if:

$$A \geq \overline{A}(\gamma) = I - \left(\frac{p_H}{\gamma}\right) \left[R - \frac{B}{p_H - p_L} \right]$$

where $\overline{A}$ is increasing in γ.

3.2 Venture capital finance

Credit rationing of firms with $A < \overline{A}$ creates a role for monitoring by venture capital firms. In this case, a monitored entrepreneur chooses not to shirk only if $p_H R_f \geq p_L R_f + b$.

Let R_{vc} be the share of the payoff paid out to the venture capital firm. We assume that monitoring has a private cost $c > 0$, so that the venture capitalist will monitor only if her expected payoff compensates for the private cost of monitoring: $p_H R_{vc} - c \geq p_L R_{vc}$.

The rate of return to venture capital, denoted by β, is given by $\beta = p_H R_{vc} / I_{vc}$, where I_{vc} is the amount of funds borrowed by monitored firms. We then see that the value of I_{vc} adjusts to satisfy the incentive compatibility constraint of the venture capitalist, so that:

$$I_{vc}(\beta) \geq \frac{c p_H}{\beta(p_H - p_L)}$$

Venture finance costs more than uniformed capital, since it must compensate for monitoring effort. It follows that in equilibrium I_{vc} takes the lowest possible value which allows venture capitalists to recover the monitoring costs, the residual financing needs of a firm being served by cheaper uninformed capital. The above equation thus holds as an equality.

A necessary and sufficient condition for a firm to be financed by both uninformed investors and venture capitalists is then:

$$A \geq \underline{A}(\gamma,\beta) = I - I_{vc}(\beta) - (\frac{p_H}{\gamma}) \left[R - \frac{b+c}{p_H - p_L} \right]$$

where it can be shown that $\underline{A}$ increases in both its arguments, so that more credit constrains become tighter as the rate of return required by either type of investor increases. Panel (a) of Figure 1 represents the firms 'financing choices, depending on their own equity capital.

3.3 Equilibrium

The aggregate demand for uninformed capital, denoted by $D_u(\gamma,\beta)$ is the sum of two components. The first is the demand from firms which can afford not to borrow venture capital , i.e. firms with $A > \overline{A}(\gamma)$. This amounts to $(I - A)$. The second component is the demand from firms which also receive venture capital, i.e. firms with $\underline{A}(\gamma,\beta) < A < \overline{A}(\gamma)$. This amounts to $(I - A - I_{vc})$. Their sum is given by:

$$D_u(\gamma,\beta) = \int_{\underline{A}(\gamma,\beta)}^{\overline{A}(\gamma)} [I - A - I_{vc}(\beta)]\, dG(A) + \int_{\overline{A}(\gamma)}^{\infty} [I - A]\, dG(A)$$

The market for uninformed capital clears when demand equals supply:

$$D_u(\gamma,\beta) = S(\gamma) \tag{1}$$

where $S(\gamma)$ denotes the supply of uninformed capital, with $S'(\gamma) > 0$. The aggregate demand for venture capital is given by:

$$D_{vc}(\gamma,\beta) = \left[G(\overline{A}(\gamma)) - G(\underline{A}(\gamma,\beta)) \right] I_{vc}(\beta) \tag{2}$$

which is increasing in p_H and decreasing in β. In equilibrium, this is equal to the supply of venture capital, K_{vc}, which we take to be fixed in the short run, as in Holmstrom and Tirole (1997). This assumption is similar to that of limited supply of venture capitalists imposed by Michelacci and Suarez (2003). It reflects the notion that it takes time to increase the supply of specialized intermediaries. While 'money is green,' venture capital requires considerable experience and skills (Bottazzi, Da Rin, and Hellmann (2004)), which need time to accumulate. Panel (b) of Figure 1 represents the venture capital market equilibrium.

To characterize the equilibrium we notice that the market clearing condition for all types of external finance is:

$$D_u(\gamma,\beta) + D_{vc}(\gamma,\beta)) \equiv \int_{\underline{A}(\gamma,\beta)}^{\infty} [I - A]\, dG(A) = S(\gamma) + K_{vc} \tag{3}$$

Panel (c) of Figure 1 represents the equilibrium of financial markets when the supply of uninformed capital is infinitely elastic. This is not an unrealistic case because the market for venture capital is small relatively to that for uninformed capital—hence the return to uninformed capital may well be insensitive to the return to private equity. This assumption is maintained below to simplify our proofs, which are found in the Appendix. Our results carry over to the case of an elastic supply of uninformed capital[3].

3.4 The innovation ratios

We denote by D^i_{vc} the demand for innovative venture capital investments, where $i = ES, HT$, ES stands for early stage investments, and HT for high-tech investments. We define D^i_{vc} as innovative investment, characterized by collateral lower than a constant A^*, with $\underline{A} \leq A^* \leq \overline{A}$:

$$D^i_{vc}(\gamma, \beta) = [G(A^*) - G(\underline{A}(\gamma, \beta))]\, I_{vc}(\beta) \tag{4}$$

and study the structure of venture capital investment. To this purpose we define the 'innovation ratios' as the ratios of innovative investment to total venture capital investment:

$$\frac{D^i_{vc}}{D_{vc}}(\gamma, \beta) \equiv \frac{[G(A^*) - G(\underline{A}(\gamma, \beta))]}{\left[G(\overline{A}(\gamma)) - G(\underline{A}(\gamma, \beta))\right]} \tag{5}$$

Our first results then characterizes the effects of changing market conditions on the equilibrium value of the innovation ratios:

Proposition 1 *The innovation ratios decrease following a reduction in either the supply of venture capital funds (K_{vc}) or projects' expected return (R), as firms with low own equity capital are denied credit.*

These two cases are portrayed in Panels (d) and (e) of Figure 1, respectively. This proposition establishes that innovative investment—being characterized by lower collateral—is sensitive to variations in the supply of private equity capital and in project returns.

3.5 Equilibrium with excess supply of venture capital

The occurrence of excess supply of venture capital may not be unrealistic, since there is evidence pointing to a 'money chasing deals' phenomenon in both the 1980s and 1990s in the U.S. industry (see Gompers and Lerner (2000) and Kaplan and Stein (1993)). We thus consider the case when the supply of venture capital exceeds its demand at the minimum rate of return acceptable to a venture firm.[4] This rate is given by $\underline{\beta} = \gamma \frac{p_H}{p_L}$, and is the lowest

[3] Restrictions must then ensure that the supply of capital to firms is more sensitive to shocks when collateral is lower.

[4] This case is not discussed by Holmstrom and Tirole (1997), who focus on asymmetric responses of β and γ to credit crunches. These rates always move together when there is excess supply of venture capital funds.

return such that venture capitalists have an incentive to monitor rather than becoming an uninformed investor. It is thus increasing in γ.

The market clearing condition for all types of funds becomes:

$$\int_{\underline{A}(\gamma,\underline{\beta})}^{\infty} [I - A]\, dG(A) = \int_{\underline{A}(\gamma)}^{\infty} [I - A]\, dG(A) = S(\gamma) + K_{vc} \tag{6}$$

where $\underline{A}(\gamma) \equiv \underline{A}(\gamma,\underline{\beta})$ is increasing in γ, so that the total demand for funds is decreasing in γ. This condition uniquely determines the equilibrium rate of return on uninformed capital. Notice that the lowest possible value of $\underline{A}(\gamma, \beta)$ is reached when $\beta = \underline{\beta}$, everything else being constant. The largest number of firms is thus getting financed by venture capital in the case of an excess supply of funds, since $\overline{A}(\gamma)$ is independent of β. The excess supply of venture capital funds, $K_{vc} - D_{vc}(\gamma,\underline{\beta})$, is invested in firms with own capital above $\overline{A}$, earning a return γ.

We now examine the effects of an increase in K_{vc} on the equilibrium allocation when $K_{vc} > D_{vc}$ at $\beta = \underline{\beta}$.

Proposition 2 *(i) A contraction in the supply of venture capital funds does not affect the innovation ratios; (ii) a reduction in project return R decreases the innovation ratios.*

We refer the reader to Figure 2.[5]

3.6 Taking the model to the data

Our empirical strategy attempts to assess, with the guidance of our model, the effects of alternative policies on the innovation ratios. We consider two different types of policies. First, we look at the amount of funds channeled to venture capital markets, which provides the empirical counterpart of K_{vc}. Second, we look at policies which may affect the innovation ratios through their influence on the return to a project, R. We consider policies which affect returns either directly, like the taxation of capital gains, the existence of a stock market for entrepreneurial companies, or public expenditure on R&D; and we look at policies which affect returns indirectly, by determining the cost of creating a new venture, namely the reduction of barriers to entrepreneurship.

After describing our data, in Section 4.2 below we spell out in more detail our empirical strategy.

[5] These results can be shown to hold also when projects are less than perfectly correlated and when monitoring effort or cost are not fixed.

4 Data and empirical strategy

4.1 Data sources and description

Our analysis is based on a panel of data gathered from several sources. We consider data for the following 14 European countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, and the UK over the years between 1988 and 2001.[6]

These countries constitute an ideal set of countries to look at for our purposes. They form a relatively homogeneous group of economies which share broadly similar institutions and are linked by a common market. At the same time, there has been a substantial variation over time in the evolution of the venture capital markets, which have matured substantially over the 1990s (Bottazzi and Da Rin (2004)). And variation has been noticeable also in our explanatory variables: the availability of stock markets for entrepreneurial companies, taxation of capital gains, the intensity of barriers to entrepreneurship, and public R&D spending.

4.1.1 Dependent variables

Our source for the dependent variables is the European Venture Capital Association (EVCA), whose yearbooks are compiled from an extensive yearly survey of member and non-member firms.[7] Yearbooks report data on a number of variables, organized by country. For each year and country, we look at the reported amount of total funds invested. This is divided into five categories: seed, start-up, expansion, replacement capital, and buyouts. We define venture capital (VC) to be the sum of the first four categories, and non-venture private equity to equal the last one. The sum of venture and non-venture private equity investments is referred to as (total) private equity (PE). We then partition venture capital investments into early stage (ES)—equal to the sum of seed and start-up investments—and late stage (LS)—equal to expansion investments and replacement capital.

We then define high-tech investments (HT) as the sum of investments in the following sectors: communications, computer related, other electronics related, biotechnology, medical and health related. Low-tech investments (LT) are the investments in the remaining sectors: energy, consumer related, industrial products and services, chemicals, industrial automation, other manufacturing, transportation, financial and other services, agriculture, and construction. Finally, we define the Early Stage Ratio as the ratio of ES to VC, and the High-Tech Ratio as the ratio of HT to PE.[8] These two ratios form the empirical correspondent of the innovation ratios we defined in the model.

[6] We do not include in our analysis the US in order to avoid mismeasurement errors. While the US constitute the world's largest private equity market, the venture capital data collected by the National Venture Capital Association (NVCA) are coded with different definitions than those of the EVCA.

[7] For details on the EVCA database, and for definitions of variables, see the methodology section of EVCA (2001).

[8] Ideally, we would like to be able to measure the High-Tech Ratio as the ratio of HT to VC. A limitation of the EVCA data is that they do not provide a separate sectoral disaggregation for venture and non-venture private equity.

4.1.2 Independent variables

We then consider our independent variables. Our measure of the funds raised by venture capital firms is the total amount of funds raised from all sources by a country's private equity firms in given year.[9] We express all values in euros, using the synthetic euro exchange rate of Datastream for the conversion. From Datastream we also download population and price indices for all countries. We use population to express values in per capita terms, and price indices to obtain constant 2000 values.

Our measure for the incremental exit opportunity is the existence of a stock market targeted at entrepreneurial companies, since several European countries opened such trading segments within their stock markets during the 1990s (Bottazzi and Da Rin (2002b)). For all European 'New' stock markets we obtain the date of opening from the respective stock exchanges.

We then introduce two new variables to this literature: a panel of capital gains tax rates and a panel of measures of barriers to entrepreneurship.

We obtain our measures of capital gains taxation from the *Worldwide Corporate Tax Guide*, published by Ernst&Young, a leading tax consulting firm. Each year, the *Guide* reports for over 140 countries the main corporate tax rates, including capital gains. Country information is compiled by Ernst&Young local offices, which ensures high professional standards and consistency, both over time and across countries.

Barriers to entrepreneurship might affect innovation ratios if early stage and high-tech investments are particularly sensitive to bureaucratic impediments. We collect our measures of barriers to entrepreneurship from yearly issues of the *World Competitiveness Yearbook* compiled by IMD, the business school, since 1989. The *Yearbook* provides 241 country-level quantitative and qualitative measures of competitiveness assembled from public data and surveys of local business leaders in 60 countries.

From the *Yearbook* we obtain seven measures of potential barriers to entrepreneurship. These are the following: (1) the extent to which anti-trust laws prevent unfair competition; (2) the extent to which bureaucracy hinders business development; (3) the extent to which improper business practices (e.g., corruption) prevail in the public sphere; (4) the extent to which access to foreign capital markets is restricted for domestic companies; (5) the flexibility of hiring and firing practices; (6) the extent to which immigration laws prevent the employment of foreign skills; and (7) the extent to which foreign investors are free to acquire control of a domestic company. All measures are normalized to lie between 0 and 10, with a higher value corresponding to a weaker barrier. We use both the individual measures and their unweighted average.

To measure the arrival of entrepreneurial opportunities, we use the amount of public R&D expenditure. From the OECD Main Science and Technology Indicators database we obtain data on country-level total research and development (R&D) expenditure, business and government R&D, and R&D in higher-education. In the Appendix we describe the

[9] Note that while funds invested are recorded according to which countries they go into (the 'country of destination' criterion), funds raised are recorded by the country where the venture firm is based (the 'country of management criterion,' see EVCA (2001)). Baygan and Freudenberg (2000) discuss the importance of cross-border capital flows, which in Europe—while increasing over time—remains relatively small.

perpetual inventory methodology we use to derive from these data the stock of public R&D for each country and year.

The following are formal definitions for all the variables we use in the analysis:

- PRIVATE EQUITY (PE_{it}) is the amount of funds invested in private equity in country i at year t. It includes both venture capital and non-venture private equity investments.

- VENTURE CAPITAL (VC_{it}) is the amount of funds invested in venture private equity in country i at year t.

- EARLY STAGE (ES_{it}) is the amount of funds invested in early stage venture private equity in country i at year t.

- HIGH-TECH (HT_{it}) is the amount of funds invested in high-tech private equity in country i at year t.

- ES-RATIO (ESR_{it})is the ratio of ES_{it} to VC_{it}.

- HT-RATIO (HTR_{it})is the ratio of HT_{it} to PE_{it}.

- SUPPLY OF FUNDS (SF_{it}) is the amount of funds raised by the private equity industry in country i in year t. It is normalized by the country's population in year t.

- NEW MARKET (NM_{it}) is a dummy that takes value 1 if a 'New Market' is available for firms to list in country i at year t.

- CAPITAL GAINS TAX RATE (CGT_{it}) is the capital gains tax rate in country i at year t.

- BARRIERS ($BARR_{it}$) is the value of our synthetic measure of the barriers to entrepreneurship in country i at year t.

- BARRIER ($BARR\text{–}J_{it}$) is the value of each measure of the barriers to entrepreneurship in country i at year t, where J=AT (anti-trust laws), BUR (bureaucracy), COR (corruption and improper business practices), FCM (access to foreign capital markets), HF (flexibility of hiring and firing practices), IMM (immigration laws), FAQ (feasibility of foreign acquisitions)

- PUBLIC R&D STOCK (RD_{it}) is the stock of public and academic expenditure in R&D in country i in year t. It is normalized by the country's population in year t. In the Appendix we describe the methodology we use to build RD_{it}.

4.2 Empirical strategy

The innovation ratios form the cornerstone of our analysis. The first reason for this is that we are interested not in the size of venture capital markets *per se*, but in the extent to which increasing the size of venture capital markets translates proportionately more into early stage and high-tech investments. The ratios capture precisely this effect.

There are also methodological reasons for our emphasis on ratios. As it is well known (see Hellmann (1998)) estimating a structural model of demand and supply is made very problematic by both the unobservability of the rate of return on venture capital investments and the difficulty to convincingly identify observable variables which affect only demand or only supply. For this reason most previous studies chose to estimate reduced form equations where the level of venture capital investment is regressed against a set of (typically time invariant) observable factors which in general are expected to affect both supply and demand. This estimation strategy, however, is likely to suffer from serious omitted variable problems.

Our panel estimation methodology allows us to disregard country-specific and time-invariant factors. However, it does not protect us from the effects of unobservable time-varying factors. Since our panel is relatively long (fourteen years), and contains a period when several economic reforms have been implemented, we run the risk that some time varying policy variables which affect the level of venture capital investing—like general reforms in product or factor markets—may have changed considerably. Our focus on ratios minimizes this mispecification risk, since it allows to omit time-varying country-specific explanatory variables to the extent that they equally affect the numerator and the denominator of the innovation ratios.

More generally our approach exploits the time-series dimension ('within' estimates) of our data, and asks which genuinely time-varying factors are responsible for the evolution of the innovation ratios, and thus for the development of active venture capital markets. We then use country fixed effects to identify time-invariant factors such as the industrial specialization of individual countries.

Our model suggests that an increase in the innovation ratios could be achieved in two ways. First, by increasing projects' expected return, and second, if there is no excess supply of monitoring capital, by channeling more funds towards the private equity industry. We address the empirical relevance of these two channels by estimating several versions of the following panel data equation:

$$y_{it} = \mathbf{x}_{it}^{'}\beta + y^{'}\mathbf{d}_t + \varepsilon_{it} \tag{7}$$

$$\varepsilon_{it} = \eta_i + \nu_{it} \tag{8}$$

where y_{it} denotes either the early stage or the high-tech ratio, and $\mathbf{x}_{it}$ is a vector of time varying country specific characteristics including the supply of funds (SF_{it}), the level of the capital gains tax rate (CGT_{it}), the barriers to entrepreneurship ($BARR_{it}$ and $BARR\text{-}J_{it}$), the availability of a 'New' stock market (NM_{it}), and the stock of public R&D (RD_{it}). As discussed in Sections 3.2 and 3.3, the first variable is expected to be positively signed only if there is no excess supply of informed capital; the other four variables should affect our ratios through projects' expected return—the second negatively and the last three positively. To control for common aggregate effects we also include a full set of time dummies, where $\mathbf{d}_t$ is a $T \times 1$ vector with 1 in the t-th position and 0 otherwise. Finally, we model the error term, ε_{it} as the sum of an individual country's heterogeneity component, η_i and an idiosyncratic error term, ν_{it}.

We recover estimates of the parameters of interest by applying the so-called within-group estimator. This estimation method allows individual (country) heterogeneity to be correlated with the observable components of the model. As we have noticed, this is particularly important in our case since there are country specific time invariant unobservable variables that are potentially correlated with some of the regressors. On the other hand, the identification of structural effects through regression coefficients in deviations from country-specific means depends on the lack of correlation between the regressors and the idiosyncratic error term at all leads and lags. This strict exogeneity assumption rules out the possibility that current values of some of the variables in the $\mathbf{x}$ vector are influenced by past idiosyncratic errors.

In our context, this does not seem an unrealistic assumption, since a transitory shock to the innovation ratios is unlikely to affect present and future institutional decisions on capital gains taxation, on public R&D expenditures, on the regulation of business activity, or on the opening of a local 'New' stock market.[10] Notice also that, in order to respect the requirement of strict exogeneity of the regressors, we normalize RD_{it} and SF_{it} by population and not by GDP, which is the measure of country size typically used in the literature. Finally, the strict exogeneity requirement is also the reason why we employ public R&D rather than business (or total) R&D expenditure.

4.3 Descriptive statistics

We start exploring our data by looking at the facts which motivate our analysis. Table 1 shows descriptive statistics for our main variables. It should be noted that less than a quarter of venture capital investment goes to early stage projects, and less than a third of the total private equity investment is in high-tech projects.

Two Figures look at the evolution over time for the aggregate of the 14 countries we consider. Figure 3 plots the two private equity ratios, and Figure 4 the total supply of funds into private equity. What stands out is the sharp upturn in the supply of funds starting in 1996 and its equally sharp fall since 2001, which is mirrored in the sharp drop in all the two private equity ratios. At first sight, this evidence suggests that the supply of funds may in fact pose a binding constraint on investment.

For each country, Figure 5 then reports 3-year moving averages of the innovations ratios, which provide further evidence of the pattern shown by Figure 3. For both innovation ratios, we notice some variability across countries. While such cross-country variability

[10] In particular, the creation of 'New' stock markets started in 1997 and was completed by 1999 in most countries. As our descriptive statistics below make clear, this should dispel concerns for endogeneity, since the opening of these markets predates the increase in supply of venture capital which took place starting from 1998.

naturally asks for an explanation, this would require suitable data to identify the determinants of variations between countries. Given the difficulty to identify, and even more obtain, such variables, we prefer to explore the time dimension of the data and control for country-specific factors by using time-invariant country-level effects.

Overall, these Figures provide evidence of a positive relationship over time between the supply of private equity funds and the early stage and high-tech ratios. Whether this visual evidence can be given a structural interpretation is a task we pick up in our regressions.

5 Regression results

5.1 Main results

Results from the estimation of our basic specification for equation (7) are presented in Tables 2 and 3. Each Table refers to a specific ratio, and reports estimated coefficients together with the corresponding standard errors. In each Table three sets of estimates are reported which include one of our three chosen measures of the barriers to entrepreneurship. We first use our summary measure (the average value of our seven measures). We then run the basic specification with each measure in turn, but we report only the two which turns out to be significant.

Notice that, since (unreported) time dummies are included in all equations, our estimates genuinely pick the effects of changes in our explanatory variables. For example, the effects of the availability of a 'New' stock market targeted at entrepreneurial companies are captured beyond what one might fear is a common cyclical trend.

Our main results can be summarized as follow. We find convincing evidence that three types of policy have an important effect on the innovation ratios: the opening of 'New' stock markets, the taxation of capital gains, and the reduction of barriers to entrepreneurship. First, the coefficients of the capital gains tax have a negative effect on the ratios which is highly statistically significant in all specifications. The economic effect is however small: moving the capital gains tax rate from the lower tail (5th percentile) to its higher tail (95th percentile) raises the high-tech ratio by about 0.003 (or 1%) and the early stage ratio by about 0.001 (or 0.5%).

The intuition behind this result is that an increase in the rate of return on venture investment (R_{vc}) makes it possible for companies with high collateral to obtain finance from uninformed investors. thus freeing up venture capital (monitored) funds for early stage and high-tech companies. This result corroborates that by Gompers and Lerner (1998), who looked at U.S. data. However, their finding was based on a panel of U.S. state-level data, where the variation in capital gains tax rates is very small; therefore they mainly relied on a short time-series of federal-level variations in capital gains taxation. Our data provide a more comforting setting for a panel analysis.

Second, we also find the opening of a 'New' market to have a positive and significant effect on both the early stage and the high-tech ratios. The economic effect in this case is also noticeable, as the opening of a 'New' market raises the high-tech ratio by about 10% and the early stage ratio by nearly 9%. This is consistent with the model's predictions if

IPOs provide larger capital gains than acquisitions or a 'trade sales'—a fact documented by Brau, Francis and Kohers (2002) and Gompers and Lerner (1997).

It also suggests a more sobering approach to the critiques of the recent experience of the 'New' stock markets, which often focus on the issue of losses to individual investors. Our results provide a different perspective.

Third, the average indicator of reduction of the barriers to entrepreneurship turns out to be positive but not statistically significant at conventional levels. However, the reduction of two of the barriers have a positive and significant effect on the high-tech ratio. This effect is also economically very large. Moving either the hiring and firing or the immigration laws measure from their 5th to its 95th percentile raises the high-tech ratio by between 0.190 and 0.240 (or 65% to 80%). This result is particularly telling, since it is arguable that lower barriers to the hiring of foreign skills are particularly important for high-technology companies. Also the reduction in hiring and firing barriers is likely to be relevant for these companies. Notice that the early stage ratio is unaffected by these policy measures. Our interpretation is that early stage companies are less dependent on skilled workers than high-tech ones, and that they are likely—almost by definition—to have a low level of employment, and so be exempt from many hiring and firing restrictions.Notice also that many high-tech companies in our sample are not early stage, and many early stage companies are not high-tech—dispelling the seeming contradiction of the results on the effects of the barriers to entrepreneurship on the two innovation ratios.

Fourth, in all reported equations the supply of funds variables are never statistically different from zero. This holds for both innovation ratios; it is also robust to several alternative definitions and time/country stability assumptions, which we describe in the next section. Therefore we do not find evidence supporting the 'no excess supply' of venture capital hypothesis in Europe during our sample period.

Finally, the stock of public R&D capital is also found to have a negligible, statistically insignificant, effect on the innovation ratios.[11] This suggests that increasing public R&D does not result in a higher return of entrepreneurial ventures.

5.2 Extentions and robustness checks

In this Section we extend our results, especially by delving more deeply into the lack of evidence for a role of the supply of funds, and address several methodological concerns. First of all, we explore different definitions of the supply of funds, and report our main extensions in Tables 4 and 5. Columns *(i)*, *(iv)*, and *(vii)* of both Tables take care of the well known fact that the funds raised by venture capital companies in one particular year are not necessarily invested in the same year (Gompers and Lerner(2000)). This may suggest that our baseline static model suffers from a dynamic misspecification problem. To address this additional concern we rerun all our equations after including the once lagged variable, SF_{it-1} to the original specification. While we lose some observations due to the use of a lagged variable, this does not alter significantly our overall results.

[11] As a check on the robustness of this result, we also use the stock of total R&D, which includes private (business) R&D, despite the fact that it clearly fails the strict exogeneity requirement.

A second extension is suggested by the fact that the 'bubble years' of the late 1990s might affect the significance of the effect of the supply of funds. Our results in Tables 1 and 2 might therefore suffer from pooling together two different regimes. Columns *(ii)*, *(v)*, and *(viii)* of Tables 3 and 4 report our results, where we identify the 'bubble' years with 1997 through 2000. We find no evidence of a different role of the supply of funds in the two periods.

Another possibility we wish to examine is that different countries may experience a different effect of the supply of funds depending on their stage of development. Arguably, countries where venture capital markets are less developed may also experience a lack of professional expertise which might have an adverse effect on the innovation ratios. Columns *(iii)*, *(vi)*, and *(ix)* of Tables 3 and 4 report our results on this issue. What we do here is to allow for a different effect of the supply of funds depending on the fact that a particular venture capital market is 'developed' or not—where we define 'developed' to be a country with a (per capita) supply of funds higher than the median at the start of our panel (1988).[12] With these equations we want to explore the possibility that evidence in favour of the 'no excess supply' of venture capital hypothesis is more likely to be found in countries with a less mature venture capital industry. One readily sees that this extension has no material effect on our estimates.[13]

We then turn to several possible methodological concerns, for which we estimate, but do not report, additional variations of our basic specification.

First, our findings might not be robust to alternative definitions for some of the innovation ratios. In particular, it might be argued that the replacement capital component should be excluded from the pure venture capital activity. This, in turn, would alter the denominator of the early stage to venture capital ratio, ESR. To address this legitimate concern we rerun all our reported equations after redefining the relevant ratios. Our findings are virtually unaltered. We also check the robustness of our results when the supply of funds variable include realized capital gains, and find comforting evidence.

The same occurs if we disaggregate the effects of different sources of funds to single out the funds supplied by institutional investors and by the government.[14] It can be argued that these two categories may have different goals than other investors, and therefore instruct venture fund managers to comply with different objectives (see Mayers, Schoors, and Yafeh (2002)). In particular, institutional investors have a longer run perspective than others, and the government may also be more interested in the creation of long-run growth opportunities than the sheer maximization of profits. However, when we separate these two categories from the total supply of funds, we do not find any significant changes, and the significance of these two new variables is far from any acceptable level.

An important assumption in our analysis so far has been that the presence of a New

[12] The countries which turn out to have a relatively less mature venture capital equity industry (in 1988) are Austria, Belgium, Finland, Germany, Greece, Italy, Portugal and Spain.

[13] In unreported regressions, we also check that this results does not change if we allow a country to switch between 'developed' and 'not developed' each year.

[14] The EVCA data breaks the sources of funds into the following categories: realized capital gains, corporations, individuals, government agencies, banks, pension funds, insurance companies, funds of funds, academic institutions, capital markets.

stock market is by itself sufficient to affect the innovation ratios—i.e., that investors are always willing to buy shares of companies which go public. However, it is well know that the markets for Initial Public Offerings (IPOs) experience cycles which bring them over waves of 'hot' or 'cold' investor appetite. In other words, the availability of an institution may by itself not be enough. To explore this possibility we introduce in the analysis a panel of stock market indices. For each country, we obtain from Datastream the yearly average of the MSCI (Morgan Stanley Capital International) stock market index for the main stock market. We take the MSCI index to be a measure of investors' appetite for stocks. Notice that we employ the MSCI index for the main market rather than for any 'New' market—or the number of IPOs in the current or previous year—in order to abide by the strict exogeneity condition. We then estimate a set of equations where we include the MSCI index as an explanatory variable. We introduce this variable both with an additive and a multiplicative term. In either case, it turns out that this variable is not significant, and in particular that it does not affect the magnitude or significance of the coefficient for the New markets.

We also explore in our context the result of Gompers and Lerner (1998) on the role of pension funds. They show that the clarification of the 'prudent man rule' in the context of the Employment Retirement Income Security Act brought to a surge of pension fund investments in venture capital. To date, pension funds remain the largest single source of venture capital in the U.S. (NVCA (2003)). Several countries in Europe began reforming the structure of their social security system from pay-as-you-go to funded in the 1990s. As a consequence, the financial assets of pension funds have increased. This may have a substantial impact on the funding of venture capital, if pension funds are allowed to invest in it. In EU member states the dominant principle governing asset allocation of pension funds is the prudent man rule. Thus these institutions are allowed to invest in venture capital, as long as adequate diversification is maintained. Member states are allowed to impose quantitative limits to investments and several do regulate portfolio shares allocated to closed funds. We then isolate the supply of venture capital which comes from pension funds. We find no evidence of a distinct role of pension funds in our data.

An important concern is that the real bottleneck is not money but people. Michelacci and Suarez (2004) do stress the human factor in financial intermediation, whose empirical importance is documented in Bottazzi, Da Rin, and Hellmann (2004). To address this issue, we construct a variable consisting, for each country and year, of the number of venture capital firms which are members of the European Venture Capital Association. We then use this variable in alternative to the supply of funds. The resulting estimates confirm our main results by not showing any sign of a shortage.

One specific concern can be raised in relation to the Early Stage Ratio. It is well known that venture-backed companies typically receive staged financing (Gompers (1995)). This means that the company will receive funds over several rounds across a few years. Since the company would then progressively mature from the seed or start-up stages to later stage deals there is clear suspicion that the figures for late stage financing simply reflect 'life-cycle' effects and not investment decisions by the venture capitalists. We can control for this important observation by including in our regressions for the ES Ratio the lagged value of the absolute amount of early stage investments. We are comforted by noticing that our results are unchanged.

Finally, one could be concerned that our results are driven by a single country. We can easily discard this possibility by re-running our regressions excluding one country at a time. Overall, therefore, our results appear to be consistently robust to a variety of checks.

6 Conclusion

In this paper we use a panel data analysis to study how public policy can contribute to the creation of active venture capital markets. We base our analysis on a simple extension of the seminal model of Holstron and Tirole (1997), which allows us to formalize the notion of 'innovation ratios' and explore the possibility of excess supply of venture capital. The results we obtain from a panel of European country-level data over 1988-2001 provide new insights on the effects of alternative policies.

The prevailing policy approach does not receive support from the data. Our results cast more than a passing doubt on the attempt to increase the share of early stage and high-tech venture investments by channeling more funds into venture capital markets, consistent with a 'money chasing deals' situation (Gompers and Lerner (2000)).

Rather, we find that policies aimed at increasing the expected return of projects are more succeful in altering the composition of venture capital markets towards projects with less collateral, namely early stage projects and projects in high-tech industries. The availability of stock markets targeted at entrepreneurial companies—which provide a lucrative exit channel—and a decrease in capital gains taxation both raise the share of early stage and high-tech investments. Interestingly, we find that a reduction in some barriers to entrepreneurship leads to a large increase in the high-tech ratio. By contrast, the stock of public R&D holds no effect on the innovation ratios.

These results also suggest a novel interpretation of the 'European Paradox' (European Commission (1994))—the fact that Europe suffers from an inability to turn scientific competence into successful ventures. In the light of our findings, the Paradox seems to be due not to a lack of funding or of attractive technological opportunities, but rather to the barriers to create new companies and make large profits from them, consistent with recent models of entrepreneurship (e.g., Gromb and Scharfstein (2002)).

Our findings also have implications for policy-makers in countries with emerging venture capital markets, where the impact of policy early in their development might be particularly important. Even if they reflect the European experience, we believe our results have a clear message: sensible policy should consider a wider set of policies than simply channeling more funds into venture capital.

While we cannot offer a conclusive cost-benefit analysis of alternative policies, we hope our study of the benefits of a comprehensive set of them may nonetheless offer a valuable contribution to policy evaluation.

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Appendix

Proof of Proposition 1

(i) Holmstron and Tirole (1997) show that $\underline{A}$ increases when K_{vc} contracts (and viceversa). Since γ is exogenous, then $\overline{A}$ is unaltered and both total venture capital investment, D_{vc}, and the innovation ratios unambiguously fall.

(ii) Holmstron and Tirole (1997) show that less capitalized firms are squeezed out when R falls. Since K_{vc} is constant and fully invested in monitoring projects, total venture investment is unaffected; since $A^* - \underline{A}$ decreases, the innovation ratios fall.

Proof of Proposition 2 :

(i) A decrease in K_{vc}—such that the excess supply of overall funds persists—causes an adjustment in S at $\gamma = \gamma_0$ so as to counterbalance the fall in private equity funds invested as uninformed capital and satisfy the market clearing condition: $\int_{\underline{A}(\gamma_0)}^{\infty}[I-A]dG(A)-K_{vc} = S(\gamma_0)$.

Thus γ is unchanged, implying that $\underline{\beta}$ is unaffected, total demand for funds and its components are unchanged and ΔK_{vc} is fully invested as uninformed capital.

(ii) A fall in project return R reduces aggregate investment, due to an increase in $\underline{A}(R,\gamma)$ given γ. Its value can be found by substituting the expression for $\underline{\beta}$ into equation (7): $\underline{A}(\gamma) \equiv \underline{A}(\gamma,\underline{\beta}) = I - \frac{c}{p_H - p_L} - (\frac{p_H}{\gamma})[R - \frac{b+c}{p_H-p_L}]$. Moreover, $\overline{A(R,\gamma)}$ increases by the same amount as $\underline{A}(R,\gamma)$, so that venture capital investment is unaffected. Since this implies that $A^* - \underline{A}$ decreases, the innovation ratios unambiguously fall.

Construction of the R&D Capital Stock

The public R&D capital stock (RD_{it}) (measured at the end of period t) in real terms is computed by a perpetual inventory method with a constant rate of depreciation ($\delta = 0.15$). The values of R&D public expenditure in local currency at current prices (R_{it}) are available for each country from 1981 onward from OECD Basic Science and Technology Statistics database. We deflate these data by using a country specific R&D deflator (P_{it}). The benchmark for the first year used in estimation (RD_{i87}) is then calculated by summing up the real expenditures from 1981 to 1987 appropriately depreciated:

$$RD_{i87} = \sum_{t=1981}^{1987} (\frac{R_{it}}{P_{it}})(1-\delta)^{1987-t} \tag{A1}$$

For subsequent years, the standard accumulation equation has been used:

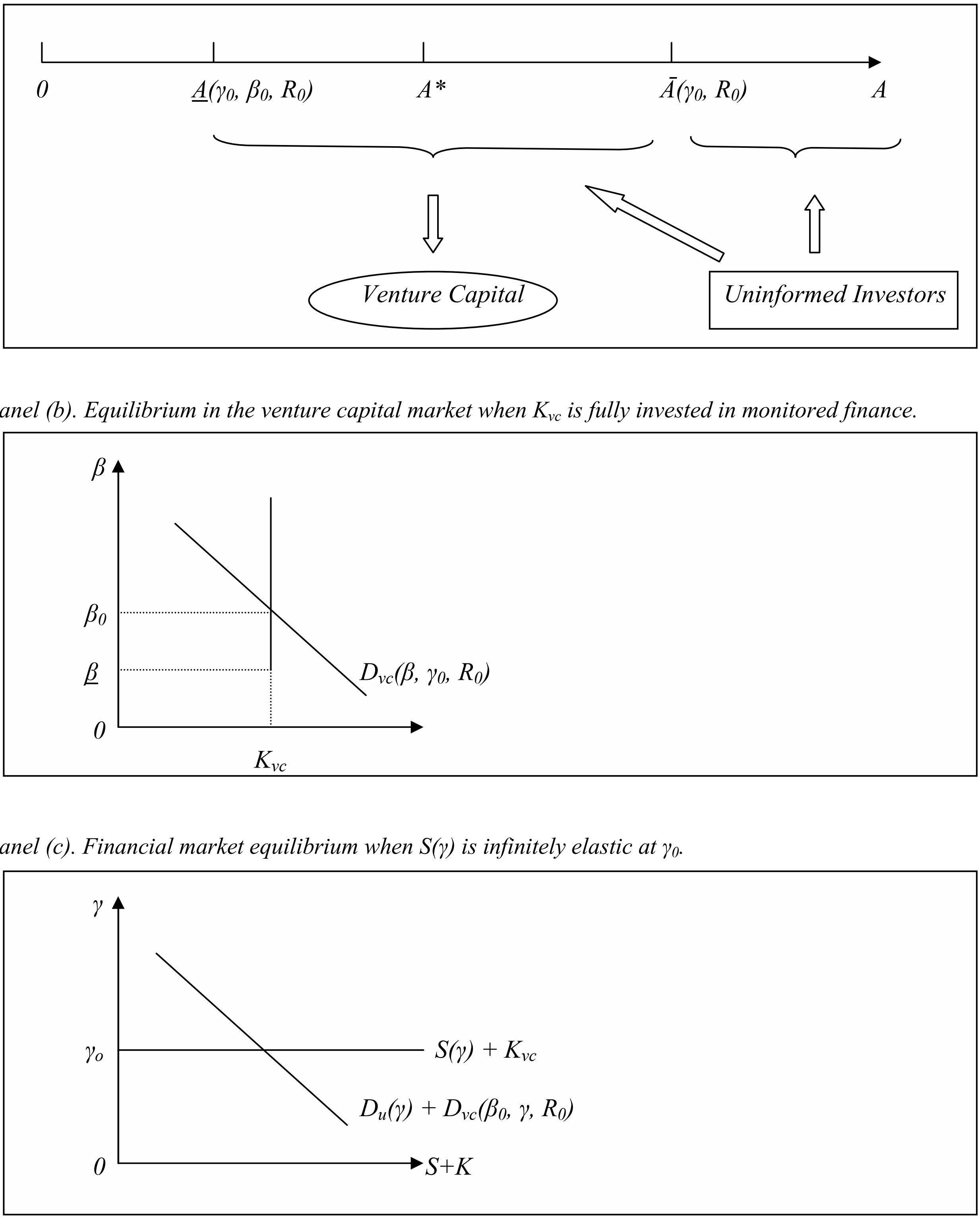
$$RD_{it} = (1-\delta)RD_{it-1} + \frac{R_{it}}{P_{it}}, t = 1988, ..., 2001 \tag{A2}$$

Finally, real R&D capital stock data have been made comparable across countries by applying the 2000 exchange rate with the euro.

Figure 1

This figure shows the equilibrium in financial markets when the supply of funds to venture capital is fully invested in monitored finance. A represents firm equity capital, γ is the rate of return to uninformed financing, β is the rate of return to venture capital, R is the return on investments, D_{vc} and K_{vc} are the demand and supply of venture capital, S is the supply of uninformed capital.

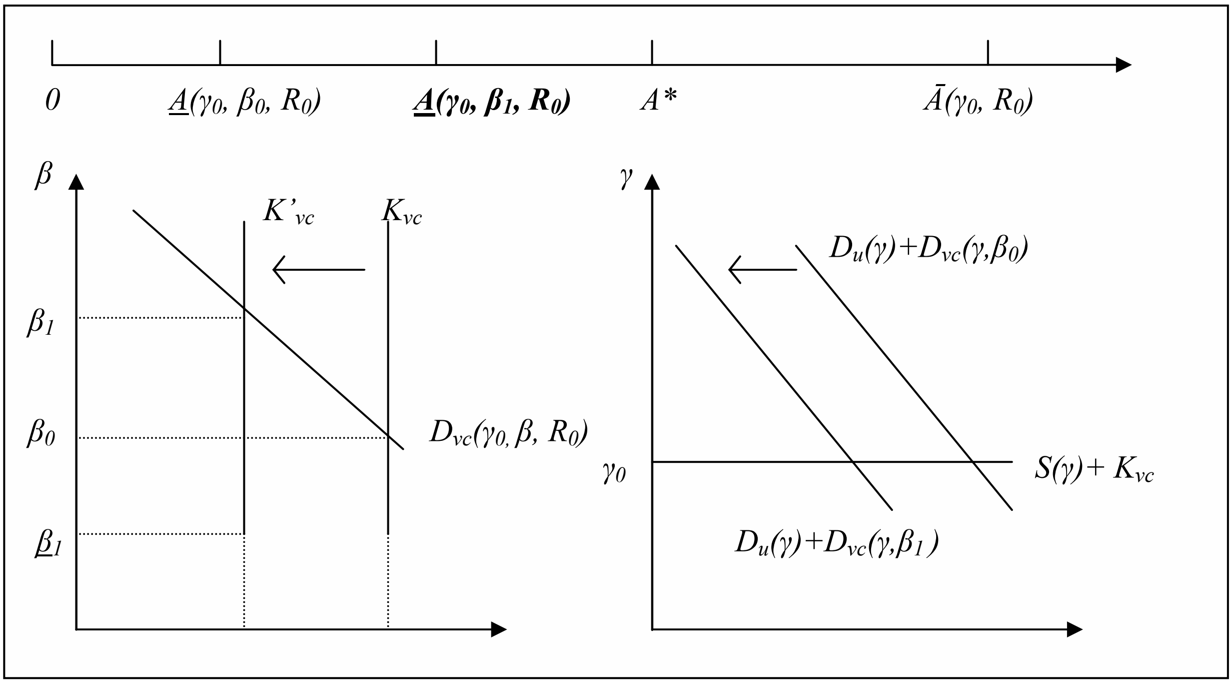
Panel (a). Firms' financing choice as a function of their equity capital, A.



Panel (b). Equilibrium in the venture capital market when K_{vc} is fully invested in monitored finance.

Panel (c). Financial market equilibrium when $S(\gamma)$ is infinitely elastic at γ_0.

Panel (d). A reduction in K_{vc} is associated with an increase in β and a reduction in aggregate investment. Moreover the innovation ratios fall because $\underline{A}$ increases with constant $\bar{A}$. This brings about a reduction in the innovation ratios.



Panel (e). A reduction in R causes an increase in both $\underline{A}$ and $\bar{A}$, a reduction in β_1 and an associated reduction in the innovation ratio.

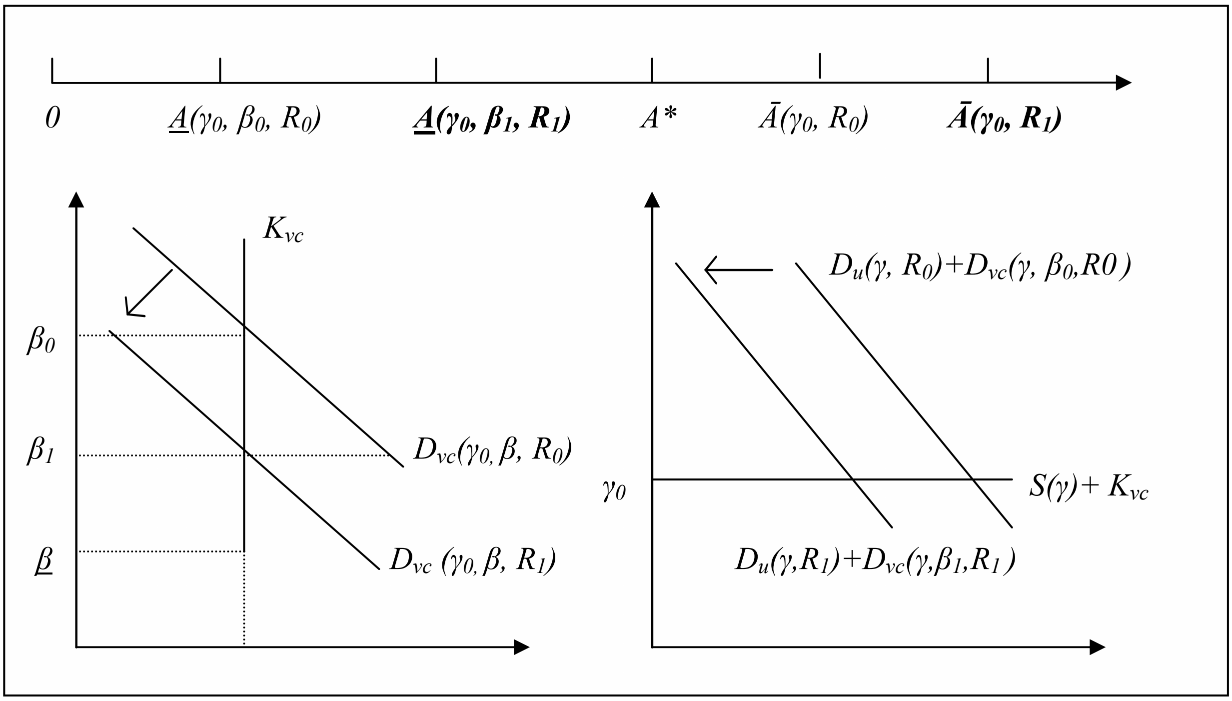
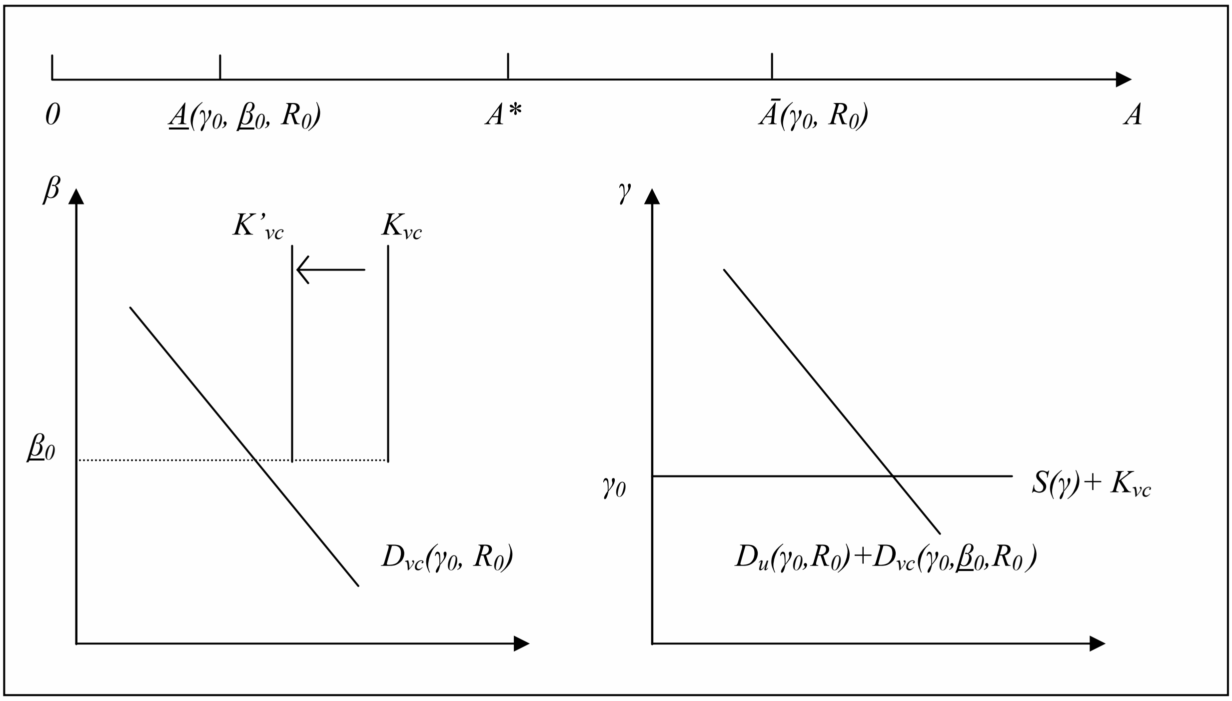


Figure 2

This figure show the equilibrium in financial markets when there is an excess supply of venture capital funds.

Panel (a). When K_{vc} falls and the excess supply persists, the allocation of venture capital funds, and therefore the innovation ratios, remain unchanged.



Panel (b). Effects of a reduction in R.

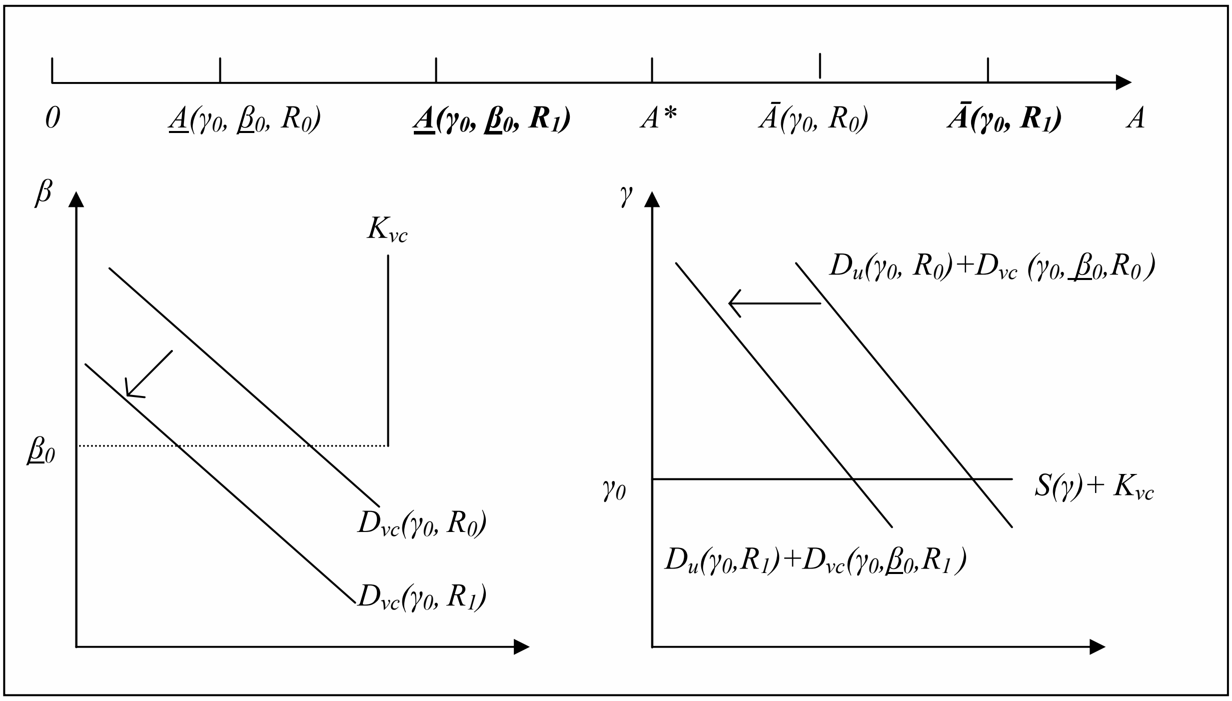


Figure 3: Innovation ratios over time

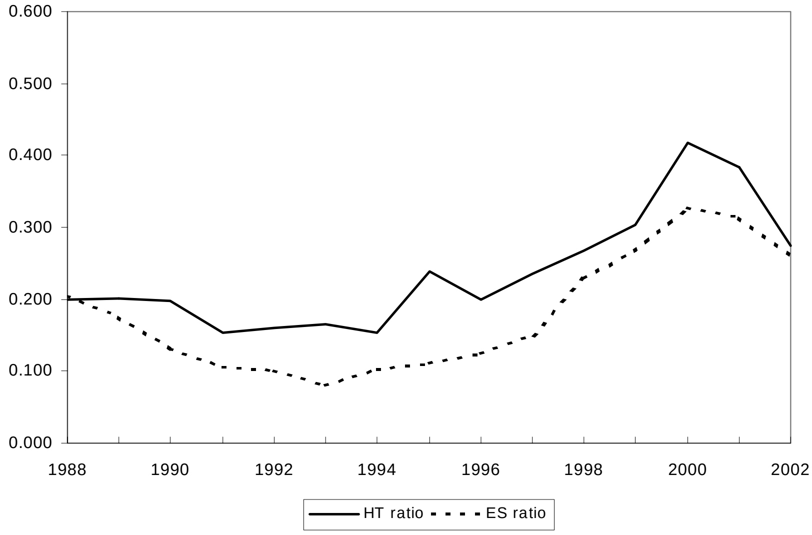
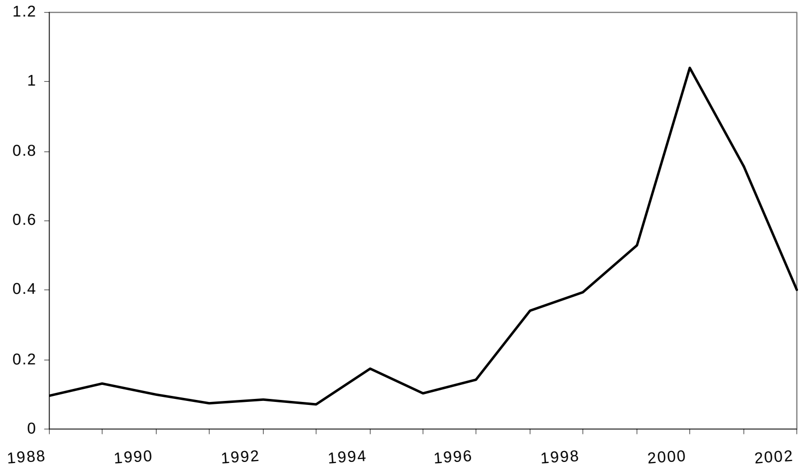
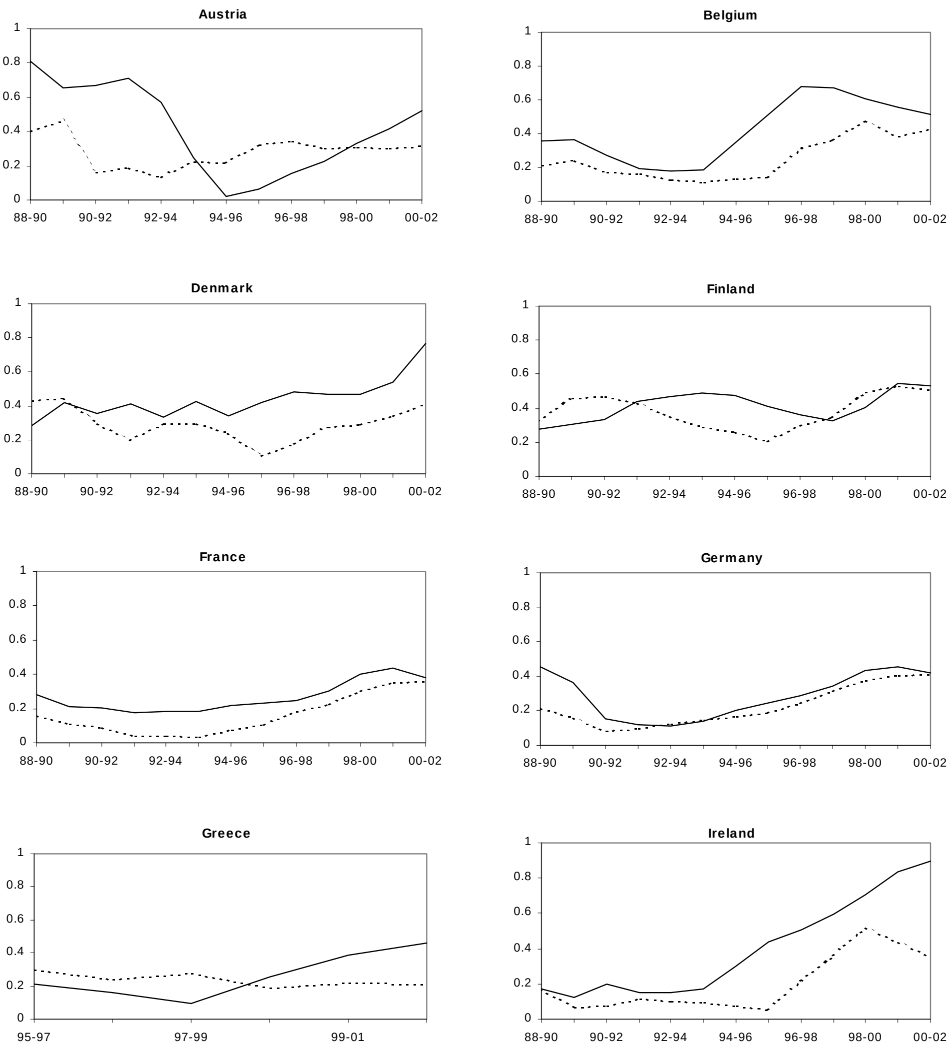


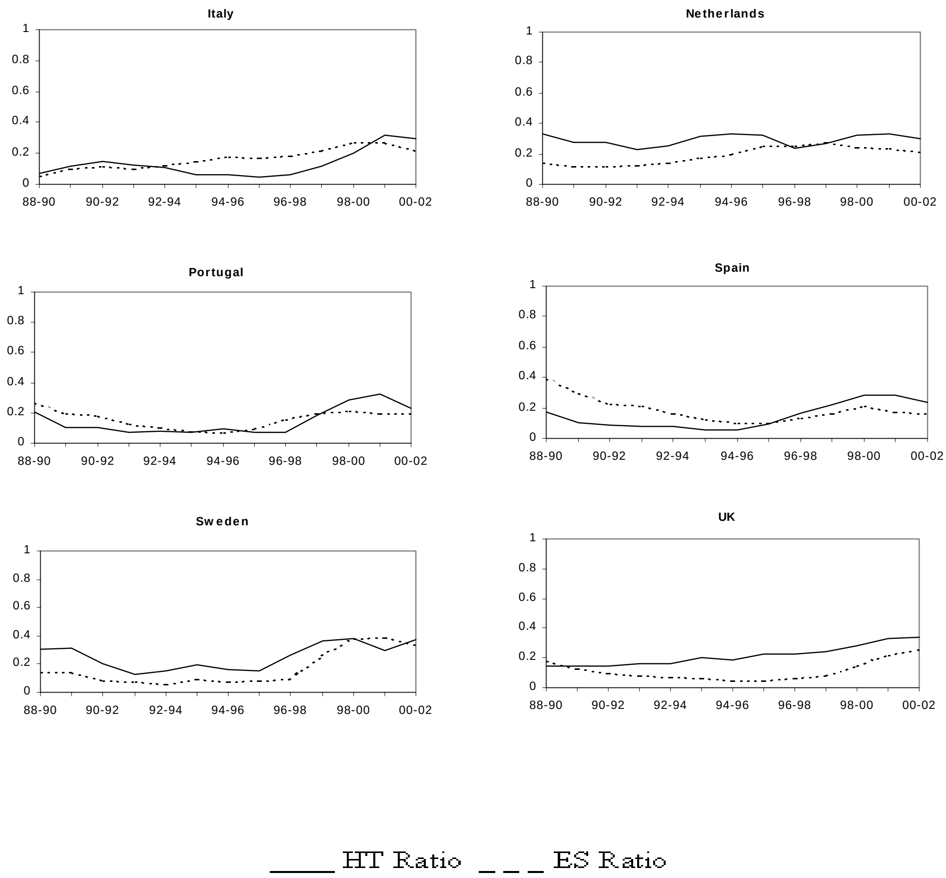
Figure 4: Supply of funds over time



Note: All Ratios are computed for the aggregate of the 14 countries we consider. The ES Ratio is defined as the ratio of ES_t *to* VC_t*. The HT Ratio is defined as the ratio of* HT_t *to* PE_t*. The Supply of Funds is the amount of funds raised by the European private equity industry. It is normalized by the European population.*

Figure 5: Innovation ratios over time by country





Note: For each country, the ES Ratio is defined as the ratio of ES_{it} *to* VC_{it}*, and the HT Ratio is defined as the ratio of* HT_{it} *to* PE_{it}*. The figure shows three-year moving averages for each ratio.*

Table 1: Aggregate descriptive statistics

	Mean	Std. Dev.	Median	5th Perc.	95th Perc.	*Obs*
High-tech ratio	0.294	0.205	0.249	0.049	0.686	*187*
Early stage ratio	0.218	0.151	0.187	0.036	0.515	*187*
Capital Gain Tax Rate	0.348	0.060	0.350	0.250	0.450	*187*
Public R&D stock	17.720	12.131	18.191	2.256	37.210	*187*
Supply of Funds	0.296	0.638	0.093	0.002	1.162	*187*
New Market dummy	0.257	–	–	–	–	*187*
Barriers to Entrepreneurship	6.299	0.976	6.353	4.657	7.940	*187*

Note: High-tech ratio is the ratio of high-tech to total private equity investments. Early stage ratio is the ratio of early stage to total venture investments. The Capital Gain Tax Rate is the rate applied to short term capital gains. Public R&D Stock is the stock of public expenditure in research and development per inhabitant, as defined in the Appendix. Supply of Funds is the per capita supply of funds, measured in millions of year 2000 euros. The New Market dummy equals one for all country-years for which a 'new market' is open for companies to list; for this variable the Mean column reports the frequency. The measure of Barriers to entrepreneurship is computed as an unweighted average of seven competitiveness indicators reported in the 1989-2002 editions of the World Competitiveness Yearbook (1: Competition law is efficient in preventing unfair competition, 2: Bureaucracy does not hinder business development, 3: Improper practices such as bribing or corruption do not prevail in the public sphere, 4: Access to foreign capital markets is not restricted for domestic companies, 5: Hiring and firing practises are flexible enough, 6: Immigration laws do not prevent companies from employing foreign skills, 7: Foreign investors are free to acquire control in a domestic company). Each indicator varies from 0 (very high barrier) to 10 (very low barrier).

Table 2: Estimated Equations for the HT–RATIO (HTR_{it})

	(i)	*(ii)*	*(iii)*
NM_{it}	0.104**	0.098**	0.102**
	(0.046)	(0.045)	(0.045)
CGT_{it}	–0.014***	–0.013***	–0.016***
	(0.003)	(0.003)	(0.003)
RD_{it}	–0.001	0.001	0.001
	(0.006)	(0.006)	(0.006)
SF_{it}	–0.011	–0.013	–0.021
	(0.028)	(0.027)	(0.027)
$BARR_{it}$	0.048		
	(0.036)		
$BARR-HF_{it}$		0.044**	
		(0.019)	
$BARR-IMM_{it}$			0.055**
			(0.022)
Time dummies included	Yes	Yes	Yes
F-test on regressors	[0.00]	[0.00]	[0.00]
F-test on time dummies	[0.03]	[0.09]	[0.01]
F-test on individual effects	[0.00]	[0.00]	[0.00]
Number of observations	187	187	187

*Note: CGT_{it} denotes the capital gain tax rate in country i at time t. NM_{it} is a dummy variable which takes value 1 if a 'New Market' is available for firms to list in country i at time t and zero otherwise. RD_{it} is the per capita stock of public R&D expenditure in country i at time t, measured in millions of 2000 euros. SF_{it} is the per capita supply of funds in country i and time t net of capital gains, measured in millions of 2000 euros. $BARR_{it}$ is a barrier indicator computed as an unweighted average of seven indicators, $BARR-HF_{it}$ is the barrier indicator which measures hiring and firing restrictions, $BARR-IMM_{it}$ is the barrier indicator which measures immigration law. Time dummies included in all equations. Standard errors (probability levels) in round (squared) brackets. *, **, and *** denote 0.10, 0.05, and 0.01 significance levels.*

Table 3: Estimated Equations for the ES–RATIO (ESR_{it})

	(i)	*(ii)*	*(iii)*
NM_{it}	0.088**	0.092**	0.091**
	(0.035)	(0.035)	(0.036)
CGT_{it}	–0.005**	–0.006***	–0.006**
	(0.002)	(0.002)	(0.003)
RD_{it}	0.003	0.003	0.003
	(0.005)	(0.005)	(0.005)
SF_{it}	0.010	0.014	0.016
	(0.022)	(0.021)	(0.021)
$BARR_{it}$	–0.029		
	(0.028)		
$BARR-HF_{it}$		–0.012	
		(0.015)	
$BARR-IMM_{it}$			–0.000
			(0.017)
Time dummies included	Yes	Yes	Yes
F-test on regressors	[0.00]	[0.00]	[0.00]
F-test on time dummies	[0.01]	[0.00]	[0.00]
F-test on individual effects	[0.00]	[0.00]	[0.00]
Number of observations	187	187	187

*Note: CGT_{it} denotes the capital gain tax rate in country i at time t. NM_{it} is a dummy variable which takes value 1 if a 'New Market' is available for firms to list in country i at time t and zero otherwise. RD_{it} is the per capita stock of public R&D expenditure in country i at time t, measured in millions of 2000 euros. SF_{it} is the per capita supply of funds in country i and time t net of capital gains, measured in millions of 2000 euros. $BARR_{it}$ is a barrier indicator computed as an unweighted average of seven indicators, $BARR-HF_{it}$ is the barrier indicator which measures hiring and firing restrictions, $BARR-IMM_{it}$ is the barrier indicator which measures immigration law. Time dummies included in all equations. Standard errors (probability levels) in round (squared) brackets. *, **, and *** denote 0.10, 0.05, and 0.01 significance levels.*

Table 4: Additional Estimated Equations for the HT–RATIO (HTR_{it})

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)
NM_{it}	0.090*	0.106**	0.099**	0.085*	0.101**	0.094**	0.088*	0.104**	0.096**
	(0.046)	(0.046)	(0.046)	(0.045)	(0.046)	(0.045)	(0.046)	(0.046)	(0.045)
CGT_{it}	–0.014***	–0.014***	–0.013***	–0.012***	–0.013***	–0.012***	–0.015***	–0.016***	–0.016***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
RD_{it}	–0.004	–0.001	–0.002	–0.001	0.001	0.001	–0.002	0.001	0.001
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
SF_{it}	–0.013	–0.017	–0.024	–0.011	–0.020	0.024	–0.022	–0.027	–0.034
	(0.039)	(0.034)	(0.030)	(0.038)	(0.032)	(0.029)	(0.038)	(0.032)	(0.028)
SF_{it-1}	0.006			–0.004			0.001		
	(0.048)			(0.048)			(0.048)		
$SF_{it} * B_{it}$		0.014			0.016			0.014	
		(0.041)			(0.040)			(0.040)	
$SF_{it} * D_{it}$			–0.302			–0.241			–0.298
			(0.215)			(0.215)			(0.212)
$BARR_{it}$	0.060	0.047	0.048						
	(0.038)	(0.036)	(0.036)						
$BARR-HF_{it}$				0.044**	0.044**	0.042**			
				(0.019)	(0.019)	(0.019)			
$BARR-IMM_{it}$							0.050**	0.055**	0.055**
							(0.023)	(0.022)	(0.022)
Time dummies included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test on regressors	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
F-test on time dummies	[0.04]	[0.03]	[0.02]	[0.13]	[0.10]	[0.02]	[0.07]	[0.01]	[0.00]
F-test on individual effects	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.00]
Number of observations	171	187	187	171	187	187	171	187	187

Note: CGT_{it} denotes the capital gain tax rate in country i at time t. NM_{it} is a dummy which takes value 1 if a 'New Market' is available for firms to list in country i at time t and zero otherwise. RD_{it} is the per capita stock of public R&D expenditure in country i at time t, measured in millions of 2000 euros. SF_{it} is the per capita supply of funds in country i and time t net of capital gains, measured in millions of 2000 euros. B_{it} is a dummy which takes value 0 in the years between 1997 and 2000, and 1 otherwise. D_{it} is a dummy variable which takes value 0 for those countries where the venture capital industry is perceived as relatively mature and 1 otherwise. $BARR_{it}^{ij}$ is a barrier indicator with j=UA (unweighted average of seven indicators), HF (hiring and firing indicator only), IL (immigration law indicator only). Time dummies included in all equations. Standard errors (probability levels) in round (squared) brackets. *, **, and *** denote 0.10, 0.05, and 0.01 significance levels.

Table 5: Additional Estimated Equations for the ES–RATIO ($\mathbf{ESR}_{it}$)

	(i)	*(ii)*	*(iii)*	*(iv)*	*(v)*	*(vi)*	*(vii)*	*(viii)*	*(ix)*
NM_{it}	0.087***	0.093**	0.088**	0.089***	0.096***	0.091**	0.088***	0.096***	0.091**
	(0.033)	(0.036)	(0.036)	(0.033)	(0.036)	(0.036)	(0.033)	(0.036)	(0.036)
CGT_{it}	–0.008***	–0.005**	–0.005**	–0.008***	–0.006***	–0.006**	–0.008***	–0.006**	–0.006**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
RD_{it}	0.000	0.003	0.003	–0.001	0.003	0.002	0.000	0.003	0.003
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
SF_{it}	0.017	–0.003	0.009	0.019	0.001	0.011	0.021	0.003	0.014
	(0.028)	(0.026)	(0.023)	(0.028)	(0.025)	(0.023)	(0.028)	(0.025)	(0.022)
SF_{it-1}	–0.003			–0.000			–0.001		
	(0.035)			(0.035)			(0.035)		
$SF_{it} * B_{it}$		0.029			0.028			0.028	
		(0.032)			(0.032)			(0.032)	
$SF_{it} * D_{it}$			–0.040			–0.059			–0.041
			(0.168)			(0.169)			(0.168)
$BARR_{it}$	–0.028	–0.030	–0.029						
	(0.027)	(0.028)	(0.028)						
$BARR-HF_{it}$				–0.009	–0.012	–0.013			
				(0.014)	(0.015)	(0.015)			
$BARR-IMM_{it}$							–0.002	–0.001	–0.000
							(0.017)	(0.018)	(0.018)
Time dummies included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test on regressors	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
F-test on time dummies	[0.00]	[0.01]	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.01]
F-test on individual effects	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Number of observations	171	187	187	171	187	187	171	187	187

Note: CGT_{it} denotes the capital gain tax rate in country i at time t. NM_{it} is a dummy which takes value 1 if a 'New Market' is available for firms to list in country i at time t and zero otherwise. RD_{it} is the per capita stock of public R&D expenditure in country i at time t, measured in millions of 2000 euros. SF_{it} is the per capita supply of funds in country i and time t net of capital gains, measured in millions of 2000 euros. B_{it} is a dummy which takes value 0 in the years between 1997 and 2000, and 1 otherwise. D_{it} is a dummy variable which takes value 0 for those countries where the venture capital industry is perceived as relatively mature and 1 otherwise. $BARR_{it}^{ij}$ is a barrier indicator with j=UA (unweighted average of seven indicators), HF (hiring and firing indicator only), IL (immigration law indicator only). Time dummies included in all equations. Standard errors (probability levels) in round (squared) brackets. *, **, and *** denote 0.10, 0.05, and 0.01 significance levels.