EIB Papers • Volume 14 • No2 • 2009

European Investment Bank • European Investment Bank • European Investment Bank • European Investment Bank • European Investment Bank

EIB **Papers**

R&D and the financing of innovation in Europe

Financing innovative firms

Editorial Policy

Editor
Hubert Strauss

Production
Anna Schumacher
EIB Graphic Workshop

The EIB Papers are published each year by the Economic and Financial Studies Division of the European Investment Bank. The journal is divided into two issues and is aimed at encouraging high-quality economic research and debate on matters of European interest. As such the *Papers* are intended to be accessible to non-specialist readers and emphasise policy dimensions rather than technical issues. They present the results of research carried out by Bank staff together with contributions from external scholars and specialists.

Articles will only be accepted for publication on the condition that they have not already been published elsewhere. All articles in the EIB Papers may be freely reproduced and quoted; however, the Editor would appreciate acknowledgement and a copy of the publication in question. They can also be freely accessed and downloaded from our website: www.eib.org/efs/

The views expressed in the articles are those of the individual authors and do not necessarily reflect the position of the EIB.

Volume 14 • No2 • 2009

EIB Papers

R&D and the financing of innovation in Europe

Financing innovative firms

Contents

Preface

Plutarchos Sakellaris
Vice-President

While the role of research and development and innovation in spurring economic growth is well recognized, many aspects of the R&D-innovation-growth nexus and their policy implications remain insufficiently understood. At a very basic level, there is the challenge of measuring how expenditure on R&D and innovation turn into knowledge capital and how knowledge capital affects economic growth. The companion issue (Volume 14, Number 1) to this issue of the *EIB Papers* discussed these questions. In addition, it also covers the possibility that due to knowledge spillovers, firms want to invest less in R&D and innovation than they should from society's perspective, triggering the question of whether and how economic policies can raise firms' expenditure on R&D and innovation.

This issue (Volume 14, Number 2) turns to another dimension of the underinvestment problem, namely the possibility that firms are unable to invest as much in R&D and innovation as they want because of financing constraints. While a possible lack of private finance for R&D and innovation is an ongoing concern, the recent financial crisis gives extra cause for concern – at least temporarily. To be clear, real-world financial markets can never be perfect, and imperfections might impede the financing of investment in general, not only investment in knowledge capital. However, it is reasonable to ask whether finance is more of a problem for investment in R&D and innovation than it is for other types of investment and, if yes, why. Zooming in on the subset of firms investing in R&D and innovation, it is worth examining whether firms are equally affected by financing constraints or whether some firms suffer more than others. For instance, new innovative firms might find it harder to secure finance than established firms. The distinction between "new" and "established" firms is, admittedly, a crude one and finer differentiations need to be made. But to the extent that the scale and scope of financing constraints systematically differ across firms, the type of finance suitable for overcoming such constraints might differ too. Likewise, the type of policy instrument suitable for unblocking investment in R&D and innovation might differ in line with the type of firm.

For obvious reasons, the European Investment Bank and its venture capital affiliate, the European Investment Fund, attach considerable importance to the financing of investment in R&D and innovation. After all, providing finance for sound investment when other sources of finance are insufficient is the *raison d'être* of the Bank. And to the extent that markets fail in bringing about the right level and type of investment, there is potential for the Bank to make a difference. While it is thus obvious that the Bank benefits from the wisdom put together in this volume of the *EIB Papers*, I am confident that they will serve a wider audience in Europe and elsewhere.

R&D and the financing of innovation in Europe

Financing innovative firms

The *2009 EIB Conference in Economics and Finance* – held at EIB headquarters in Luxembourg on October 22 – examined the role of investment in R&D and other intangibles for innovation and growth and highlighted the importance of access to finance for innovative firms. It shed light on a number of policy-relevant issues including fiscal measures to boost R&D spending, the role of patents as an output of the innovation process and as a means to secure external finance for innovative firms as well as the importance of technology transfer and venture capital in transforming inventions into economically relevant innovations.

Speakers included:

Laura BOTTAZZI
of the University of Bologna, Italy

Dirk CZARNITZKI
of the Catholic University of Leuven, Belgium

Jacques DARCY
of the European Investment Fund

Bronwyn H. HALL
of the University of California at Berkeley, USA

Dietmar HARHOFF
of Ludwig-Maximilians University Munich, Germany

Jacques MAIRESSE
of Centre de Recherche en Economie et en Statistique, Ecole Nationale de la Statistique et de l'Administration Economique, Paris, France

Werner RÖGER
of the European Commission, DG ECFIN

Hubert STRAUSS
of the European Investment Bank

Kristian UPPENBERG
of the European Investment Bank

Bart VAN ARK
of The Conference Board, USA

Bruno VAN POTTELSBERGHE DE LA POTTERIE
of the Université libre de Bruxelles, Belgium

ABSTRACT

To what extent are new and/or innovative firms fundamentally different from established firms, and therefore require a different form of financing? *The theoretical background for this proposition is presented, and the empirical evidence on its importance is reviewed. Owing to the intangible nature of their investment, asymmetric-information and moral-hazard, these firms are more likely to be financed by equity than debt and behave in some cases as though they are cash-constrained, especially if they are small. Recognising the role for public policy in this area, many countries have implemented specific policies to bring the cost of financing innovation more in line with the level that would prevail in the absence of market failures.*

Bronwyn H. Hall (bhhall@econ.berkeley.edu) is Professor in the Graduate School, University of California at Berkeley and Professor of Technology and the Economy at the University of Maastricht. She is also a Research Associate of the National Bureau of Economic Research (NBER) in Cambridge (MA) and the Institute for Fiscal Studies, London.

The financing of innovative firms

Bronwyn H. Hall

1. Introduction

In a market-based economy, those who create and manage firms (entrepreneurs) are usually not the same individuals as those who have the means to finance this activity. This fact implies that there is likely to exist an information gap between those asking for funds and those supplying them. As will be discussed in more detail below, economists refer to the extra costs thus induced as arising from the problems of "asymmetric-information" and "moral-hazard". Both of these are expected to raise the costs of obtaining finance from sources external to the firm. And although this will be true to some extent for all firms, the problem is particularly salient in the case of new firms and firms undertaking innovative activities.

Three different levels of difficulty need to be distinguished: the problems of existing innovating firms in acquiring sufficient funds for their investments, the reluctance of non-innovators to undertake innovation due to its high cost, and the problems faced by new start-up firms. Although all of these difficulties arise from the same ultimate set of causes, the empirical analysis of each will differ substantially and the possible range of policy solutions will differ. In particular, the first case, on which most of the econometric literature has focused, is subject to marginal analysis, whereas the second two cases involve the overcoming of (often substantial) fixed costs of entry into innovation.

This paper reviews the theoretical and empirical economic literature on the financing of innovation and draws some conclusions with respect to policy designed to ameliorate some of the problems.[1] Section 2 of the paper discusses the characteristics that make innovation investment different from ordinary investment. Then the theories of asymmetric-information and moral-hazard as applied to financing innovation are reviewed, followed by a summary of the empirical evidence on this topic. The concluding section discusses implications for public policy.

2. Why is investment in innovation different?

Investment in innovation usually consists of Research and Development spending (R&D), design and marketing expenses for bringing a new product to market, investment in the necessary new capital equipment, and investment in training.[2] The relative importance of each of this varies with the industry and type of innovation, although the most important spending in most sectors is R&D, accounting for more than 50 percent of innovation expenditures.

From the perspective of investment theory, innovation investments have a number of characteristics that make them different from ordinary investment. First and most importantly, most of the expenditures, with the exception of those on new capital equipment, consist of worker wages and salaries. From considerable survey evidence over the past 50 years, we know that in practice 50 percent or more of the R&D portion of this investment goes toward paying scientists and engineers, who are usually highly

1 The paper draws from – and updates – an earlier survey (Hall 2002).

2 For example, the European Community Innovation Survey Wave 4 (CIS4) asks whether the firm has the following types of innovation expenses: 1) internal R&D; 2) external R&D; 3) acquisition of new capital equipment or software; 4) acquisition of external knowledge or know-how including licenses, IP rights, *etc.*; 5) training; 6) marketing; and 7) other expenses associated with launching new products or processes, such as design and engineering.

educated. Their efforts create an intangible asset, the firm's knowledge base, from which profits in future years will be generated. Added to this knowledge base is the specific human capital created by worker training in new products and processes and the knowledge created by design and marketing investments. To the extent that all this knowledge is "tacit" rather than codified, it is embedded in the human capital of the firm's employees, and is therefore lost if they leave or are fired.

R&D investments require higher average rates of return due to higher adjustment costs and greater uncertainty.

This fact has an important implication for the conduct of R&D investment and to a lesser extent, innovation investment more broadly. The focus in the discussion below is on R&D as it is the measure on which empirical research has usually been based. Because part of the resource base of the firm itself disappears when knowledge workers leave or are fired, firms tend to smooth their R&D spending over time, in order to avoid having to lay them off. This implies that R&D spending at the firm level will behave as though it has high adjustment costs (confirmed empirically for the US by Hall *et al.* 1986; Lach and Schankerman 1988), with two consequences, one substantive and one that affects empirical work in this area. First, the equilibrium required rate of return to R&D may be quite high simply to cover the adjustment costs. Second, and related to the first, is that it will be difficult for empirical studies to measure the impact of changes in the costs of capital on such investment, because such effects can be weak in the short run due to the sluggish response of R&D to any changes in its cost.

The above conclusion needs to be tempered somewhat by the observation that in the recent past, the variance of R&D spending growth in publicly traded US firms has increased somewhat, for at least two reasons. The first is the increased importance of the ICT sector, where there is fairly rapid obsolescence of R&D outputs, and a consequent reduction in the incentives to safeguard human capital (Hall 2006). The second is that markets for technology have become somewhat more important, which reduces the need to keep firm's entire knowledge in-house (Arora *et al.* 2001). Nonetheless, it remains true that the variance in R&D investment growth rates is about one quarter to one fifth that for ordinary investment.

A second important feature of R&D investment is the degree of uncertainty associated with its output. This uncertainty tends to be greatest at the beginning of a research program or project, which implies that an optimal R&D strategy has an options-like character and should not really be analyzed in a static framework. R&D projects with small probabilities of great success in the future may be worth continuing even if they do not pass an expected rate of return test. The uncertainty here can be extreme and not a simple matter of a well-specified distribution with a mean and variance. There is evidence such as that in Scherer (1998) that the distribution of profits from innovation sometimes takes the form of a Pareto distribution where the variance does not exist.[3] When this is the case, standard risk-adjustment methods will not work well. Looked at from the perspective of standard finance theory, the variance of a portfolio constructed from such assets is unbounded so the usual diversification analysis does not apply.

High uncertainty of returns to innovation has been exacerbated in the recent past by the rise of network, or "winner-take-all" industries, such as software or Web-based services. Examples such as Microsoft, Goggle, Yahoo, eBay, and now Facebook are familiar – these are characterized by very high returns to the initial investment, but there are a number of similar entrants who either fail or never reach critical mass and settle for a small niche of the market. In fact, the high returns experienced by a few firms do succeed in attracting a number of entrants, but there is no guarantee that it is the "right" number.

An important characteristic of uncertainty for the financing of investment in innovation is the fact that as investments are made over time, new information arrives, which reduces or changes the uncertainty.

3 The simplest Pareto distribution is a one-parameter probability distribution with the property that under certain values of the parameter the variance of the outcomes drawn according to such a distribution is infinitely large.

The consequence of this fact is that the decision to invest in any particular project is not a once and for all decision, but has to be reassessed throughout the life of the project. In addition to making such investment a real option, the sequence of decisions complicates the analysis by introducing dynamic elements into the interaction of the financier (either within or without the firm) and the innovator.

The final characteristic of R&D as investment that has implications for financing is that the "capital" thus created is intangible. Not only is it intangible, but as discussed above, much of it is in the form of human capital embedded in the heads of the employees. Such capital typically has relatively low salvage value because it is also idiosyncratic – for example, the fact that the firm owning the capital goes out of business is a signal that its value turned out to be low. Except for the type of effort now underway to harvest patents from such firms (e.g., Ocean Tomo or Intellectual Ventures), there is little market for distressed intangible assets. The human capital involved goes with the employee, and usually he or she will capture any residual value from that in the form of wages in future employment. Thus debt instruments that are secured by the value of the capital asset are not likely to provide a useful source of funding for R&D. See Harhoff (2009) for a description of recent efforts to change this situation *via* the creation of patent funds for the commercial exploitation of unused inventions.

The capital created by R&D is largely intangible and firm-specific, limiting its resale market value.

Summarizing, R&D and other innovation investments have the following characteristics: (i) they need to be smoothed in order to retain valuable employees and their knowledge; (ii) they are highly uncertain and information about success or failure is revealed over time; and (iii) they create an idiosyncratic intangible capital with a limited resale market. The next section of the paper reviews the theory of investment in the light of these characteristics and discusses the implications of the theory for the financing of innovation.

3. Theoretical framework: Is finance different for innovative firms?

What follows focuses on the analysis of ongoing innovative firms rather than new start-ups. The greater part of empirical work has been performed using data on these kinds of firms, partly because they perform the great bulk of R&D and partly due to data availability.[4] The start-up problem will be discussed later in the paper.

The usual starting point for the analysis of any type of investment financing is the "neo-classical" marginal profit condition, suitably modified to take the special features of R&D into account. This condition sets the marginal product of capital equal to the rate of return on investment in that capital. Ignoring adjustment costs and uncertainty for the moment, the discrete time cost-of-capital condition is the following:

$$MPK = c_t = p_t - \frac{(1-\delta)}{(1-\rho)} p_{t+1}$$

That is, the marginal product of capital (MPK) that is used during period t is equal to its price less what the firm would receive from selling the capital at $t+1$ (which is $(1-\delta)\, p_{t+1}$), discounted by the required rate of return ρ. ρ is the return received by the investor, which is after corporate taxes are paid but before any personal or capital gains taxes are paid.

The above formulation implicitly contains three factors that will affect R&D financing: the rate at which the knowledge capital thus created depreciates or becomes obsolescent, the required rate of return, and rate of change of the real R&D price (the price of R&D inputs relative to the price of the firm's output).

4 Firms with more than 250 employees account for 90 percent of R&D worldwide (OECD 2007).

It is obvious that higher depreciation rates increase the cost of capital, while lower post-corporate-tax required returns, as in the case of an R&D tax credit, would lower it. In addition, if R&D is expected to become relatively more expensive tomorrow ($p_{t+1} > p_t$), this lowers the cost of capital today but this effect is relatively small in practice.

The source of funds affects the required return on investment for tax reasons.

The required rate of return in the equation above is the return after corporate taxes have been paid. However, as Auerbach (1984), among others, has shown, the marginal source of financing used by the firm will also impact the required rate of return that a prospective investor perceives. He analyzed the US case, where interest expense is deductible to the corporation, and the tax on capital gains has generally been lower than that on dividends. The same type of analysis would apply whenever profits from longer holding periods are taxed at a lower rate than those from shorter holding periods. The table below shows the cost of financing based on source of finance that he derived; in general, tax considerations suggest that debt finance will be cheapest, followed by retained earnings, and lastly by new share issues.

Table 1. Tax-adjusted financing cost

Source of finance	*Cost of finance*	*Assumptions*
Debt	$\rho\,(1-\tau)$	Interest is deductible at the corporate level
Retained earnings	$\rho\,(1-\tau_p)/(1-\tau_c)$	Avoids personal tax on dividends in favour of eventual capital-gains tax
New share issues	$\rho\,/(1-\tau_c)$	Eventual capital-gains tax paid

ρ= required return; τ = corporate tax rate; τ_p = personal tax rate; τ_c = capital-gains tax rate

Source: Auerbach (1984)

Obviously the story does not end here. Implicitly in constructing this table I have assumed that there is a single risk-adjusted rate of return available, but we have already seen that this is unlikely to be true, given the degree of uncertainty faced by innovating firms. That is, some innovation investments are so risky that a simple risk-adjustment based on the variance of returns is not available. In addition, different types of investors are likely to prefer different risk profiles. Bondholders will care more about salvage value (which also favours tangible over intangible assets), whereas equity holders may see an unbounded upside to the returns and may therefore prefer risk.

Two other major reasons for differences in the required rate of return across financing source have been the subject of considerable theoretical and empirical interest, on the part of both industrial organization and corporate finance economists: asymmetric-information and moral-hazard. These factors are widely viewed as driving a wedge between the cost of internal and external sources of finance, a wedge that is likely to be larger in the case of innovation investment than it is for ordinary investment.

One of the implications of the well-known Modigliani-Miller theorem (1958, 1961) was that a firm choosing the optimal levels of investment should be indifferent to its capital structure, and should face the same price for all types of investment (including investments in creating new products and processes) on the margin. The last dollar spent on each type of investment should yield the same expected rate of return (after adjustment for non-diversifiable risk). A large literature, both theoretical and empirical, has questioned the bases for this theorem, but it remains a useful starting point.

Of course, there are a number of reasons why the theorem might fail to hold in practice. First, uncertain returns in combination with incomplete markets imply that insurance over all outcomes is not available. Second, the cost of capital may vary across the source of the funds either for non-tax reasons or for tax reasons. Finally, the cost of capital may also vary across type of investment (tangible and intangible) both for tax and for other reasons.

Summing up, with respect to innovation investment, economic theory advances a plethora of reasons why there might be a gap between the external and internal costs of capital; these can be divided into three main types, of which the first two arise from market failures: (i) asymmetric-information between innovator and investor; (ii) moral-hazard arising from the separation of ownership and management; and (iii) tax considerations that drive a wedge between external and internal finance. The following three sections treat each of these in turn.

3.1 Asymmetric-information problems

External funds are more expensive than internal funds due to a 'lemons' premium, too.

In the R&D setting, the asymmetric-information problem refers to the fact that an inventor or entrepreneur frequently has better information about the nature of the contemplated innovation project and the likelihood of its success than potential investors. Therefore the marketplace for financing the development of innovative ideas looks like the "lemons" market modelled by Akerlof (1970). In his model, the good (used) cars sells for a lower price in order to compensate the buyer for the possibility that the car is a lemon. In this setting, the seller of potential returns to R&D or innovation offers a higher return (lower price) to compensate the buyer for the possibility that the project is not as good as is claimed. The lemons' premium for R&D or innovation will be higher than that for ordinary investment because investors have more difficulty distinguishing good projects from bad when the projects are long-term R&D investments than when they are short-term or low-risk projects (Leland and Pyle 1977).

In the most extreme version of the lemons model, the market for R&D projects may disappear entirely if the asymmetric-information problem is too great. Informal evidence suggests that some potential innovators believe this to be the case in practice. Reducing information asymmetry via fuller disclosure is of limited effectiveness in this arena, due to the ease of imitation of inventive ideas. Firms are reluctant to reveal their innovative ideas to the marketplace and the fact that there could be a substantial cost to revealing information to their competitors reduces the quality of the signal they can make about a potential project (Bhattacharya and Ritter, 1983; Anton and Yao, 1998). Thus the implication of asymmetric-information coupled with the costliness of mitigating the problem is that firms and inventors will face a higher cost of external than internal capital for R&D due to the lemons' premium. When the level of R&D expenditure is an observable signal subject to external audit, as it is under current accounting rules in several countries, we might expect that the lemons' problem is somewhat mitigated, but certainly not eliminated.

Asymmetric-information problems can sometimes be mitigated by reputations developed through repeated interactions and this setting is no exception. There are several forms of reputation-building observed. One of the important roles played by specialized venture capital (VC) funds is precisely to supply informed monitoring of early stage technology start-ups, but experienced venture capitalists will also have developed a reputation for honouring nondisclosure agreements that will enable them to gather better information about projects being proposed. On the other side of the transaction, serial entrepreneurs often face less difficulty in obtaining financing for new ventures, presumably because they have developed a reputation in prior start-ups.

3.2 Moral-hazard problems

Moral hazard also widens the gap between external and internal cost of capital.

Moral-hazard in R&D investing arises in the usual way: Modern industrial firms normally have separation of ownership and management. This leads to a principal-agent problem when the goals of the two conflict, which can result in investment strategies that are not share value maximizing, and hence can lead to under or over-investment. Two possible scenarios may co-exist: one is the usual tendency of managers to spend on activities that benefit them but not necessarily their firm (growing the firm beyond efficient scale, nicer offices, *etc*.) and the second is a reluctance of risk-averse managers to invest in uncertain R&D projects.

Agency costs of the first type may be avoided by reducing the amount of free cash flow available to the managers by leveraging the firm, but this in turn forces them to use the higher-cost external funds to finance R&D (Jensen and Meckling, 1976). Empirically, there seem to be limits to the use of the leveraging strategy in R&D-intensive sectors. See Hall (1990, 1994) for evidence that the leveraged-buyout (LBO) and restructuring wave of the 1980s, viewed by most researchers as driven by the need to reduce free cash flow in sectors where investment opportunities were poor, was almost entirely confined to industries and firms where R&D was of no consequence. One reason for this fact may be that over-investment in R&D and innovation is not usually a major problem for ongoing managerial firms and therefore the discipline of cash-flow limiting leverage is unnecessary for restraining these kinds of investment.

According to the second type of principal-agent conflict, managers are more risk averse than shareholders and avoid innovation projects that will increase the riskiness of the firm. If bankruptcy is a possibility, managers whose next best opportunity is a job with lower compensation than their present job and potential bondholders may both wish to avoid variance-increasing projects that shareholders would like to undertake. The argument of the theory is that long-term investments can suffer in this case. The optimal solution to this type of agency cost would be to increase the long-term incentives faced by the manager rather than reducing free cash flow. Many innovative firms make heavy use of stock option compensation for this reason, although this solution comes with its own incentive problems.

In the case of start-up firms, there is often a third type of principal-agent conflict, involving overconfidence on the part of the entrepreneur. When there is uncertainty and the probability of innovation success is revealed only gradually over time, the possibility of asymmetric-information and moral-hazard in the investor-innovator relationship creates further problems for achieving the optimal contract. For example, it is often observed that entrepreneurs or R&D managers wish to continue projects that investors would like to terminate (Cornelli and Yosha 2003), presumably because the possibility of an ultimate benefit to the entrepreneurs looms large and they do not face the investment cost in the case of failure. If they are also over-confident (as is often the case), they will be even more biased toward continuation. Asymmetric-information about the project will imply that the investor has relatively more difficulty than the innovator even in determining the probability of success. The combination of information rents and agency costs will lead to inefficient funding of projects over time (waiting too long to cancel them or cancelling them too soon) as well as to inefficiently low levels of funding.

In a recent paper, Bergemann and Hege (2005) have analyzed these tradeoffs in a multi-stage investment financing decision under changing uncertainty, with renegotiation allowed. They look at the choice between relationship financing (where the investor is able to monitor the progress of the project accurately) and arm's length financing (where the investor must rely on the innovator for information). Investors are able to speed up or slow down the rate of financing, depending on the progress of the project and their expectations of success. In general, Bergemann and Hege find that agency costs will lead to non-optimal stopping rules for projects, stopping them too soon on average. Surprisingly, arm's length contracts can lead to higher project values, because in these the investor can commit in advance to a stopping rule, which eliminates any benefit to the entrepreneur from attempts to prolong the project.

3.3 Taxes and the source of funds

As discussed earlier, tax considerations that yield variations in the cost of capital across source of finance have been articulated by Auerbach (1984) among others. In many tax systems including that in the US, interest is deductible against earnings and the proceeds from equity held for longer periods is taxed at a lower rate. Therefore the cost of financing new investment by debt has been effectively lower than that of financing it by retained earnings, which is in turn less than that of issuing new shares.[5] However, based on the discussion above, this ranking of the financing costs is unlikely to hold for the intangible assets created by innovation investment. Low salvage values relative to the original investment makes these assets unsuitable for debt finance in spite of the tax advantage, so that firms whose investments are mostly intangible will rely more heavily on retained earnings and equity.

Differential tax treatment not only obtains for the sources of funds but also for their use. The specific tax treatment of R&D and other innovation investments in most OECD economies is very different from that of other kinds of investment. Because R&D, marketing costs, training costs, *etc*. are expensed as they are incurred, the effective tax rate on the corresponding assets is lower than that on either plant or equipment, with or without various tax credits in place. The economic depreciation of innovation assets is considerably less than the depreciation allowed for tax purposes - which is 100 percent - so that the required pre-tax rate of return for such investment would be lower relative to ordinary investment. In addition, some countries offer a tax credit or subsidy to R&D spending and occasionally to other activities such as employee training, which can reduce the after tax cost of capital even further.[6]

New debt and equity finance from external sources are more expensive for R&D and innovation than for ordinary investment.

Thus the conclusions from the theoretical analysis of firm-level investment in innovation is that the presence of either asymmetric-information or a principal-agent conflict or both implies that new debt or equity finance from sources external to the firm will be relatively more expensive for R&D and innovation than for ordinary investment, and that considerations such as the lack of collateral further reduce the possibility of debt finance. Together, these arguments suggest an important role for retained earnings in the R&D investment decision. In addition, retained earnings may serve as a signal of future profitability. Hall (1992) and Himmelberg and Petersen (1994) have argued that positive cash flow may be more important for R&D than for ordinary investment, a proposition that has since received empirical support (see Section 4).

A final important conclusion from the theory above is that whatever problems are created for the financing of innovative firms by asymmetric-information and moral-hazard are likely to be exacerbated in the case of young firms and start-ups. These firms are often the most reliant on external sources of finance and of course they have not yet developed reputations that would allow them to signal their quality adequately. Evidence that this is true in practice as well as theory is provided in Section 4.5.

5 A detailed discussion of tax regimes in different countries is beyond the scope of this survey, but it is quite a common feature in several countries for long term capital gains on funds that remain with a firm for more than one year to be taxed at a lower rate than ordinary income. Yet even if the tax rates on the two kinds of income are equal, the inequalities will hold. Only in the case where dividends are not taxed at the corporate level (which was formerly the case in the UK) will the ranking given above not hold.

6 See Hall and Van Reenen (2000) and Warda (2008) for details.

4. Empirical evidence

Almost all of the empirical evidence for the presence of a wedge between internal and external finance, and the consequent underinvestment in innovation that is discussed in this section uses R&D investment as a proxy for long term investment or investment in innovative activities. There are good reasons for this – R&D is frequently the only measure of innovation that has been observed over long time periods at the firm level and it is highly related to innovative activities, at least in the manufacturing sector. The recent wave of innovation surveys in Europe and elsewhere is beginning to provide us with alternative measures, although thus far it appears that R&D still has greater predictive power for firm performance than the newer measures, at least where it is observed (Mairesse *et al.* 2006). Later in this section some results obtained using the innovation surveys will be presented.

In the discussion below, the empirical studies in this area are divided into two groups: those based on variations of an investment equation derived from economic theory (Sections 4.1 and 4.2), and other studies – mostly financial-market studies based on stock-price announcement effects on the impact of various corporate-governance settings on the financing of innovation (Section 4.3). The section concludes with a discussion of the evidence on the resulting capital structure of innovating firms.

4.1 Investment-equation studies

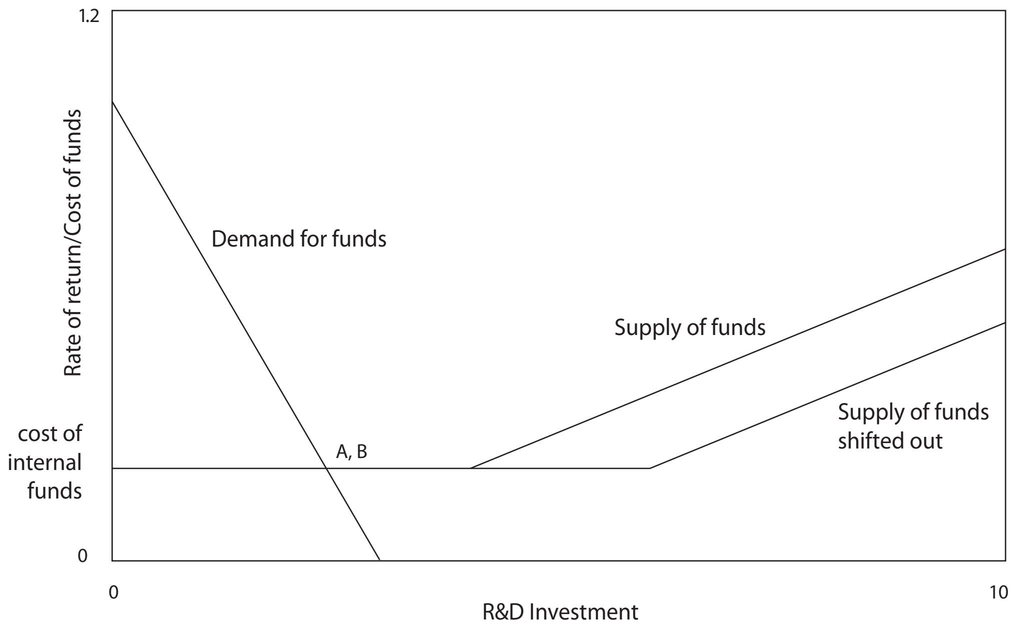
R&D investment demand may be excessively sensitive to cash-flow shocks in liquidity-constrained firms.

For a firm already operating, the presence of "liquidity" constraints on their investment (ordinary as well as innovation and R&D investment) implies that they are unable to obtain funds from external sources to finance all the investment that they would undertake if they had sufficient funds available within the firm. Thus the usual way to examine the empirical relevance of the arguments in the previous section is to estimate R&D investment equations and test whether liquidity constraints or excess sensitivity to cash-flow shocks are present and perhaps more pronounced than for ordinary investment. This approach builds on the extensive literature developed for testing ordinary investment equations for liquidity constraints (Fazzari *et al.* 1988; Arellano and Bond 1991). It suffers from many of the same difficulties as the estimates in the investment literature (lack of good instruments to isolate supply shocks, measurement error, unobserved differences across firms, and so forth), plus one additional problem that arises from the tendency of firms to smooth R&D spending over time.

The ideal experiment for identifying the effects of liquidity constraints on investment is to give firms additional cash exogenously, and observe whether they pass it on to shareholders or use it for investment and/or R&D. If they choose the first alternative, either the cost of capital to the firm has not fallen, or it has fallen but they still have no good investment opportunities. If they choose the second, then the firm must have had some unexploited investment opportunities that were not profitable using more costly external finance. A finding that investment is sensitive to cash flow shocks that are not signals of future demand increases would allow rejecting the hypothesis that the cost of external funds is the same as the cost of internal funds. However, lack of true experiments of this kind forces researchers to use econometric techniques such as instrumental variables to attempt to control for demand shocks when estimating the investment demand equation, with varying degrees of success.

The methodology for the identification of R&D investment equations is based on a simple supply and demand heuristic, as shown in Figure 1. The curve sloping downward to the right represents the demand for R&D investment funds and the curves sloping upward the supply of funds. Internal funds are available at a constant cost of capital until they are exhausted, at which point it becomes necessary to issue debt or equity in order to finance more investment. When the demand curve cuts the supply curve in the horizontal portion, a shock that increases cash flow (and shifts supply outward) has no effect on the level of investment.

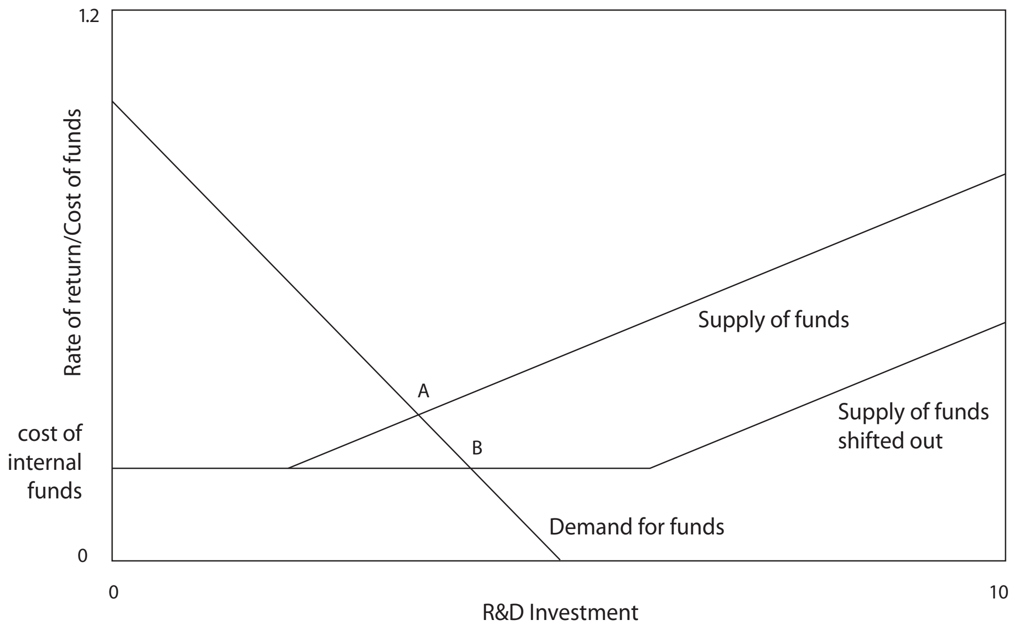
Figure 1. **Financially unconstrained firm**



However, if the demand curve cuts the supply curve where it is upward sloping, it is possible for a shock to cash flow to shift the supply curve out in such a way as to induce a substantial increase in R&D investment. Figure 2 illustrates such a case, where the firm shifts from point A to point B in response to a cash flow shock that does not shift the demand curve.

When does an increase in the supply funds lead to additional R&D investment?

Figure 2. **Financially constrained firm**



During the past several years, various versions of these methodologies have been applied to data on the R&D investment of US, U.K., French, German, Irish, and Japanese firms and possibly others. The firms examined are typically the largest and most important manufacturing firms in their economy.

For example, Hall (1992) finds a large positive elasticity between R&D and cash flow, using an accelerator-type model and a very large sample of US manufacturing firms. The estimation methodology here controls for both firm effects and simultaneity. Similarly and using some of the same data, Himmelberg and Petersen (1994) look at a panel of 179 US small firms in high-tech industries and find an economically large and statistically significant relationship between R&D investment and internal finance.

R&D is strongly correlated with cash flow and new public equity, especially in young high-tech firms.

More recently, J. Brown *et al.* (2009) have shown that both cash flow and the issuance of public equity are very important for younger US firms during the period 1990-2004, while they have little impact on mature firms' R&D investment. They focus on the high-technology sector (drugs, office and computing equipment, communications equipment, electronic components, scientific instruments, medical instruments, and software), which accounts for almost all of the increase in R&D during this period, and use Euler-equation methods with fixed firm effects and industry-level year dummies to remove most of the variation due to unobserved differences in firm characteristics and demand shocks across industry.[7] A novel finding in this paper and a companion paper by J. Brown and Petersen (2009) is the increased importance of public-equity issuance in financing R&D in the United States, which doubtless reflects a shift in expectations on the part of investors during this period that lowered the cost of this kind of capital to the firm.

Harhoff (1998) find weak but significant cash-flow effects on R&D for both small and large German firms, although Euler-equation estimates for R&D investment were uninformative due to the smoothness of R&D and the small sample size. Combining limited survey evidence with his regression results, he concludes that R&D investment in small German firms may be constrained by the availability of finance. Bond *et al.* (1999) find significant differences between the cash flow impacts on R&D and investment for large manufacturing firms in the United Kingdom and Germany. German firms in their sample are insensitive to cash flow shocks, whereas the investment of non-R&D-doing UK firms does respond. Cash flow helps to predict whether a UK firm does R&D, but not the level of that R&D. They interpret their findings to mean that financial constraints are important for British firms, but that those which do R&D are a self-selected group that face fewer constraints. This is consistent with the view that the desire of firms to smooth R&D over time combines with the relatively high cost of financing it to reduce R&D well below the level that would obtain in a frictionless world. That is, some firms do not find it worthwhile to begin an R&D program that they expect will have to be curtailed in the future due to financial constraints.

Mulkay *et al.* (2001) perform a similar exercise using large French and US manufacturing firms, finding that cash-flow impacts are much larger in the US than in France, both for R&D and for ordinary investment. Except for the well-known fact that R&D exhibits higher serial correlation than investment (presumably because of higher adjustment costs), differences in behaviour are between countries, not between investment types, suggesting that they are due to differences in the structure of financial markets rather than the type of investment, tangible or intangible. This result is consistent with evidence reported in Hall *et al.* (1999) for the US, France, and Japan during an earlier time period, which basically finds that R&D and investment on the one hand, and sales and cash flow on the other, are simultaneously determined in the United States (neither one "Granger-causes" the other).[8] In the other countries, however, both types of investment are causal for sales and cash flow, with little feedback from sales

7 The Euler equation for investment is an equilibrium condition derived from the firm's value maximization problem. It expresses the tradeoff between investing today and having one more period of production from the capital versus investing tomorrow and forgoing today's production.

8 Granger causality is a definition of causality in a time-series context that is due to the late Clive Granger. One variable "Granger-causes" another if its prior values but not its current values help to predict the variable in the presence of the variable's own history.

and cash flows to the two types of investments. Using a non-structural R&D investment equation together with data for the US, UK, Canada, Europe, and Japan, Bhagat and Welch (1995) find similar results for the 1985-1990 period, with stock returns predicting changes in R&D more strongly for the US and UK firms. Thus in all the countries studied, R&D investment is a predictor of increased performance contemporaneously (measured as sales, cash flow, or stock returns), whereas in the US and the UK, there is immediate feedback from the performance measures to R&D investment, which can be due either to liquidity effects or the positive demand signal from increased sales or cash flow.

Bougheas *et al.* (2001) examine the effects of liquidity constraints on R&D investment using firm-level data for manufacturing firms in Ireland and also find evidence that R&D investment in these firms is financially constrained, in line with the previous studies of US and UK firms.

4.2 Studies using innovation survey data

Recently a number of authors, mostly in Europe, have combined innovation survey data and firm financial data in order to look more closely at the relationship between innovative activities and the presence of financial constraints. This endeavour is welcome given the fact that the prior work was confined only to R&D investment, but it has suffered to some extent from the fact that in order for a firm to experience financial constraints related to innovation, they must at least want to be an innovator, leading to substantial simultaneity between the two.[9] Various approaches are taken to mitigate this problem in the studies described below.

Financial constraints also hamper innovative activities other than R&D, and innovators are more likely to encounter financial constraints.

Savignac (2008) and Hajivassiliou and Savignac (2008) examine a simultaneous model of the two discrete states (facing financial constraints and innovating) directly, using a large sample of French firms. They do indeed find simultaneity between the two: binding financing constraints discourage innovation and at the same time innovative firms are more likely to face binding financing constraints. Using data on UK firms, Canepa and Stoneman (2008) find that the cost and availability of finance matters for innovation, especially for high-technology firms and for the smaller firms in their sample.

W. Brown (1997) argues that existing tests of the impact of capital market imperfections on innovative firms cannot distinguish between two possibilities: (i) capital markets are perfect and different factors drive the firm's different types of expenditure or (ii) capital markets are imperfect and different types of expenditure react differently to a common factor (shocks to the supply of internal finance). He then compares the sensitivity of investment to cash flow for innovative and non-innovative firms in the UK. The results support the hypothesis that capital markets are imperfect, finding that the investment of innovative firms is more sensitive to cash flow.

Magri (2009) also compares the cash flow sensitivity of innovative and non-innovative firms, this time for Italian firms. She finds that investment in small innovative firms is more sensitive to cash flow than in small non-innovative firms, but that there is no difference for large firms. Note that this analysis is for ordinary investment rather than for innovation investment itself, but it is still suggestive of financial constraints for smaller innovating firms.

Jensen and Webster (2009) look at the cyclical response to macro-economic conditions of success in commercialization of new products and services by Australian firms. The most important macro-economic determinant of success is the cost of bank overdrafts (lower is better, obviously), followed

9 This difficulty is compounded by the fact that the skip patterns in some versions of the innovation surveys mean that non-innovating firms are never asked whether they faced financial constraints that prevented them from innovating.

by the interest rate, and the cost of R&D. In general, commercial success is pro-cyclical in their sample, although others have found some evidence that research itself (as opposed to development) is counter-cyclical.

4.3 Corporate-governance structure and the financing of R&D

The challenge for direct tests of the relationship between management and ownership structures and firm investment strategies is that in any given firm, the two have co-evolved to be adapted to one another, and therefore observed correlations do not admit much of a causal story. In particular, any attempt to look at variations in performance that result from variations in strategy and governance will struggle with the fact that selection for "fitness" tends to eliminate some of the experiments one might like to see.

The usual way around this problem is to look for announcement effects, that is, for market reaction to information surprises or news that firms have not yet adapted to. The event study methodology is described in detail in Campbell *et al.* (1997). Briefly, it involves computing the returns to an investor from holding a share of stock in a firm during the 3 to 5 day period around the time that some news that affects the firm is revealed publicly. The returns computed are "abnormal," that is, they are adjusted for the overall market returns during the same period.

Both Alam and Walton (1995) and Zantout (1997) find higher abnormal returns to firm shares following new debt issues when the firm is more R&D-intensive. The argument is that the acquisition of new sources of financing is good news when the firm has an asymmetric-information problem because of its R&D strategy. Similarly, Szewczyk *et al.* (1996) find that investment opportunities (as proxied by Tobin's q) explain R&D-associated abnormal returns, and that these returns are higher when the firm is highly leveraged, implying a higher required rate of return for debt finance in equilibrium. Of course, in both of these cases, the evidence is non-experimental and the links between the theory and the empirical tests somewhat tenuous, but the results are suggestive.

Incentives for managers can boost long-term R&D. Institutional ownership need not reduce it.

Evidence on the importance of agency costs as they relate to R&D takes several forms. Several researchers have studied the impact of anti-takeover amendments (which arguably increase managerial security and willingness to take on risk while reducing managerial discipline) on R&D investment and firm value. Johnston and Rao (1997) find that such amendments are not followed by cuts in R&D, while Pugh *et al.* (1999) find that adoption of an Employee Stock Ownership Plan (ESOP), which is a form of anti-takeover protection, is followed by R&D increases. Cho (1992) finds that R&D intensity increases with the share that managerial shareholdings represent of the manager's wealth and interprets this as incentive pay mitigating agency costs and inducing long-term investment.

Some have argued that institutional ownership of the managerial firm can be conducive to more R&D by reducing the agency costs due to free-riding by owners that is a feature of the governance of firms with diffuse ownership structure. Others however have held that such ownership pays too much attention to short-term earnings and therefore discourages long-term investment.[10]

There is some limited evidence that this may indeed be the case. Eng and Shackell (2001) find that firms adopting long-term performance plans for their managers do not increase their R&D spending but that institutional ownership is associated with higher R&D. In addition, R&D-performing firms tend not to be held by banks and insurance companies, at least in the US. These types of firms are presumed

10 Institutions such as mutual and pension funds often control somewhat larger blocks of shares than individuals, making monitoring firm and manager behaviour a more effective and more rewarding activity for these organizations.

to be poor at monitoring R&D performance. Majumdar and Nagarajan (1997) find that high institutional-investor ownership does not lead to short-term behaviour on the part of the firm; in particular, it does not lead to cuts in R&D spending. Francis and Smith (1995) find that diffusely held firms are less innovative, implying that monitoring alleviates agency costs and enables investment in innovation.

In a study of German manufacturing firms, Czarnitzki and Kraft (2009) use patent data as an indicator of innovative activity and find the opposite result. Companies with dispersed ownership are more active in innovation as measured by patent applications, but patenting falls as leverage increases. They interpret this result as suggesting that leverage acts as a disciplinary device that restrains overinvestment by managers. Although they attempt to control for the endogeneity of leverage using instrumental variables, the instruments (lagged cash flow and tangible-asset intensity) are arguably also related to unobserved determinants of innovative activity; in the absence of independent measures of over- or under-investment, it is difficult to know whether leverage is a discipline device or merely an indicator that the firm is not as innovation intensive as some others.

In general, the evidence summarized above is fairly clear and indicates that long-term incentives for managers can encourage R&D and that institutional ownership does not necessarily discourage R&D investment. However, it is fairly silent on the magnitude of these effects, and whether these governance features truly close the agency cost-induced gap between the cost of capital and the return to R&D.

4.4 Capital structure and R&D

Another way to look at the financing-innovation nexus is to examine the capital structure that results from the financing decisions of R&D-intensive firms. Here the evidence that debt is disfavoured is quite clear. Work using US data such as Friend and Lang (1988) and Hall (1992) shows a clear negative correlation between R&D intensity and leverage. The same is true of unpublished results for European firms (Hall *et al.* 2009).

There is a clear negative correlation between R&D intensity and leverage.

Although leverage may be a useful tool for reducing agency costs in the firm, it is of limited value for R&D-intensive firms. As discussed above, because the knowledge asset created by R&D investment is intangible, partly embedded in human capital, and ordinarily very specialized to the particular firm in which it resides, the capital structure of R&D-intensive firms customarily exhibits considerably less leverage than that of other firms. Banks and other debt holders prefer to use physical assets to secure loans and are reluctant to lend when the project involves substantial R&D investment rather than investment in plant and equipment. In the words of Williamson (1988), "redeployable" assets (that is, assets whose value in an alternative use is almost as high as in their current use) are more suited to the governance structures associated with debt. Additional empirical support for this idea is provided by Alderson and Betker (1996), who find that liquidation costs and R&D are positively related across firms. The implication is that the sunk costs associated with R&D investment are higher than that for ordinary investment.

In addition, servicing debt usually requires a stable source of cash flow, which makes it more difficult to find the funds for an R&D investment program that must be sustained at a certain level in order to be productive. For both these reasons, firms are either unable or reluctant to use debt finance for R&D investment, which may raise the cost of capital, depending on the precise tax treatment of debt versus equity. Confirming empirical evidence for the idea that limiting free cash flow in R&D firms by issuing debt is a less desirable method of reducing agency costs is provided by Chung and Wright (1998), who find that financial slack and R&D spending are positively correlated with the value of growth firms, but not correlated with that of other firms. Czarnitzki and Kraft (2009) find that more leveraged German firms have lower innovation output (measured by patents), especially when ownership of the firm is dispersed.

In the view of some observers, the LBO wave of the 1980s in the United States and the United Kingdom arose partly because high real interest rates meant that there were strong pressures to eliminate free cash flow within firms (Blair and Litan 1990). For firms in industries where R&D is an important form of investment, such pressure should have been reduced by the need for internal funds to undertake such investment and indeed Hall (1993, 1994) and Opler and Titman (1993) find that firms with high R&D intensity were much less likely to do an LBO. Opler and Titman (1994) find that R&D firms that were leveraged suffered more than other firms when facing economic distress, presumably because leverage meant that they were unable to sustain R&D programs in the face of reduced cash flow.

In related work using data on Israeli firms, Blass and Yosha (2003) report that R&D-intensive firms listed on the US stock exchanges use highly equity-based sources of financing, whereas those listed only in Israel rely more on bank financing and government funding. The former are more profitable and faster-growing, which suggests that the choice of where to list the shares and whether to finance with new equity is indeed sensitive to the expected rate of return to the R&D being undertaken. That is, investors supplying arms-length finance require higher returns to compensate them for the risk of a "lemon".

4.5 Young innovative companies

More developed financial-markets are conducive to faster entry and post-entry growth of small firms.

Before leaving this topic, I briefly review the evidence on the financing of young innovative firms and start-ups. At the macro-economic level and beginning with Rajan and Zingales (1998), a number of studies have related the overall financial development level with measures such as the entry of new firms in a country. Using a set of 16 countries including the US, European, and mid-level developing countries in Eastern Europe and Latin America, Aghion *et al.* (2007) show that the level of financial development in a country (private credit and the size of market capitalization) strongly influences entry and post-entry growth of small firms but has little impact on large-firm growth.

These authors highlight the differences in the level of market capitalization between the US, the U.K., and a few Nordic countries on the one hand and continental Europe on the other. Although to some extent the growth of small firms and stock markets are endogenously related in that they grow together, the methodologies chosen by Rajan-Zingales and Aghion *et al.* are designed to minimize the identification problem that results, which makes their results robust. This work does not relate directly to innovative firms *per se*, but it is suggestive, as these are often very prominent among new firms, especially in the manufacturing sectors that are studied by these authors.

An entirely different approach that looks directly at the cash flow impact on entrepreneurial firms was pursued by Holtz-Eakin *et al.* (1994). Using tax data on US entrepreneurs (sole proprietors) some of whom received inheritances, they were able to show that the reception of funds from inheritance increased entrepreneurial survival and that those that survived grew faster, suggesting that such firms were financially constrained prior to the cash influx. Turning to R&D-doing and innovative small firms in particular, in most of the work reviewed in Section 4.1, when the authors have looked they have found greater financial constraints for these firms than for the larger firms in their samples. For examples, see Himmelberg and Petersen (1994) and J. Brown *et al.* (2009).

Of course, looking at smaller firms that have successfully entered but face some financial constraints is only part of the story. We would also like to know about entry that never takes place, or failure to innovate due to constraints. Here the innovation surveys can be helpful, especially if they survey non-innovative firms carefully. For example, Canepa and Stoneman (2008) found that finance mattered especially for the smaller innovative firms in their UK sample, as does Magri (2008) for Italian firms. Audretsch and Lehmann (2004) examined the financing of young innovative firms on the German

Neuer Markt, finding a negative correlation between bank debt and VC financing. They also show that the VC-backed firms have much higher growth rates. They argue that these two findings show the importance of financiers willing to risk capital for the success of young innovative firms, especially in a country like Germany where bank finance dominates.

5. Conclusions and policy implications

A number of conclusions have emerged from this body of theoretical and empirical work, conclusions that are fairly consistent across the various samples and methodological variations. It is perhaps important to emphasize that the market failures catalogued and explored here are confined to those due to the separation of owner and manager, or financier and entrepreneur. However, the principle public policy argument for subsidizing innovative firms may be different, as it is based on the social benefits to be derived from the unpriced knowledge spillovers from such firms. That is, the problem of inappropriability of the returns to investment in knowledge that was pointed out long ago by Arrow (1962) and Nelson (1959). The arguments and evidence here are in addition to these.

First, there is solid evidence that debt is a disfavoured source of finance for R&D investment. Second, the "Anglo-Saxon" economies, with their thick and highly developed stock markets and relatively transparent ownership structures, typically exhibit more sensitivity and responsiveness of R&D to cash flow than continental economies. Third, and much more speculatively, this greater responsiveness may arise because they are financially constrained, in the sense that they view external sources of finance as much more costly than internal, and therefore require a considerably higher rate of return to investments done on the margin when they are tapping these sources. However, it is perhaps equally likely that this responsiveness occurs because firms are more sensitive to demand signals in thick financial markets; a definitive explanation of the "excess sensitivity" result awaits further research.

Finally, there is now considerable evidence that young and/or small firms are more likely to face financial constraints than large established firms, a result that is not surprising, if the source of the problem is a "lemons" premium. Presumably such firms have a weaker track record on which investors can base their evaluations.

Governments should lower the cost of financing innovation.

There are a number of policy implications from the results discussed in this paper. One implication is for governments to design policies conducive to lowering the cost of financing innovation, which many governments have done. The chief instrument in this area is a simple tax credit or subsidy, in some cases targeted towards small firms. Others include various programmes that are project related or targeted towards pre-commercial research and development (*e.g.*, see David *et al.* (2000) for an international survey of this literature; Czarnitzki and Hussinger (2004) for a detailed study of R&D subsidies in Germany; and Hall and Maffioli (2008) for a survey of such programs in Latin America and their evaluation).

One of the problems in designing policy in this area is that different countries face different problems. For example, although one can argue that financing constraints are not absent in the United States, it is fairly clear that the rise of the VC industry has mitigated the problem, at least for high technology start-ups (including those in green technologies). In other countries, creating such an industry may be more of a challenge. In Israel, for example, it appears to have been kick-started successfully by the government, but only on the second try (Gilson 2003; Avnimelech and Teubal 2004).

Several European governments have also attempted to behave somewhat as VCs towards their own start-ups and small innovative firms. In Germany, more than 800 federal and state government financing programs have been established for new firms in the recent past (OECD 1995). In 1980, the Swedish government established the first of a series of investment companies (along with instituting a series of measures such as reduced capital-gains taxes to encourage private investment in start-ups), partly on the United States model. By 1987, the government share of VC funding was 43 percent (Karaomerliolu and Jacobsson 1999). Recently, the UK has instituted a series of government programs under the Enterprise Fund umbrella which allocate funds to small and medium-sized firms in high technology and certain regions, as well as guaranteeing some loans to small businesses (Bank of England 2001).

Winning a competitive R&D grant might enable young firms to obtain more funds from private sources.

In a recent theoretical paper, Takalo and Tanayama (2008) argue that government R&D subsidies based on screening of firms and projects can serve as important signals to private-equity markets and venture capitalists of the quality of the recipients, which will reduce to some extent the "lemons" premium demanded by non-government investors. Lerner (1999) studied US recipients of Small Business Innovation Research (SBIR) grants and concluded the same: Receiving such a grant enabled firms to obtain more resources elsewhere, and in addition such firms grew faster afterwards, when compared to a matched sample of firms that did not receive funds from SBIR. This suggests an important role for government policy in screening firms for funding.

For established firms, estimates of cash-flow sensitivity point to differences between the US and UK on the one hand and continental European countries on the other, with the former more sensitive than the latter, so in principle US and UK firms should be more subject to financial constraints. But there is little evidence that this leads to lower innovative activity, in fact somewhat the contrary, so other forces must be at work, too. The largest of these firms in all countries and the ones that perform the greatest amount of R&D tend to compete with each other in international markets, so that it is not likely that the behaviour of firms from different countries can diverge too far.

References

Aghion, P., Fally, T. and Scarpetta, S. (2007). "Credit constraints as a barrier to the entry and post-entry growth of firms". *Economic Policy* (October), pp. 731-779.

Akerlof, G.A. (1970). "The market for 'lemons': Quality, uncertainty, and the market mechanism". *Quarterly Journal of Economics,* (84), pp. 488-500.

Alam, P. and Walton, K.S. (1995). "Information asymmetry and valuation effects of debt financing". *Financial Review,* (30:2), pp. 289-311.

Alderson, M.J. and Betker, B.L. (1996). "Liquidation costs and accounting data". *Financial Management,* (25:2), pp. 25-36.

Anton, J.J. and Yao, D.A. (1998). "The sale of intellectual property: Strategic disclosure, property rights, and incomplete contracts". Working paper, The Wharton School, University of Pennsylvania, USA.

Arellano, M. and Bond, S. (1991). "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations". *Review of Economic Studies,* (58), pp. 277-297.

Arora, A., Fosfuri, A. and Gambardella, A. (2001). *Markets for Technology*. MIT Press, Cambridge, MA, USA.

Arrow, K.J. (1962). "Economic welfare and the allocation of resources for invention", in Nelson, R. (Ed.), *The Rate and Direction of Inventive Activity*. Princeton University Press, Princeton, NJ, USA.

Audretsch, D.B. and Lehmann, E.E. (2004). "Financing high-tech growth: The role of banks and venture capitalists". *Schmalenbach Business Review*, (56), pp. 340–357.

Auerbach, A.J. (1984). "Taxes, firm financial policy, and the cost of capital: An empirical analysis". *Journal of Public Economics,* (23), pp. 27-57.

Avnimelech, G. and Teubal, M. (2004). "Emergence and development of venture capital in Israel and the role of policy: a macro / microeconomic perspective", in Bartzokas, A. and Mani, S. (eds.), *Financial Systems, Corporate Investment in Innovation and Venture Capital.* Edward Elgar, London, UK.

Bank of England. (2001). *Finance for Small Firms – An Eighth Report*. Domestic Finance Division, Bank of England, London.

Bergemann, D. and Hege, U. (1998). "Venture capital financing, moral hazard, and learning". *Journal of Banking and Finance,* (22), pp. 703-735.

Bhagat, S. and Welch, I. (1995). "Corporate research and development investments: International comparisons". *Journal of Accounting and Economics,* (19), March-May.

Bhattacharya, S. and Ritter, J.R. (1983). "Innovation and communication: Signalling with partial disclosure". *Review of Economic Studies,* (50:2), pp. 331-346.

Blair, M.M. and Litan, R.E. (1990). *Corporate Leverage and Leveraged Buyouts in the Eighties*, Brookings Institution, Washington, DC, USA.

Blass, A.A. and Yosha, O. (2003). "Financing R&D in mature companies: An empirical analysis". *Economics of Innovation and New Technology*, (12:5), pp. 425-447.

Bond, S., Harhoff, D. and Van Reenen, J. (1999). "Investment, R&D, and financial constraints in Britain and Germany". Institute of Fiscal Studies Working Paper No. 99/5, London.

Bougheas, S., Görg, H. and Strobl, E. (2001). "Is R&D financially constrained? Theory and evidence from Irish manufacturing". *Review of Industrial Organization*, (22:2), pp. 159-174.

Brown, J. R. and Petersen, B.C. (2009). "Why has the investment-cash flow sensitivity declined so sharply? Rising R&D and equity market developments". *Journal of Banking and Finance,* (33): pp. 971-984.

Brown, J.R., Fazzari, S.M. and Petersen, B.C. (2009). "Financing innovation and growth: Cash flow, external equity, and the 1990s R&D boom". *Journal of Finance*, (64:1), pp. 151-185.

Brown, W. (1997). "R&D intensity and finance: Are innovative firms financially constrained?". London School of Economics Financial Market Group, London, UK.

Canepa, A. and Stoneman, P. (2008). "Financial constraints to innovation in the UK: evidence from CIS2 and CIS3". *Oxford Economic Papers*, (60), pp. 711-730.

Campbell, J. Y., Lo, A.W. and MacKinlay, A.C. (1997). *The cconometrics of financial markets*. Princeton University Press, Princeton, NJ, USA.

Cho, S. (1992). "Agency costs, management stockholding, and research and development expenditures". *Seoul Journal of Economics*, (5:2), pp. 127-152.

Cornelli, F. and Yosha, O. (2003). "Stage financing and the role of convertible debt". *Review of Economic Studies*, (70), pp. 1-32.

Czarnitzki, D. and Hussinger, K. (2004) "The link between R&D subsidies, R&D spending, and technological performance". ZEW Discussion Paper No. 04-56, Mannheim, Germany.

Czarnitzki, D. and Kraft, K. (2009). "Capital control, debt financing and innovative activity". *Journal of Economic Behavior and Organization*, forthcoming.

Chung, K.H. and Wright, P. (1998). "Corporate policy and market value: A theory approach". *Review of Quantitative Finance and Accounting*, (11:3), pp. 293-310.

David, P.A., Hall, B.H. and Toole, A.A. (2000). "Is public R&D a complement or substitute for private R&D? A Review of the Econometric Evidence", *Research Policy*, (29), pp. 497-529.

Eng, L.L. and Shackell, M. (2001). "The implications of long term performance plans and institutional ownership for firms' research and development investments". *Journal of Accounting, Auditing and Finance*, (16:2), pp. 117-139.

Fazzari, S.M., Hubbard, R.G. and Petersen, B.C. (1988). "Financing constraints and corporate investment". *Brookings Papers on Economic Activity*, (1988:1), pp. 141-205.

Francis, J. and Smith, A. (1995). "Agency costs and innovation: Some empirical evidence". *Journal of Accounting and Economics*, (19:2/3), pp. 383-409.

Friend, I. and Lang, L.H.P. (1988). "An empirical test of the impact of management self-interest on corporate capital structure". *Journal of Finance*, (43), pp. 271-283.

Gilson, R.J. (2003). "Engineering a venture capital market: Lessons from the American experience". *Stanford Law Review*, (55), pp. 1067-1103.

Hajivassiliou, V. and Savignac, F. (2008). "Financial constraints and a firm's decision and ability of innovate: Establishing direct and reverse effects". London School of Economics and Banque de France: manuscript.

Hall, B.H. (1990). "The impact of corporate restructuring on industrial research and development". *Brookings Papers on Economic Activity*, (1990:1), pp. 85-136.

Hall, B.H. (1992). "Research and development at the firm level: Does the source of financing matter?" NBER Working Paper No. 4096.

Hall, B.H. (1993). "R&D tax policy during the Eighties: Success or failure?". *Tax Policy and the Economy*, (7), pp. 1-36.

Hall, B.H. (1994). "Corporate capital structure and investment horizons in the United States, 1976-1987". *Business History Review*, (68), pp. 110-143.

Hall, B.H. (2002). "The financing of research and development". *Oxford Review of Economic Policy*, (18:1), pp. 35-51.

Hall, B.H. (2006). "Measuring the returns to R&D: The depreciation problem". *Annales d'Economie et de Statistique*, N° 79/80, forthcoming.

Hall, B.H., Griliches, Z. and Hausman, J.A. (1986). "Patents and R&D: Is there a lag?". *International Economic Review* (27), pp. 265-283.

Hall, B.H. and Maffioli, A. (2008), "Evaluating the impact of technology development funds in emerging economies: Evidence from Latin America". *European Journal of Development Research*, *(*20:2), pp. 172–198.

Hall, B.H., Mairesse, J., Branstetter, L. and Crepon, B. (1999). "Does cash flow cause investment and R&D: An exploration using panel data for French, Japanese, and United States firms in the scientific sector". In: Audretsch, D., Thurik, A.R. (Eds.), *Innovation, Industry Evolution and Employment*. Cambridge University Press, Cambridge, UK.

Hall, B.H., Thoma, G. and Torrisi, S. (2009). "The market value of patents and R&D: evidence from European firms". UC Berkeley, University of Maastricht, University of Bologna, and University of Camerino, manuscript.

Hall, B.H. and Van Reenen, J. (2000). "How effective are fiscal incentives for R&D? A new review of the evidence". *Research Policy*, (29), pp. 449-469.

Harhoff, D. (1998). "Are there financing constraints for R&D and investment in German manufacturing firms?". *Annales d'Economie et de Statistique* N° 49/50, pp. 421-456.

Harhoff, D. (2009). "The role of patents and licenses in securing external finance for innovation". *EIB Papers*, (14:2), in this issue.

Himmelberg, C.P. and Petersen, B.C. (1994). "R&D and internal finance: A panel study of small firms in high-tech industries". *Review of Economics and Statistics*, (76), pp. 38-51.

Holtz-Eakin, D., Joulfaian, D. and Rosen, H.S. (1994). "Sticking it out: Entrepreneurial survival and liquidity constraints". *Journal of Political Economy*, (102), pp. 53-75.

Jensen, M.C., and Meckling, W. (1976). "Theory of the firm: Managerial behavior, agency costs, and ownership structure". *Journal of Financial Economics*, (3), pp. 305-360.

Jensen, P.H., and Webster, E. (2009). "Macroeconomic conditions and successful commercialization". Intellectual Property Research Institute of Australia WP 04/09, University of Melbourne.

Karaomerliolu, D.C. and Jacobsson, S. (1999). "The Swedish venture capital industry – an infant, adolescent, or grown-up?". Chalmers Institute of Technology, Goteborg, Sweden.

Lach, S. and Schankerman, M. (1988). "Dynamics of R&D and investment in the scientific sector". *Journal of Political Economy*, (97:4), pp. 880-904.

Leland, H.E. and Pyle, D.H. (1977). "Informational asymmetries, financial structure, and financial intermediation". *Journal of Finance*, (32), pp. 371-387.

Lerner, J. (1999). "The government as venture capitalist: The long-run effects of the SBIR program". *Journal of Business*, (72), pp. 285-318.

Magri, S. (2009). "The financing of small innovative firms: The Italian case". *Economics of Innovation and New Technology*, (18), pp. 181-204

Mairesse, J., Mohnen, P. and Kremp, E. (2006). "The importance of R&D and innovation for productivity: A re-examination in light of the French innovation survey". *Annales d'Economie et de Statistique* N° 79/80, forthcoming.

Majumdar, S.K. and Nagarajan, A. (1997). "The impact of changing stock ownership patterns in the United States: Theoretical implications and some evidence". *Revue d'Economie Industrielle*, (82), pp. 39-54.

Miller, M.H. and Modigliani, F. (1961). "Dividend policy, growth, and the valuation of shares". *Journal of Business*, (34), pp. 411-433.

Modigliani, F. and Miller, M.H. (1958). "The cost of capital, corporation finance and the theory of investment". *American Economic Review*, (48), pp. 261-297.

Mulkay, B., Hall, B.H. and Mairesse, J. (2001). "Investment and R&D in France and in the United States". In: Deutsche Bundesbank (Ed.), *Investing Today for the World of Tomorrow*. Springer Verlag.

Nelson, R.R. (1959). "The simple economics of basic scientific research". *Journal of Political Economy*, (49), pp. 297-306.

OECD. (1995). *Venture Capital in OECD Countries*. Organization for Economic Cooperation and Development, Paris.

OECD. (2007). *OECD Science, Technology and Industry Scoreboard 2007*. Organization for Economic Cooperation and Development, Paris.

Opler, T.C. and Titman, S. (1994). "Financial distress and corporate performance". *Journal of Finance*, (49:3), pp. 1015-1040.

Opler, T.C. and Titman, S. (1993). "The determinants of leveraged buyout activity: Free cash flow vs. financial distress costs". *Journal of Finance*, (48:5), pp. 1985-1999.

Pugh, W.N., Jahera Jr., J.S. and Oswald, S. (1999). "ESOPs, takeover protection, and corporate decision making". *Journal of Economics and Finance*, (23:2), pp. 170-183.

Rajan, R.G. and Zingales, L. (1998). "Financial development and growth". *American Economic Review*, (88:3), pp. 558-586.

Savignac, F. (2008). "Impact of financial constraints on innovation: What can be learned from a direct measure?". *Economics of Innovation and New Technology*, (17), pp. 553-569.

Scherer, F.M. (1998). "The size distribution of profits from innovation". *Annales d'Economie et de Statistique* N° 49/50, pp. 495-516.

Szewczyk, S.H., Tsetsekos, G.P. and Zantout, Z.Z. (1996). "The valuation of corporate R&D expenditures: Evidence from investment opportunities and free cash flow". *Financial Management*, (25:1), pp. 105-110.

Takalo, T. and Tanayama, T. (2008). "Adverse selection and financing of innovation: is there need for R&D subsidies?". Bank of Finland and University of Jyväskylä; HECER.

Warda, J. (2008). "B-index for R&D cost: international comparison". OECD, Paris.

Williamson, O.E. (1988). "Corporate finance and corporate governance". *Journal of Finance*, (43), pp. 567-591.

Zantout, Z.Z. (1997). "A test of the debt monitoring hypothesis: The case of corporate R&D expenditures". *Financial Review*, (32:1), pp. 21-48.

ABSTRACT

Venture capital is considered to be the most appropriate form of financing for innovative firms in high-tech sectors. *We provide an assessment of venture capital looking at the involvement of venture capital with some of Europe's most innovative and successful companies: those listed on Europe's 'new' stock markets. Venture capital is effective in helping these firms overcome credit constraints but has a limited effect on their ability to grow and create jobs. This result clashes with the evidence on the role of VC for US companies. Yet, VC is not only about money but also about steering and supporting portfolio companies, activities which depend on venture capitalists' educational and organizational background as well as on the legal and cultural environment in which they operate.*

Laura Bottazzi (laura.bottazzi@unibocconi.it) is professor of economics at Bologna University, researcher at IGIER (Bocconi University) Milan as well as research fellow at Fondation Banque de France and senior fellow at Rimini Centre for Economic Analysis.

The role of venture capital in alleviating financial constraints of innovative firms

Laura Bottazzi

1. Introduction

It has long been discussed in academia and among policy makers whether firms are hindered in their performance by the lack of finance. Researchers have documented through surveys that firms report the lack of provision of risk capital and the inefficient functioning of the financial markets as important obstacles to their growth, investment and innovation, justifying government intervention to alleviate financial constraints.

The success of US venture capital (VC) funds in supporting dynamic companies, which create jobs and wealth, brought many governments to look for ways to nurture a national venture capital industry. Several official documents of European governments and institutions suggest bolstering venture capital and revamping the regulation of stock markets as remedies to Europe's economic sluggishness and dismal unemployment (*e.g.* European Commission 1998 and Committee of Wise Men 2001). At the same time, the high returns enjoyed by US venture capital firms induced venture capitalists to become active in other countries, too.

The aim of this article is to provide an overview of the role of venture capital in affecting innovative firm performance, thereby answering two relevant questions: firstly, how important is venture capital in alleviating financial constraints of innovative firms; secondly, what is the role that venture capital really plays in the financing of firms. To obtain a convincing answer we turn to firm-level data. In particular, we use evidence derived from two datasets that we have gathered and which are to some extent complementary: a dataset on VC-backed firms (Bottazzi and Da Rin 2002) and a dataset on European venture capitalists (VCs) for the period 1997-2001. Although rather comprehensive the data can not capture the more recent development of the VC industry.

The article is organized in six more sections. Section 2 discusses the extant literature and evidence on firm credit constraints. Sections 3 to 6 analyse the role of venture capitalists, in the financing of innovative firms, as well as the determinants of their investment style. Section 7 examines evidence on the role of VCs across firms in Europe and discusses the relationship between investor activities and performance. Section 8 presents conclusions and policy implications.

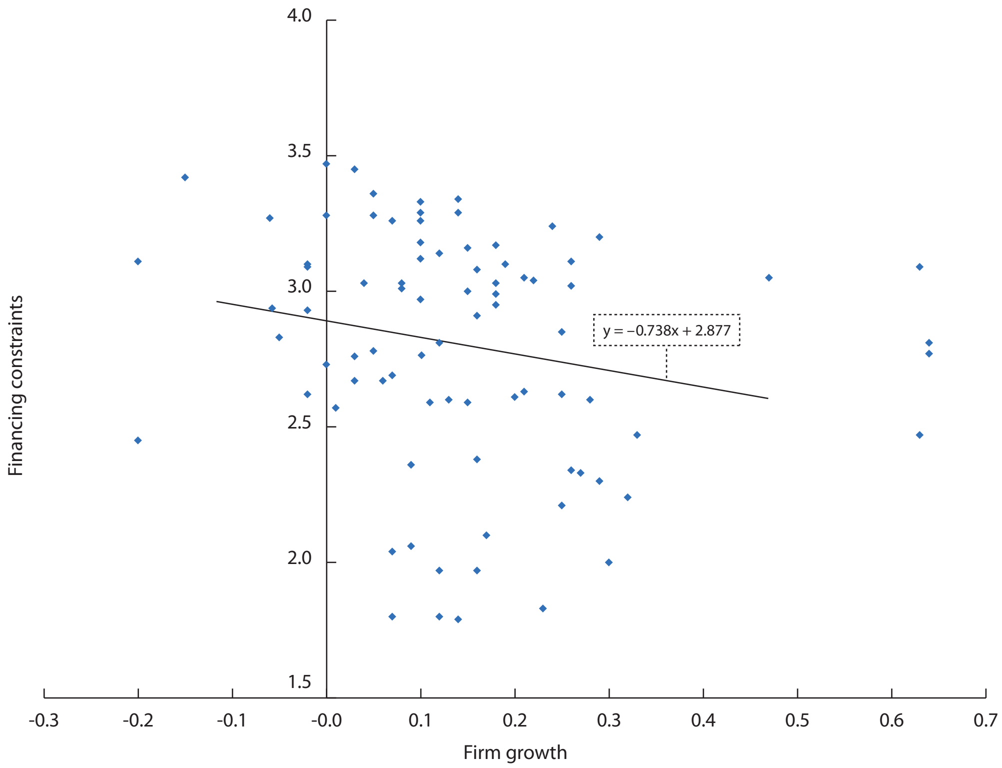
2. The evidence on credit constraints

Understanding the obstacles to firm growth has been a challenging aspiration of researchers in finance and economics. Researchers have documented that low government quality, macroeconomic instability as well as many features of the business environment are important impediments to firms' growth. In particular, several papers have identified the important role of financing obstacles. Rajan and Zingales (1998) show that industries that are more dependent on external finance grow faster in countries which have been able to develop a better financial system. Demirgüç-Kunt and Maksimovic (1998) and Beck, Demirgüç-Kunt and Maksimovic (2005) (hereafter BDM) provide evidence that firms consider the quality of the financial system and of the legal enforcement, as well as the level of corruption, as the three most important factors affecting firm's external financing constraints.

More recently, Ayyagari, Demirgüç-Kunt and Maksimovic (2008) (hereafter ADM) use evidence from the World Business Environment Survey (WBES), a major firm level survey conducted by the World Bank in 1999 and 2000 in 80 developed and developing countries around the world.[1] By comparing the economic relevance of the reported obstacles they find that finance, crime and policy instability are the most significant.

Stronger financing constraints are associated with slower firm growth.

Figure 1. Growth and financial contraints



Source: ADM (2008)

Note: "Firm growth" is the percentage change in firm sales over the period 1996-99. "Financing" is an index of financial constraints which takes the value 1 to 4, with higher values indicating higher obstacles.

Figure 1 reports average firms' growth (of sales) over the years 1996-99 in the 80 countries considered and the index of financing obstacles, which takes values from 1 to 4, with higher values indicating greater obstacles, averaged over all the firms in each country. The graph shows a significant negative correlation between firm growth and financing constraints. ADM discern which components of the financing obstacles can be deemed the most significant. They find that collateral requirements of banks and financial institutions, the need of a special connection with banks and financial institutions, the lack of money to lend by banks and the difficult access to financing for leasing equipment are all elements which significantly influence firms' growth. Interestingly, the finance obstacle is binding regardless of which country or firms are included in the sample although larger firms are affected to a significantly lesser extent.

There exists also a more direct effect of the lack of finance. As documented by Haussman *et al.* (2004), the population of firms is itself endogenous, as financing constraints affect the creation of new entrepreneurial firms, while, as shown by BDM, firms' size distribution adapt to the business environment. A large proportion of the literature in this area has concentrated on analysing the effect of financial variables (cash flow) on fixed capital investment. Fazzari, Hubbard and Petersen (1988) (hereafter FHP) use firm-level panel data on 427 US manufacturing firms from 1970 to 1984. They divide firms into three fixed categories (low,

1 See Dollar *et al.* (2004), Gelb *et al.* (2007), Carlin *et al.* (2005) and Svejnar and Commander (2007).

medium, high) by the level of dividend payout, which is assumed to be a proxy of the financial constraints and estimate investment functions with cash flow and Tobin's Q (where 'Q' represents the ratio of the market value of a firm's existing shares (share capital) to the replacement cost of the firm's physical assets) as explanatory variables. As long as Q reflects firm's investment opportunities adequately, sensitivity of investment to cash flow could suggest that capital markets are not perfect and financial constraints matter. They find significantly larger estimated coefficients of cash flow for the low-dividend-payout firms than the high-dividend-firms. The correlation of investment with cash flow in "financially-constrained" firms has also been confirmed by several other studies with different cross-sectional criteria or with different countries' panel data (Hoshi *et al.* 1991; Schaller 1993).

Investment is more sensitive to cash-flow variations in low-dividend than in high-dividend firms.

Subsequent research has addressed several problems involved in this empirical literature. There are some important issues. First of all, several researchers consider that a sufficient indicator for representing investment opportunities is marginal Q, which is the present value of expected future marginal returns to capital, and not average Q as in FHP (Whited 1992; Hubbard *et al.* 1995). Gilchrist and Himmelberg (1995) construct the expected value of marginal q conditional on observed fundamentals including cash flow ("fundamental Q"), by estimating a set of VAR forecasting equations. Gilchrist and Himmelberg (1998) introduce financial friction into their model and consider two variables that affect investment, "fundamental Q", the expected present value of future marginal productivity of capital, and "financial Q", the expected present value of a future financial state variable of the firm. They find that investment is significantly correlated to both measures for the average firm in their sample and detect no sensitiveness of investment to liquidity for bond rating firms but find liquidity effects for unrated firms, small firms or low-dividend-payout firms. Cummins *et al*. (2006), by using earning forecasts from securities analysts, construct more direct measures of the fundamentals that represent future profitability. Their surprising result is that internal funds are not correlated to investment spending even for selected firms, for example, those without bond rating or dividend payout, which have been found to be "financially constrained" in other studies.

Kaplan and Zingales (1997) question the relevance of the country grouping implemented by FHP as well as their results. They re-examine 49 firms that are grouped as low-dividend-payout firms in FHP and further divide those firms into five categories, by their own operational classification criteria, based on statements contained in annual reports of these firms. They assume that a firm does not face "financing constraints" if it can invest more at a given point in time. Using this definition, they find that in 85 percent of all observations (firm-year pairs) of FHP's sample, the firms are not financially constrained, since they could have increased their investment.

Bond *et al*. (2003) construct firm panel data sets for manufacturing firms in Belgium, France, Germany and the United Kingdom for the period 1978-1989 and estimate a range of investment equations (accelerator, error correction and Euler equation specifications) including additional financial variables (cash flow and profits) by using General-method-of-moment (GMM) techniques which control for biases due to both correlated effects and lagged dependent variables. Their main aim is to compare results for the same investment model across different countries. They find that financial variables play an important role in France, Germany and the United Kingdom. More robustly, cash flow and profit terms are found to be both statistically and quantitatively more significant in the United Kingdom than in other European countries, implying that financial constraints may be more severe in the more market-oriented UK financial system.

The issue of financing constraints is even more pertinent for innovative firms, given the nature of their products. Funding projects with external finance is costly to these firms due to the strong information asymmetry associated with innovative investments. R&D results cannot be easily used as collateral[2] and most inputs to the innovative process are firm-specific or specific to the product developed. As a

2 See Hall (1992).

consequence an external financier cannot expect to recover a significant share of the investment in case of an unsuccessful project. In addition, given the innovativeness of the projects, firms are unwilling to reveal the detail of the project. As a result, they may find it difficult and costly to raise external funds for their investment financing (Myers and Majluf 1984).

R&D tends to be more reliant on cash-flow in the US and the UK with their market-based financial systems than in other developed countries.

Hall *et al*. (1999) construct more comparable panel data of firms in the high-tech sectors in the United States, Japan and France. Using a VAR methodology, they test for causal relationship between liquidity variables (sales and cash flow) and investment variables (capital investment and R&D), and find that both capital investment and R&D are more sensitive to cash-flow and sales in the United States than in Japan and France. This result is quite comparable to that of Bond *et al*. (2003) and hints at financial constraints possibly being more severe in the United States or the United Kingdom with their market-based financial systems.

Empirically, the existence of financial constraints for innovative firms is most frequently investigated by examining the sensitivity of R&D investment to financial factors (Himmelberg and Petersen 1994; Harhoff 1998; Mulkay *et al.* 2001). Most of these studies find a large and significant relationship between R&D and internal finance for small US firms in high-tech industries. The results for Europe are less conclusive (Harhoff 1998).

Could venture capital alleviate financial constraints of innovative firms?

3. The role of venture capital

There exists a wide consensus among economists, business leaders and policy-makers that a vibrant venture capital industry is a cornerstone of America's leadership in the commercialisation of technological innovation. A related and widely held belief is that the lack of VC hinders European firms from competing on an equal footing (European Commission 1994), although the lack of data has limited the analysis of European VCs for a long time.

The maturation of the VC industry in the US has not been smooth (Gompers 1994). During the 1980s, VC firms were in large part publicly funded Small Business Investment Companies (SBICs). While SBICs trained many venture capitalists and helped the industry reach a critical mass by channelling large sums to start-ups, their ability to perform was limited by bureaucratic constraints, lack of professional expertise, a faulty design of capital structure and incentives (Lerner 1994a). The big change for VC came in 1979 when the relaxation of investment rules for US pension funds led to historically large inflows from these investors.

Until the early 1990s, venture capital remained essentially an American phenomenon. In 1998, the United States and then Europe woke up to the Internet and VC started looking also at Europe, opening up London offices or establishing joint ventures. In Europe, because of the poor exit alternatives offered by the stock markets, funds developed mainly from banks and financial institutions, supported by their own limited resources.

The development of the VC industry has experienced periods of boom and bust because it is a highly pro-cyclical activity. Many funds had been raised, which were invested at the peak of the dot-com boom, and quite a few were managed by self-assured people new to VC. After the dot-com bubble burst, in 2000, funds stopped making new investments in order to concentrate on their existing portfolios, reduce headcounts, and revaluate their investment.

Table 1 shows the evolution of VC fund-raising and investment from 1996 to 2007 in the US and in Europe. Although fund-raising had increased at a similar pace in the two economies until 2000, when it was about five times as large as in 1996, it diverged in 2002, when venture investment came close to a halt in the United States, going below its 1995 level. Europe, by contrast, shows more resilience and its investment was still substantially higher in 2002 than in 1996.

Table 1. Funds raised and invested in VC in Europe and the US

	Funds raised		Funds invested	
	Europe	US	Europe	US
1996	5,546	9,891	4,009	9,676
1997	9,537	22,360	4,625	14,931
1998	9,432	22,031	6,738	19,190
1999	11,526	25,919	11,390	54,111
2000	24,948	106,181	18,192	100,622
2001	17,940	37,961	10,898	39,030
2002	9,204	3,774	9,236	21,300
2003	8,834	10,641	9,520	19,300
2004	11,335	19,156	15,239	22,100
2005	26,368	28,767	17,297	22,900
2006	14,300	31,925	9,506	20,300
2007	51,017	36,065	48,046	30,600

Source: EVCA (2007)
Notes: Data in million of current dollars. The funds raised and invested each year may diverge, since VC firms invest the money they raise over a three-to-five-year time span, accumulating resources when good investment opportunities are scarce.

Venture capital has become, by now, a sizeable industry also in Europe, as Table 2 shows, and the form of financial intermediation most closely associated with dynamic entrepreneurial start-ups, especially in high-tech industries like biotechnology, information technology (IT), and e-commerce. Many of today's most dynamic and successful corporations received venture capital at the initial stages of their lives: Amazon, Apple, Cisco, e-Bay, Genentech, Genetic Systems, Intel, Microsoft, Netscape, and Sun Microsystems, to name just a few. Venture capital also works in more traditional areas; Federal Express, Staples, and Starbucks, all received venture financing.

Venture capital is the form of financial intermediation most closely associated with dynamic start-ups in high-tech industries.

Table 2. Venture capital in the US and in Europe
VC invested (percent of GDP)

Year	Europe	USA
2000	0.22	1.01
2001	0.13	0.38
2002	0.10	0.20
2003	0.08	0.17
2004	0.10	0.18
2005	0.11	0.18
2006	0.07	0.15

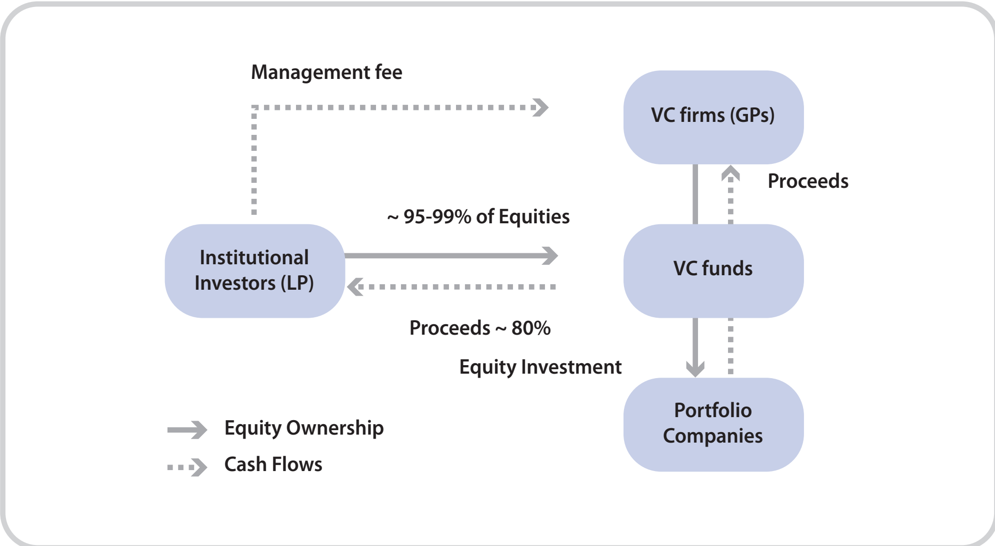
Source: EVCA (2007) and Eurostat

4. Venture capital governance structure

Venture capitalists are financial intermediaries who collect funds from limited partners and invest them in firms with a 5- to 10-year horizon.

Venture capitalists are financial intermediaries who organize limited partnerships to finance their activity by raising funds from institutional investors, such as pension funds, insurance companies, or endowments that are passive *limited partners* (LPs) (Figure 2). Typically, these funds raise equity at the time they are formed, and raise additional capital when investments are made. This additional capital usually takes the form of debt when the investment is collateralizable, such as in buyouts, or it may be equity from syndication partners, as in a start-up. Gaining a reputation for having produced good returns is a key determinant of future successful fund-raising.

Figure 2. Venture capital governance structure



Professional private-equity fund managers, who serve as general partners (GPs), invest each "fund" in a number of firms with a five- to ten-year horizon. As long as the basic covenants of the fund agreement are followed, LPs do not intervene in the GPs' investment decisions. Common covenants include restrictions on how much fund capital can be invested in a single company, the types of securities a fund can invest in, and restrictions on debt at the fund level (as opposed to borrowing at the portfolio company level, which is unrestricted). Once a "fund" is ended – by sale to another company, an Initial Public Offering (IPO), or recapitalization – its cash proceedings are distributed to investors together with any remaining equity holdings.

Some VC funds are publicly quoted. In this case they do not return capital to investors after realization but they pay dividends, as any other public company. In the United Kingdom (Jenkinson 2008), there are currently over 100 venture capital trusts (VCTs), which are quoted investment vehicles focussing on smaller companies and whose development was encouraged by government providing generous tax-relief to individual investors.

The compensation structure of VCs implies LPs paying an annual management fee of 1 to 3 percent and a carried interest representing up to 20 percent of the profits of the partnership. Generally, only capital gains above a certain annual percentage return, the so-called hurdle rate, are considered for the carried-interest calculation.

5. What do venture capitalists do?

Venture capitalists also provide portfolio firms with expert advice and stringent performance incentives.

Venture capital is a specialized form of financial intermediation. Its success in supporting innovative companies, through the provision of finance and expert advice together with stringent incentives to perform, has generated much research interest. Venture capitalists' expertise and their network of contacts with potential suppliers and customers (Hochberg *et al.* 2007) allow entrepreneurs to focus on what they are best at: technical development.

VCs concentrate on start-up firms and use their knowledge of industries and markets to evaluate and mentor entrepreneurs. The role of venture capital in this context is potentially very important. Their strong commitment to generate high returns in the medium term makes them active investors in portfolio companies (*e.g.* Bottazzi *et al.* 2008; Gorman and Sahlman 1989; Lerner 1995). In particular, VCs speed up product commercialization (Hellmann and Puri 2000), the adoption of human-resource policies (Hellmann and Puri 2002) and they strengthen companies' commercialization strategies (Gans *et al.* 2002; Hsu 2006). They can therefore "make the difference" by effectively directing portfolio companies' strategies towards commercial success. VCs also provide 'reputation capital' (Megginson and Weiss 1991) so as to attract top-fly executives or to obtain new contracts.

But venture capitalists are also demanding investors. For instance, they do not provide full financing upfront, but disburse money in instalments at different stages of a firm's development, contingent on the achievement of milestones such as a certain amount of sales, or the hiring of key management figures. Financing at different stages allows VCs to gather information over time, thus keeping the option of abandoning firms whose hopes of success have dwindled. VCs are also found to closely oversee investee firms, and to be active board members who step in and take control when times get difficult. The combination of the "soft" and "hard" components of VCs' activity is widely seen to provide venture-backed start-ups with an advantage over others firms, since it should increase the chances of their survival.

Some recent analyses of the influence of venture capital on corporate strategy and performance provide even stronger evidence that non-financial aspects are crucial to define the activity of VCs. Venture investors are "company builders" who influence innovation as much as professionalization and commercialization strategies. This view, based on the double-moral-hazard model of VC of Holmstrom and Tirole (1997),[3] stresses the active role of venture capitalists as mentors and monitors of inexperienced entrepreneurs (Baker and Gompers 2003; Gorman and Sahlman 1989; Lerner 1995).

There is also another possible, though opposite, view of the role of venture capitalists'. They attract companies which already have good growth opportunities (Sørensen 2007), so that venture investors would mainly need to bring them to a successful exit. According to this view, venture investors are particularly good at timing market conditions (see Gompers *et al.* 2008). They invest in companies at the "right" time with the goal to take them public (or sell them) at the "right" moment (Michelacci and Suarez 2004). Therefore, they finance companies whose innovation strategies are already well developed, with the perspective of turning them soon into "cash cows" (Bottazzi and Da Rin 2002). Verifying which of these two views is closer to reality is important both from a management and from a policy point of view.

Finally, venture capitalists also play an important role in the process of going public. Their experience helps companies choose the most favourable time for their IPOs and experience lower under-pricing (Megginson and Weiss 1991; Lee and Wahal 2003). Venture-backed companies that went public in the

3 See also Casamatta (2003), Hellmann (2006) and Schmidt (2003).

US in the 1970s and 1980s are also found to perform better subsequently than non venture-backed companies. VCs shield companies from the need to rush to markets, thus prematurely disclosing strategic information to competitors. They also allow firms to wait for the most favourable market conditions before going public.

However, whether venture firms affect strategies at the innovation stage remains an open question. This is an important question since it goes to the heart of how venture financing might contribute to the innovation process. Some studies consider how VC stimulates innovation or start-ups. Kortum and Lerner (2002) examine the impact of the provision of VC funds on the rate of patenting for 20 US manufacturing industries over a three-decade period and find a 5-18 percent increase in the rate of patents caused by venture disbursements.

Recent studies have started examining how VC investors contribute to the formation of cooperative alliances for the commercial exploitation of innovations (Gans *et al.* 2002 and Hsu 2006, using US data), and of "explorative" formal R&D alliances (Colombo *et al.* 2006, using Italian data)

6. How do venture capitalists finance companies?

Moral hazard in the relationship between entrepreneurs and venture capitalists can be overcome by a careful allocation of rights.

Start-ups rely on the talent and skills of its founder, making it particularly difficult for financiers to evaluate performance. In addition, the right to control future strategic decisions is even more important in determining success for start-ups than for mature firms. These characteristics of start-ups provide good economic reasons for the coexistence of the 'hard' and 'soft' sides of venture capital. Unlike in standard financial contracting, neither the entrepreneur's effort nor the venture capitalist's mentoring and monitoring are verifiable by a court, and therefore cannot be contracted upon. A start-up therefore creates a situation where both sides have special skills to contribute for which they experience a problem of moral hazard. This situation is fundamentally different from that of a bank loan, and in the context of start-up finance a standard debt contract simply does not work. One of the first decisions in contract negotiations is the type of security issued to the VCs. Separate securities are used for VCs and entrepreneurs in order to give VCs different rights. Rights regarding board control and liquidation, for example, are tied to the VC's stock.

Kaplan and Stromberg (2003) find that convertible preferred stock is the most common security, used in 204 of the 213 financing rounds existing in their study.[4] The "convertible preferred" aspect of the stock allows the VC to convert the stock into a common stock if the company does well, and to use the stock like a bond if the company does poorly. Even in cases where common stock is used, VCs get a different class of common stock with different rights from those of the founders. Similarly, contracts allow for different cash flow rights for venture capitalists and founders. Cash flow rights determine how the pie will be split between VCs and entrepreneurs once the company goes public, and the split is often contingent on performance measures. In the sample contracts, the VC usually controls approximately 50 percent of the cash flow rights on average, the founders control 30 percent, and others control 20 percent, indicating that founders give up a large fraction of ownership. Liquidation cash-flow rights and redemption rights work together to protect the venture capitalist's investment if the company is sold or performs poorly. In nearly all cases, VCs have claims in liquidation that are senior to the common stock claims of founders. In 98 percent of the cases, VC claims are at least as large as their investment. Board and voting rights allow VCs to have input in decisions on top

4 Kaplan and Stromberg base their study on a sample of 213 investments in 119 companies by 14 VC firms. Each firm provided the contractual agreements governing each financing round in which the firm participated. When available, the VC firm also provided the company's business plan, internal evaluations of the investment, and information on subsequent performance.

management, corporate strategies and any other action not already specified in the original contract. In some cases, provisions are made so that VCs will get full control of the board if the company performs poorly. In first venture capital rounds, almost half of the cases allow VCs to have voting majority.

Kaplan and Stromberg find that VC financings include a number of additional terms and conditions beyond the basic rights. For example, VC financings often include automatic-conversion provisions under which the security held by the venture capitalist automatically converts into common stock under certain conditions. These conditions require that certain financial targets be met, and almost exclusively depend on an initial public offering that exceeds a designated common stock price. If the company goes public for a high value, the VCs only keep their cash flow rights, ceding the majority of control to the entrepreneurs. At some point after VCs give up control, they sell their stock and move on to new investments. An automatic-conversion provision is present in 95 percent of the financing rounds. Financings that include this provision also require that the stock price of the initial public offering be on average three times higher than the stock price of the financing round. The VCs are therefore not willing to give up control unless they triple their money. Many contracts also utilize vesting and non-compete clauses to make it costly for the entrepreneur to leave the firm. Tying the entrepreneur to the firm is particularly important in cases where most of the value of the venture lies in the entrepreneur's unique skills. Vesting clauses also give the VCs a way to remove a badly performing Chief Executive Officer (CEO) without having to keep him or her as a potentially obstructing minority investor down the road. The vesting provision requires that the entrepreneur's shares vest over time, and thus if the entrepreneur leaves before the end of the vesting period, they will lose all of their stock.

VC financings often feature the automatic conversion of the venture capitalist's security into common stock.

Most of the contracts contain at least one contingency clause. Additional funding is contingent on subsequent performance and actions. Along with financial performance, VCs may also consider such indicators as product performance, approvals by the Federal Drug Administration (FDA) or patent approvals. VCs can and do write contracts with a variety of contingencies, indicating managerial actions that the VC is trying to induce or avoid.

7. The European venture capital industry

How effective is European venture capital in nurturing fast-growing companies? Has the growth in the size of the industry corresponded to a growing ability to support the creation of innovative companies? The only way to obtain a convincing answer is to turn to firm-level data. In particular, we use evidence derived from two datasets that we have gathered and which are to some extent complementary: a dataset on VC-backed firms (Bottazzi and Da Rin 2002) and a dataset on European VCs for the period 1997-2001 (Bottazzi *et al.* 2004).

7.1 Evidence on corporate growth

The first dataset tries to infer the effect of VCs on companies that went public on Euro.nm, the alliance of Europe's 'new' stock markets for innovative companies in high-growth industries, from its inception in 1996 to December 2000. The companies' data are collected from listing prospectuses which contain detailed balance sheet information. Such information is not confined to the IPO year, but extends back in time, up to the three previous years. We use prospectuses and annual reports to derive quantitative information on several financial and business variables. We also collect data for all the available post-IPO years from annual reports. The final data set consists of 511 companies[5] together with data about

5 Companies in the financial services sector are excluded because their financial structure, funding requirements and strategic behaviour differ substantially from those of industrial and (non-financial) services companies (see Bottazzi *et al.* 2007).

the financing from VCs and their involvement with these companies. We were able to collect data on the extent of ownership and on the timing of VC financing while the exact amount of funding generally remains undisclosed. An advantage of looking at Euro.nm listed companies is that they belong to a small number of high-tech industries, are of fairly similar age, and come from a small number of countries. This makes them a relatively homogeneous group of 'venturable' companies where we naturally find a reliable control sample, avoiding sample design problems. Focusing on Euro.nm listed companies also gives an advantage: Companies which make it to the stock market are among the most dynamic ones, and therefore we expect VC to be involved with them. Indeed nearly a third of Europe's VCs finance companies listed on Euro.nm.

Higher sales and profitability tend to decrease the probability of VC financing, underlining the role of VC at early stages of firm development.

Theory predicts VC to be associated with young innovative companies that, being at an early stage of development are characterised by low profitability and a small amount of sales. We create a dummy that takes a value of one if a company has obtained VC financing and we estimate the probability of being VC-backed. To avoid endogeneity the independent variables are measured before the arrival of the first venture capitalist. Controlling for sectors and national market effects, we do find that higher sales and profitability decrease the probability of obtaining VC financing.[6] These findings are consistent with the view of venture capital getting involved with firms that are at a very early stage of development and not yet able to sell.

We then turn to look at how VCs affect corporate growth by looking at differences in several key variables pre and post-IPO, thereby distinguishing between venture-backed and non venture-backed companies. The results are shown in Table 3. The figures are obtained by taking the median over time of firm-level observations and then averaging these medians across firms. We investigate whether differences between VC-backed and non VC-backed companies are statistically significant. Stars indicate significant differences between the two groups of companies within each period (pre- and post-IPO). By contrast, bold figures show those values which differ significantly across time within each group of companies.

The table shows that virtually all variables differ across time, with the exception of profitability for venture-backed companies and R&D intensity for independent companies. Notably, when we look at the data within periods, we see that before the IPO, venture and non venture-backed companies do not differ systematically. We find statistically significant differences only in four variables: profitability, sales and employment, which are lower for VC-backed companies, and R&D intensity, which is higher. After the IPO, non VC-backed firms become significantly bigger in terms of intangible assets, sales (which we interpret as a sign of maturity) and capital expenditure. Both types of companies show the same level of leverage while the percentage of foreign sales abroad is higher for VC-backed companies. We do not find a significant difference between venture-backed companies in terms of post-IPO employment or equities.

Although the analysis of Table 3 is suggestive, it can not be considered conclusive. We need to control for the characteristics of the firms in order to ascertain the impact on venture financing on corporate growth. We thus turn to a regression analyses (not reported) but the results we obtain are similar. In Bottazzi and Da Rin (2002) we estimate the determinants of the average growth rate of employment and sales in the period up to three years after the IPO.[7] VC itself plays no role: if anything, it brings about a decrease in the employment growth, which is however statistically insignificant. By contrast,

6 By contrast, being a French firm or a firm in the biomedical sector increases the probability of VC backing.

7 The model we have in mind is very simple: the capacity of an innovative firm to grow is a function of its ability to invest, which can be financed either from revenues or from external finance (debt or equity). Age is an indicator of the stage of corporate development and is also relevant because we expect younger companies to grow faster.

leverage, age and country are relevant explanatory variables. For example, German companies have a 31 percent higher employment growth rate.

Table 3. The effects of venture financing: VC-backed and non VC-backed companies before and after going public

Company indicator	Venture capital involvement	Pre-IPO	Post-IPO
Assets	non-VC-backed	14.3	55.3*
	VC-backed	10.7	45.5*
Debt	non-VC-backed	4.3	16.6*
	VC-backed	3.8	11.4*
Equity	non-VC-backed	1.7	34.9
	VC-backed	1.4	28.1
EBITDA	non-VC-backed	1.1*	2.4
	VC-backed	0.2*	0.7
Leverage	non-VC-backed	0.8	0.33
	VC-backed	0.8	0.31
ROA	non-VC-backed	0.13*	0.05*
	VC-backed	0.05*	0.02*
Sales	non-VC-backed	13.2*	33.5*
	VC-backed	9.8*	21.9*
Employees	non-VC-backed	85*	210
	VC-backed	62*	175
Capital expenditure	non-VC-backed	0.7	6.8*
	VC-backed	0.5	4.8*
Foreign sales (percent)	non-VC-backed	0.27	0.02*
	VC-backed	0.35	0.19*
Intangible assets	non-VC-backed	0.21	7.7*
	VC-backed	0.24	3.6*
R&D intensity	non-VC-backed	0.07*	0.09
	VC-backed	0.13*	0.11

Source: Bottazzi and Da Rin (2002)

Notes: Variables are in levels. For each variable we report the average values of the medians for the (up to) three years before the IPO or after the IPO, separately for non-venture-backed and for venture-backed companies. Bold figures indicate statistically significant differences across time (5-percent significance level) as diagnosed by a Wilcoxon test. Stars (*) indicate statistically significant differences between VC-backed and non-VC-backed companies within a given time period (5-percent significance level, using Kruskal-Wallis sign-rank test). Financial data are in millions of euro. Debt is the sum of book value of short and long-term liabilities. Equity is total shareholders' equity. Leverage is debt over debt plus equity. Capital expenditure equals investment in property, plants and equipment. ROA is return on assets computed as operating margin over assets, and operating margin equals EBITDA (earnings before interest, taxes, depreciation, and amortization), an accounting measure of profitability. R&D intensity equals R&D expenditure over sales.

All in all, European VC-backed firms are not the superstars among the firms listed on the New Markets.

When we restrict our sample to the more innovative (*i.e.* R&D-performing) companies, we finally find that VC does play a role: venture-backed companies decrease their sales after the IPO. Age and leverage retain their negative effect on sales, while profitability and country become insignificant. All in all, the results show that VC-backed firms are not the "superstars" among those listed on the New Markets.

VC involvement has little influence on the time to listing but is positively related to the amount raised at IPOs.

Finally, we look at two other dimensions on which VCs might play a role: the time to listing (TTL) – defined as the period of time between the birth of the firm and the IPO – and the amount of capital raised at IPO. VC turns out to have little effect on the TTL of European companies listed on the "New Markets" but it has a positive and significant effect on the amount raised at IPO. By contrast, for the US the National Venture Capital Association claims US venture-backed companies were 70 percent more likely to become listed than other start-ups that within the same period of time (NVCA 1998).

We interpret these findings as suggesting that the role of VC in Europe is somewhat different from that in the United States. The provision of early-stage financing, which has grown very fast in the past three years, seems to be crucial to allow innovative start-ups to overcome credit constraints, which are arguably tighter on the old continent. These companies then go public to raise capital, invest, and grow, consistently with the relaxation of credit constraints *via* the IPO. But we cannot say at this stage whether the lack of a systematic association with the most successful innovative companies is due to the immaturity of European VC or to a lack of "superstars" among young European firms.[8]

7.2 Evidence on venture capitalists in Europe

A tentative answer to the question left open in the previous sub-section can be found by looking at our second dataset which helps understand the peculiarity of the European VC industry. Through a questionnaire sent to 780 VCs firms in the 15 EU countries, Switzerland and Norway, we have obtained information on more than 150 funds, 480 GPs, 600 LPs (investors), and 1,300 portfolio companies in Europe. This information is relative to funds raised and investments made between January 1998 and December 2001, and to the partners active at the end of that year focussing on the pure VC financing, excluding firms which operate solely in leveraged buy-outs (LBOs) and management buy-outs (MBOs).[9] Not surprisingly, the big three European private equity markets – France, Germany, and the U.K. – show the largest number of firms financed.

Our sample is quite representative of the entire population of European venture firms. As Table 4 shows, the respondents are fairly evenly distributed among countries with most national response rates close to the overall rate of 15 percent.

Information gathered shows that venture capitalists' partners range widely in age, but most of them with an average work experience as VCs of seven years, ranging from zero to 32 years. There is a large share of partners with less than five years of experience which indicates that nearly half of them must come from other occupations; nearly half of all partners have professional experience in the financial sector, and about 40 percent have professional experience in the corporate sector.

8 A sensible objection to our interpretation is that, since all companies listed on Euro.nm received a high valuation, the true value of being venture-backed had been masked.

9 We contacted only those venture firms which, in 2001, (i) were members of the European Venture Capital Association (EVCA) or of a national VC organization, (ii) were actively engaged in VC and (iii) were still in operation in 2002. We thus deliberately excluded pure MBO management buy-out firms. The overall response rate was 15 percent. We received 118 responses with various degrees of completeness. We then spent considerable time augmenting the data with information from a variety of sources, such as the websites of the respondents and commercially available databases like Amadeus or Zephyr.

Table 4. Country composition and response rate

	Population	Sample	Response Rate (percent)
Austria	23	8	34.8
Belgium	34	4	11.8
Denmark	29	4	13.8
Finland	33	6	18.2
France	101	14	13.9
Germany	146	19	13.0
Greece	8	4	50.0
Ireland	15	3	20.0
Italy	37	5	13.5
Luxembourg	3	1	33.3
The Netherlands	52	4	7.7
Norway	22	2	9.1
Portugal	10	2	20.0
Spain	38	10	26.3
Sweden	17	6	35.3
Switzerland	43	6	14.0
UK	139	21	15.1
Total	750	119	15.8

Source: Bottazzi *et al.* (2004)

Another intriguing finding concerns the educational attainment of European venture capitalists. More than three-quarters of venture capitalists have a graduate degree. Business degree is common. Graduate scientific education, while less common, is far from negligible: 11 percent have a Master in engineering or sciences, and over 16 percent a Ph.D. Most of the Ph.D.s are in natural sciences. It is surprising that less than a third have an engineering or science education. However, we have seen that a scientific background is most popular among Ph.D.s. This suggests that while relatively few in number, partners educated in science have a strong background.

Although VC is considered a local phenomenon we note that a significant number of VC firms have secondary offices: one out of four opened a secondary office, most of them in France and in the U.K. It also shows the countries where these are located. Within Europe, the Netherlands and Germany registered the most secondary offices. We also find a considerable amount of cross-border integration at the partnership level. Overall, nearly a quarter of all partners come from another country, suggesting that the largest markets for venture capital are "exporting" venture expertise.

There is considerable cross-border integration at the partnership level and a high level of cross-border investment.

Surprisingly, the data show a high level of cross-border investments. We find 314 foreign venture deals in our survey, which constitutes nearly a quarter of our sample investments. The most active cross-border investors are Germany, Switzerland and the U.K. Within Europe, the U.K. and France attracts the most foreign investments.

Overall, our data show a surprisingly high integration of the European VC industry at all levels. This changes the common perception of VC as a purely local business and of European VCs limiting themselves to investing in the domestic economy. Naturally, the US also has an influence on the

European VC market. While we find that only 8 percent of all European venture capitalists are originally from the US, 34 percent of all European partners have some work experience in the US. Yet the number of partners with specific VC experience in the US is lower, at about 7 percent.

Some types of investors are more widely represented across funds than others, and the share held in each fund also differs across investor types.

A last word is about the investors in VC firms. We look into the types of investor which supply these funds. Table 5 provides a detailed breakdown of these investors. The table shows the average percentage of funds held by each investor type and the percentage of funds that have at least one investor of each type. Bank and institutional investors are the investors which are present in most funds, while corporate venture capitalists invest very selectively. Public investors, who are present in relatively few funds, typically provide a majority of the capital, while corporate investors invest the smallest share. These data thus suggest that different investor types behave quite differently.

Table 5. Investor types

Investor type	Average holding of investor (percent)	Percent of funds in which this investor type is present (percent)
Bank investors	40	44
Corporate investors	25	23
Financial investors	30	31
Institutional investors	44	40
Public investors	53	28
Individual investors	45	24

Source: Bottazzi *et al.* (2004)
Note: Average holding of investor is the average percentage of funds held by each type of investor.

7.3 Education, experience and venture capitalists' activism

Compared with their US colleagues, European venture capitalists have the reputation of being conservative and non-interfering ("hands-off"). Our dataset points to the presence of an increasing variety of investment styles across the continent. Sixty percent of all deals are seed or early-stage investments, indicating a healthy level of risk tolerance. In terms of getting involved with their companies, 68 percent of venture capitalists sit on the board of directors, 69 percent monitor their company on a monthly or weekly basis, and 42 percent help to recruit key managers for their investment companies. The industry is undergoing changes: new entrant firms invest more at the seed stage and monitor their investments more closely. Interestingly, partners in new entrant firms have more prior professional experience and are more likely to have a business education and a Master's degree. All of these characteristics help to explain why the new entrant firms adopt investment styles that more closely resemble those of US VC firms.

A unique feature of the European market is that a significant number of venture capital firms are owned and managed by banks and corporations. Corporate VC firms, which may also have strategic objectives (Hellmann 2002), invest more in early-stage companies. Partners in these firms have relatively less VC experience although they are more likely to have Master's degrees and/or a science education. By contrast, partners in bank-owned VC firms are more likely to have a business education. Most strikingly, bank VC firms also invest much less in early-stage deals and are less likely to monitor their firms frequently or to sit on the board of directors.

One possible question is whether these investor characteristics influence investor activism and whether an active investment style matters for the success of portfolio companies. In Bottazzi *et al.* (2008) we have examined how human capital and organizational characteristics affect the activity level of VC firms by distinguishing between three types of human capital effects: (i) the accumulation of job-specific knowledge enabling VCs to become better over time at providing services (measured by a partner's years of experience as a venture capitalist); (ii) the partner's knowledge of what it takes to create and run a company (measured by a partner's earlier business experience); and (iii) the partner's formal knowledge (measured by a partner's scientific education). For each of these measures, we construct the average human capital profile of the venture firm. This allows us to examine what kind of human capital is conducive to an active investment style. In terms of organizational structure, we emphasize the distinction between private, independent VC firms and so-called captive firms, which are affiliated with corporations, banks or the government.

Experienced partners of independent VC firms are more activist investors, which tends to boost exit performance.

Our first central finding is that human capital and organizational structure are significantly related to investor activism. Venture firms whose partners have prior business experience are significantly more active in the companies they finance. Interestingly, the partner's VC experience itself does not have a significant effect on this, and science education has only little effect. In terms of organizational structure, we find that private independent VC firms are significantly more involved with their portfolio companies than captive firms.

Information about different partner roles inside VC firms allows us to examine the allocation of tasks within venture firms. We find that having more venture experience or business experience increases the likelihood that a partner is put in charge of supervising portfolio companies. Within VC firms, greater venture experience has a positive and significant effect on the level of activism.

The next important step is to examine whether these activities affect performance. We are faced with two main challenges: measurement and identification. Concerning the first, ideally one would like to measure investor returns but VC returns are not publicly available. We therefore follow the extant literature and adopt an approach similar to Gompers *et al.* (2008) and Sørensen (2007) of measuring performance by whether the invested companies experience a successful exit, defined either as an IPO or an acquisition.

We examine the influence of investor activism on exits, controlling for a possible endogeneity effect, since investors might be more active with companies that are facing performance challenges. We find that a positive relationship exists between investor activism and exit performance, and that this relationship is both statistically and economically significant.

These results provide some important answers to the question about what makes venture capital firms effective investors. The strongest predictor of whether a VC firm adopts an active investment style is whether the partners have prior industry experience. Moreover, activism seems to improve performance. These findings are interesting since in many countries venture capitalists have more financial than industry backgrounds. However, one should not simply conclude that hiring partners with prior industry experience will always increase activism and improve performance.

Our study is not the only one that analyses the effect of experience on VC. In a concurrent research project, Gompers *et al.* (2008) examine the role of experience on the investment behaviour of VC firms. They provide evidence that prior deal flow experience helps VC firms to take advantage of deal opportunities by ramping up investments when opportunities improve, and that ramp-up often leads to a better exit performance.[10]

10 Gompers *et al.* use US data from Thompson VentureXpert. This has the advantage of providing a long history of VC deals, but also the disadvantage of containing little deal-specific information while in our study we can build direct measures of VCs' human capital.

7.4 Which companies do European venture capitalists finance?

The European venture capital industry is well-diversified.

Contrary to a common perception, and differently from the US, the European venture capital industry did not invest only in fashionable Internet projects. In fact, the industry is surprisingly well diversified across several high-technology industries, with the majority of companies receiving only a single round of financing over the sample period.[11]

Traditionally, it has been argued that European VC favours already existing firms with a track record. But the contrary holds since venture financing at early stages, which typically requires relatively small sums, is becoming more common in Europe: more than half of the financing rounds are at the seed or start-up stage.

Another myth we can debunk is that European venture capitalists do not know how to cooperate. Instead we find that almost half of all deals are syndicated. In fact, more than 75 percent of our venture firms took part in a syndicated deal, and about half took on the role of lead at least once.

An interesting question regards the dynamic evolution of VCs' characteristics as Europe has experienced new entrants in the industry. While partners of new entrants are not younger than the older ones, they differ in other respects such as educational background: they show a higher proportion of Master's degrees and greater emphasis on business education. Also, their overall educational attainment is higher than for the incumbents.

By contrast, analysis of professional backgrounds reveals milder differences. Partners in the younger firms tend to have only slightly more of a consulting, and less of a finance background than their incumbent colleagues.

An intriguing result of our study is that over and above being different from incumbents, new entrants also specialize in different sectors, emphasizing software and Internet deals. Both partners' backgrounds and investment patterns are consistent with the notion that the VC boom of the late nineties was largely driven by business opportunities (in particular the Internet) rather than more technological opportunities. Note, however, that the difference with the old guard is not enormous, mainly because the old guard itself invested heavily in that sector and remains strongest in the biotechnology and medical sectors.

Interestingly, new entrants focus much more on investing in early-stage companies, especially at the seed stage, and tend to be more closely involved with their companies, in terms of a higher monitoring intensity: they are 10 percent more likely to monitor their companies intensively.

Overall we see that the new entrants have adopted an investment style that by and large can be characterized as more risk-tolerant and more hands-on than the older generation of European VC firms.

7.5 The degree of contractual sophistication

Our dataset allows us to study the degree of contractual sophistication of European VCs and to study whether the marked differences which exist across countries in legal and tax environments influence the appeal of different financial instruments.

11 This is likely to be due to the relatively short time horizon covered in the data.

We define four broad classes of financial instruments: pure debt, convertible debt, pure equity, and preferred equity. The result is that pure equity is the true workhorse of European VC but European venture capitalists are certainly no strangers to more sophisticated contracts such as preferred equity or convertible debt or contingent clauses in their contracts. A contingent clause specifies the circumstances under which a venture capitalist can take certain actions such as liquidating the company, taking control of the board, or firing the CEO. We find that the right to force a trade sale is used in more than half of the cases. Other contingent clauses are less common but they are typically used in at least a third of the deals. On average, each deal entails the use of more than two contingent clauses and more than two-thirds of the deals make use of at least one contingent clause.

Pure equity is the workhorse of European VC but more sophisticated contracts are also used.

In addition to crafting financial deals, VCs can play an important role in terms of monitoring and supporting their companies. More than a third of VCs state that they visit their portfolio companies at least monthly, reflecting an active attitude regarding the management. Moreover, for 66 percent of companies we find that VCs monitor them by taking a board seat, thus contributing directly to honing strategies.

In Bottazzi *et al.* (2009), we examine how optimal contracts, and the resulting investor behaviour, depend on the legal system. We propose a simple theory that makes three predictions. First, the better the legal system the more investors provide value-adding support. The underlying intuition is that investing in support activities is only worthwhile if the legal system provides investors with sufficient guarantees that these efforts will not be wasted. Second, the better the legal system, the higher is investors' demand for contractual downside protection using securities such as debt, convertible debt or preferred equity. The main intuition is that in a better legal system it is optimal to give the entrepreneur stronger upside incentives. In order to satisfy their participation constraint, investors thus require additional cash flow rights on the downside. Third, we consider the influence of the legal system on intermediaries' incentives to develop the competencies necessary to provide value-adding services, predicting that intermediaries from countries with a better legal system will provide more value-adding services, even when investing abroad.

We find clear empirical support for our theoretical predictions. Better legal systems are associated with more investor involvement and more downside protection for the investors. The results hold for legal origin, using the standard interpretation that the Anglo-Saxon common law system is better for investors than systems based on civil law. They also hold for two widely used index measures of the quality of the legal system: the rule of law and the degree of legal procedural complexity.[12]

Furthermore, the data allow us to examine whether the effects of legal systems come through the company or the investor, an issue that has not yet been fully answered in the earlier literature. We introduce a novel empirical approach of determining the relative importance of company and investor legal-system effects comparing two sets of regressions: one with company legal-system variables and investor country fixed effects, the other with investor legal system variables and company country fixed effects.

We find robust investor legal-system effects, that is, such effects are present whether our equations do or do not control for company country fixed effects. However, company legal-system effects are not robust: they cease to be found when the analysis takes into account investor country fixed effects.

12 Legal scholars classify national legal systems according to the legal origins of the commercial code: legal systems with common-law origin and legal systems with civil-law origin. The rule of law index measures the quality of legal enforcement while the index of procedural complexity measures the degree of legal formalism by averaging the cost, length of time and number of steps necessary to perform two simple legal operations, like recovering a bounced check and evicting a tenant.

These results are consistent with the theoretical model prediction that investors from countries with stronger legal protection provide more support and demand more downside protection. They suggest that the legal system affects financial transactions not only directly, but also indirectly by affecting the practices adopted by financial intermediaries. In particular, they point to the importance of considering the relationship between investor and entrepreneur in its entirety, accounting both for contractual and non-contractual aspects. Moreover, the analysis shows how the legal system affects not only contracts, but also investors' actions and their investment styles. These findings also have implications for our understanding of cross country differences.

7.6 Do different types of venture capital firms behave differently?

The last question we ask is whether different types of venture capitalists – independent, bank, public and corporate VC firms – behave differently.

There is a debate about whether we should expect each of these firm types to invest differently. For instance, one may ask whether banks are well positioned to take a leadership role in the origination of early-stage venture deals, or whether a strategic motivation precludes corporate investors from investing in lower-technology companies.

Independent, corporate, public and Bank VC firms differ with respect to partner profiles, sector of activity and investment stage.

The results are interesting. First, in terms of age and experience of partners across the four different types of venture firms, independent VCs have twice as much experience as corporate or public VCs. Regarding education, while the percentage of partners with a Master's degree is particularly high among corporate VCs, who also have the highest percentage of partners with a graduate degree, public VCs show distinctly lower average educational attainment. Independent and corporate VCs are very similar in this respect, preferring people with an engineering or science education. By contrast, bank VCs show a particularly strong preference for people with a business education and public VCs for those with a background in humanities or social sciences. Strikingly, no partner of a public VC firm has a science background.

Not only do different types of venture capital firms hire different kinds of partners, they also make different types of investments. We see that public venture capitalists stayed away from software and Internet investments. Unlike other venture firms, they also concentrated most of their investments on industrial products, biotech and the media. They are, therefore, much less diversified, as a category, than the others. Interestingly, corporate investors chose to stick to their industrial expertise, contributing a large share of investments in medical products and industrial services, while investing relatively little in software, the Internet and the media. Bank-backed venture firms were the most aggressive investors in Internet deals as well as in industrial products.

Different types of VC firms also emphasize different stages of investment. Independent and corporate VCs are similar in their focus on earlier investment stages, which is definitely more pronounced than that of bank or public venture firms. The commitment to monitor or take a board seat is also quite different across types of venture firms. We say that VCs have a high monitoring intensity if they personally interact with a company at least on a monthly basis. Independent VCs have the highest monitoring intensity, closely followed by corporate investors. Once again, bank and public VCs behave differently and interact less frequently with the firms they invest in.

Overall, we find considerable differences in the investment styles between independent, public, corporate, and bank venture capitalists.

8. Conclusions

Does venture capital alleviate financial constraints of innovative firms? Preliminary analyses of the role of venture capitalists in Europe shows that, in the period 1997-2000, VC is not associated with particularly dynamic or successful companies, whether we look at sales growth or employment. This result clashes with the evidence of the role of VC on US companies.

Yet, VC is not only about money. It is also about steering and supporting portfolio companies. This is done in a number of ways which differ depending on VCs' educational and organizational background as well as on the legal and cultural environment in which they operate.

Human capital is a key driver of the investment activities of venture capital firms since it affects the level of activism of VCs and, ultimately, the success of portfolio companies. Improving the availability of postgraduate education, including executive education or other professional training, is likely to have a very positive effect on the level of professionalism in the industry. Interestingly, Europe has experienced new entrants in the industry during the tech-bubble 1999-2000. Overall we see that Europe's new entrants to the VC industry have adopted an investment style that, by and large, can be characterized as more risk-tolerant and more hands-on than that of the older generation of VC firms, closer to the US investment style.

Cross-country activity within Europe – and across the Atlantic – shows promising signs of an integrating market. European venture capitalists clearly consider it important to be able to invest outside their own country. Simplifications of tax rules and cross-border investment regulations are likely to have a strong beneficial impact on the integration of the European VC industry.

Lower regulatory barriers and simpler tax rules would foster the internationalization of VC and the demand for VC funds.

Finally, the data document a wide variety of behaviours by different types of venture firms. It is important to encourage healthy competition among these different approaches to venture financing. Reducing red tape and increasing limited partners' ability to invest in all types of venture firms, as well as across borders, are likely to serve this purpose.

More generally, as other researchers have suggested, the greatest assistance to venture capital may be provided by government programs that seek to enhance the demand for these funds rather than the supply of capital.

References

Ayyagari, M., Demirgüç-Kunt, A. and Maksimovic, V. (2008). "How Important Are Financing Constraints? The role of finance in the business environment". World Bank, mimeo.

Baker, M. and Gompers, P. (2003). "The Determinants of Board Structure at the Initial Public Offering". *Journal of Law and Economics*, (46), pp. 569-598.

Beck, T., Demirgüç-Kunt, A. and Maksimovic, V. (2005). "Financial and Legal Constraints to Firm Growth: Does Firm Size Matter". *Journal of Finance*, (60:1), pp. 137-177.

Bond, S., Elston, J.A., Mairesse, J. and Mulkay, B. (2003). "Financial factors and investment in Belgium, France, Germany, and the United Kingdom: A comparison using company panel data", *Review of Economics and Statistics*, (85:1), pp. 153–165.

Bottazzi, L. and Da Rin, M. (2002). "Venture Capital in Europe: Euro.nm and the Financing of European Innovative Firms", *Economic Policy*, (17:1), pp. 229-269.

Bottazzi, L., Da Rin, M. and Hellmann, T. (2004). "The Changing Face of the European Venture Capital Industry: Facts and Analysis". *Journal of Private Equity*, (7:2), pp. 26-53.

Bottazzi, L., Da Rin, M. and Hellmann, T. (2008). "Who are the Active Investors? Evidence from Venture Capital". *Journal of Financial Economics*, (89:3), pp 488-512.

Bottazzi, L., Da Rin, M. and Hellmann, T. (2009). "What Role of Legal Systems in Financial Intermediation? Theory and evidence". *Journal of Financial Intermediation*, (18), pp. 559-598.

Casamatta, C. (2003). "Financing and Advising: Optimal Financial Contracts with Venture Capitalists". *Journal of Finance*, (58:5), pp. 2059-2085.

Carlin, W., Schaffer, M. and Seabright, P. (2005). "Where are the Real Bottlenecks? A Lagrangian Approach to Identifying Constraints on Growth from Subjective Survey Data". Centre for European Policy Research Discussion Paper No. 5719.

Committee of Wise Men (2001). "Final Report of the Committee ofWise Men on the Regulation of European Securities Markets", Brussels. http:\\europa.eu.int/comm/internal market/en.

Colombo, M., Grilli, L. and Piva, E. (2006). "In Search of Complementary Assets: The Determinants of Alliance Formation of High-tech Start-ups". *Research Policy*, (35:8), pp. 1166-1199.

Cummins, J.G., Hassett, K.A. and Oliner, S.D. (2006). "Investment behavior, observable expectations, and internal funds". *American Economic Review*, (96:3), pp. 796–810.

Demirgüç-Kunt, A. and Maksimovic, V. (1998). "Law, finance, and firm growth", *Journal of Finance*, (53), pp. 2107-2137.

Dollar, D., Hallward-Driemeier, M. and Mengistae, T. (2004). "Investment Climate and Firm Performance in Developing Countries", World Bank, mimeo.

European Commission (1994). "Green Paper on Innovation". Brussels. http:\\europa.eu.int/en/record/green/gp9512

European Commission (1998). "Risk Capital: A Key to Job Creation in the European Union", Brussels. http:\\europa.eu.int/comm/off/com/riskkal.

EVCA (2007). *EVCA Yearbook 2007*, European Private Equity and Venture Capital Association, Brussels, Belgium.

Fazzari, S., Hubbard, R. and Petersen, B. (1988). "Financing Constraints and Corporate Investment", *Brookings Papers on Economic Activity*, (1988:2): pp. 141-195.

Gans, J., Hsu, D. and Stern, S. (2002). "When Does Start-up Innovation Spur the Gale of Creative Destruction?". *RAND Journal of Economics*, (33:4), pp. 571-586.

Gelb, A., Ramachandran, V., Manju Kedia Shah and Turner, G. (2007). "What Matters to African Firms? The Relevance of Perceptions Data". World Bank Policy Research Working Paper No. 4446.

Gilchrist, S. and. Himmelberg, C.P. (1995). "Evidence on the role of cash flow in reduced-form investment equations". *Journal of Monetary Economics*, (36), pp. 541-572.

Gilchrist, S. and Himmelberg, C.P. (1998). "Investment, fundamentals and finance". NBER Working Paper No. 6652.

Gompers, P.A. (1994). "The Rise and Fall of Venture Capital". *Business and Economic History*, (23), pp. 1-24.

Gompers, P., Kovner, A., Lerner, J. and Scharfstein, D. (2008). "Venture Capital Investment Cycles: The Impact of Public Markets". *Journal of Financial Economics*, (87:1), pp. 1-23.

Gorman, M. and Sahlman,W. (1989). "What do Venture Capitalists Do?". *Journal of Business Venturing*, (4:2), pp. 231-248.

Hall, B.H. (1992). "Investment and Research and development at the firm level: Does the source of financing matter?". NBER Working Paper No. 4096.

Hall, B.H., Mairesse, J., Branstetter, L. and Crepon, B. (1999). "Does cash flow cause investment and R&D: An exploration using panel data for French, Japanese, and United States scientific firms", in Audretsch, D. and Thurik, A.R. (eds.), *Innovation, Industry Evolution, and Employment*, Cambridge University Press, Cambridge, UK.

Harhoff, D. (1998). "Are there Financing Constraints for R&D and Investment in German Manufacturing Firms". *Annales d'Economie et de Statistique*, (49-50), pp. 422-456.

Hausmann, R., Rodrik, D. and Velasco, A. (2004). "Growth Diagnostics". Harvard University Working paper.

Hellmann, T., (2002). "A Theory of Strategic Venture Investing". *Journal of Financial Economics*, (64:2), pp. 285-314.

Hellmann, T. (2006). "IPOs, acquisitions, and the use of convertible securities in venture capital". *Journal of Financial Economics*, (81:3), pp. 649-679.

Hellmann, T. and Puri, M. (2000). "The Interaction between Product Market and Financing Strategy: The Role of Venture Capital". *Review of Financial Studies*, (13:4), pp. 959-984.

Hellmann, T. and Puri, M. (2002). "Venture Capital and the Professionalization of Start-ups: Empirical Evidence". *Journal of Finance*, (57:1), pp. 169-197.

Himmelberg, C. and Petersen, B. (1994). "R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries". *Review of Economics and Statistics*, (76:1), pp. 38-51.

Hochberg, Y., Ljungqvist, A. and Yang Lu (2007). 'Whom You Know Matters: Venture Capital Networks and Investment Performance", *Journal of Finance*, (62:1), pp. 252-302.

Holmstrom, B. and Tirole, J. (1997). "Financial Intermediation, Loanable Funds, and the Real Sector". *Quarterly Journal of Economics*, (112:3), pp. 663-691.

Hoshi, T., Kashyap, A. and Scharfstein, D. (1991). "Corporate Structure, Liquidity, and Investment: Evidence from Japanese Industrial Groups". *Quarterly Journal of Economics*, (106:1), pp. 33-60.

Hsu, D. (2006). "Venture Capitalists and Cooperative Start-up Commercialization Strategy". *Management Science*, (52), pp. 204-219.

Hubbard, R.G., Kashyap, A. and Whited, T.M. (1995). "Internal finance and firm investment". *Journal of Money, Credit and Banking*, (27:3), pp. 683-701.

Jenkinson, T. (2008). "The development and performance of European private equity". OFRC Working Papers Series 2008fe17, Oxford Financial Research Centre.

Kaplan, S. and Zingales, L. (1997). "Do Financing Constraints Explain Why Investment is Correlated with Cash Flow?" *Quarterly Journal of Economics*, (112), pp. 169-215.

Kaplan, S. and Stromberg, P. (2003). "Financial Contracting Theory Meets the Real World: An Empirical Analysis of Venture Capital Contracts". *Review of Economic Studies*, (70:2), pp. 281-315.

Kortum, S. and Lerner, J. (2002). "Assessing the Contribution of Venture Capital to Innovation". *RAND Journal of Economics*, (31:4), pp. 674-692.

Lee, P.M. and Wahal, S. (2004). "Grandstanding certification and the underpricing of venture capital backed IPOs". *Journal of Financial Economics*, (73:2), pp. 375-407.

Lerner, J. (1994). "Venture Capitalists and the Decision to go Public". *Journal of Financial Economics*, (35:1), pp. 293-316.

Lerner, J. (1995). "Venture Capitalists and the Oversight of Private Firms". *Journal of Finance*, (50:1), pp. 301-318.

Megginson, W. and Weiss, K. (1991). "Venture Capital Certification in Initial Public Offerings". *Journal of* Finance, (46:3), pp. 879-903.

Michelacci, C. and Suarez, J. (2004). "Business Creation and the Stock Market". *Review of Economic Studies*, (71:2), pp. 459-481.

Mulkay, B., Hall, B.H. and Mairesse, J. (2001). "Firm Level Investment and R&D in France and the United States: A Comparison". Nuffield College Economics Papers 2001-W2, University of Oxford.

Myers, S. and Majluf, N.S. (1984). "Corporate financing and investment decisions when firms have information that investors do not have", Journal of Financial Economics, (13), pp. 187-221.

National Venture Capital Association (NVCA) (1998). *Eighth Annual Economic Impact of Venture Capital Study*, study conducted by Coopers & Lybrand and Venture One, Arlington, USA.

Rajan, R. and Zingales, L. (1998). "Financial dependence and growth", *American Economic Review*, (88), pp. 559-587.

Schaller, H. (1993). "Asymmetric Information, Liquidity Constraints and Canadian Investment". *Canadian Journal of Economics*, (26:3), pp. 552-574.

Schmidt, K. (2003). "Convertible Securities and Venture Capital Finance". *Journal of Finance*, (58:3), pp. 1139-1166.

Sørensen, M. (2007). "How Smart is Smart Money: An Empirical Two-Sided Matching Model of Venture Capital". *Journal of Finance*, (62:6), pp. 2725-2762.

Svejnar, J. and S. Commander, (2007). "Do Institutions, Ownership, Exporting and Competition Explain Firm Performance? Evidence from 26 Transition Countries". IZA Discussion Paper No. 2637.

Whited, A.M. (1992) "Debt, liquidity constraints and corporate investment: Evidence from panel data", *Journal of Finance*, (47:4), pp. 1425-1460.

ABSTRACT

Global policy discussions increasingly focus on innovation and the knowledge economy as a driver of long-term growth. *In parallel new forms of innovation processes are emerging, notably open innovation and innovation networks stressing the importance of connections between various stakeholders. Links between universities and the business sector are of particular importance as many inventions come out of universities but have to be further developed to become economically relevant innovations. New financing instruments and attracting private investors to technology transfer (TT) are necessary but difficult as the pattern of risk and information in this 'in-between area' is complex: Technology is not basic anymore and it requires large amounts of capital to be scaled up – with uncertain market prospects. This paper addresses new financial instruments for TT, building on European Investment Fund's experience in this field.*

Jacques Darcy (darcy@eif.org) heads product development and incubation at European Investment Fund (EIF); **Helmut Krämer-Eis** (h.kraemer-eis@eif.org) is head of research and market analysis at the EIF, **Dominique Guellec** (Dominique.guellec@oecd.org) is in charge of the productivity and innovation unit at OECD; **Olivier Debande** (o.debande@eib.org) works on cohesion and innovation policies in the Projects Directorate at the EIB.

Financing technology transfer

Jacques Darcy

Helmut Krämer-Eis

Dominique Guellec

Olivier Debande

1. Innovation and the Knowledge Economy

1.1 Where is Lisbon?

According to the European Commission, "Europe's research and industrial base suffers from a series of weaknesses. The greatest perceived weakness, however, is Europe's comparatively limited capacity to convert scientific breakthroughs and technological achievements into industrial and commercial successes" (*e.g.* European Commission 1994). This assessment has served as major catalyst for making innovation policy a strategic priority for the EC. In its broad-based innovation strategy for the EU, the importance of improving knowledge transfer between public research institutions and third parties, including industry, has been identified by the EC as one of the key areas for action (European Commission 2007b) and reiterated in its recent review of the EU innovation policy (European Commission 2009).

There is the well-known Lisbon-objective that the EU shall become in 2010 "the most competitive knowledge-based economy of the world" (Lisbon Summit 2000) with expenditures of 3 percent of GDP for R&D. However, with only a few months left in 2009 and despite increased financial efforts and structural reforms implemented in several countries during the past years, Europe has not significantly improved its competitive position (Guellec and Sachwald 2008). Europe will not be able to meet the target in 2010, so what is necessary to improve the situation in the future?

Strengthening EU invention capacity is a necessary but not sufficient condition as already stressed by Schumpeter (1951) "Economic leadership must be distinguished from invention. As long as they are not carried out into practice, inventions are economically irrelevant". Future growth will be determined by the Schumpeterian entrepreneur being able to transform the invention and new knowledge into practice through innovation. In this context, the term "marriage of new knowledge with its successful introduction into the marketplace" is often used (*e.g.* Baumol *et al.* 2007, p. 5).

1.2 Innovation is key

Hence, stronger innovation is the key element. The Oslo manual (OECD, Eurostat 2005) defines Innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relation. The minimum requirement for an innovation is that the product, process, marketing method or organisational method must be new (or significantly improved) to the firm".[1] It is – to say it with Peter Drucker's words – the change that creates a new dimension of performance.

The sources and conditions for innovation are variegated. Many innovations, notably non-technological ones (marketing, organisation, distribution *etc.*) come directly from the effort of firms and specialised in-house departments implementing their own ingenuity. However, many other innovations proceed from inventions, often based on R&D performed by high-tech firms or universities. They are more intensive in scientific knowledge, they are often more radical or disruptive (transformative of market conditions). This demonstrates the importance of a high-quality, vibrant university sector which performs the best basic research.

1 Source: http://ec.europa.eu/enterprise/policies/innovation/glossary/index_en.htm

The issue in those cases is how to bring the invention from the lab to the market, gathering both the funding and the knowledge transfer which are required. This is all the less trivial when the invention is made in a university (as opposed to a corporate) laboratory, which usually does not have the skills and incentives to transform the invention into an innovation. The two issues, raising capital and transferring knowledge, cannot be addressed separately: designing the right incentives and sharing risk optimally between the parties requires the two aspects to be solved simultaneously, using then appropriate intellectual-property (IP) and financial instruments. This is the focus of the rest of this paper.

1.3 Small is beautiful – but so is large

Innovative SMEs grow faster and create more jobs than non-innovative SMEs.

Innovation is important for SMEs and corporates – and SMEs and corporates are essential for innovation. Empirical studies show that innovative small and medium-sized enterprises (SMEs) grow faster and create more jobs than non-innovative SMEs. They are the so-called Gazelles. Empirical studies (see *e.g.* KfW 2006) show as well that innovative start-ups (where the creation of the start-up was based on an innovation) create more new jobs than non-innovative start-ups. However, policy measures should not only focus on SMEs. The share of innovative SMEs increases gradually with the size of the companies. As early as 1942, Schumpeter describes the innovative power of bigger enterprises – they have the necessary resources to finance substantial R&D project. These ideas have also been discussed by Galbraith (1952) and Arrow (1962). Policy measures should recognise that large firms are essential for the innovation system. The recent trend of concentrating resources on SMEs ignores the natural ecology of industry. An often neglected target group is the medium-sized firm above the SME threshold. This category probably has the greatest potential for increasing R&D spending but has also been struggling to do so in recent years (Aho 2006).

The contribution of small and medium-sized innovative firms is also key for large firms: many of the smaller firms are acquired at some stage by large ones, which use them as a source of radical innovations that the more closed and stratified context of large firms does not facilitate. At the same time, access to the funding, manufacturing and distribution capacities of a large firm allows in many cases to leverage the innovative performance of small firms. In the information technology or biotechnology sectors this dynamic has been essential to industrial development.

The reasons why Europe is currently not able to meet the Lisbon goals have been discussed extensively in various reports (see *e.g.* Guellec and Sachwald 2008; Aho 2006). The connection between academia, which generates new inventions, and the business sector, which can transform them into innovations is too weak. Innovative businesses face difficulties to access capital and markets; reasons are risks, external benefits associated to R&D programmes, and the cost structure (high fixed costs, low marginal costs). Hence the need for new financial instruments as part of public policies to boost technology transfers between universities and businesses and to ease the setting-up of new businesses exploiting university inventions.

1.4 Knowledge exploitation

Knowledge creation and diffusion are more and more integrated into the notion of open innovation (see OECD 2008), corresponding to the increased organisation of innovative activities across firm boundaries to optimise the use of internal and external sources of innovation. The sourcing of external knowledge and the commercialisation of in-house innovations leads to the emergence of new networks to share and exchange knowledge. In turn, the development of innovation networks helps create new markets for ideas and technologies to facilitate the exchange of Intellectual Property (IP) between parties, the signing of research contracts or the creation of spin-outs. New forms of knowledge exploitation and the creation of technology markets require the design of appropriate financial instruments to support the circulation and commercialisation of knowledge.

Such an evolution should be connected to Europe's own ability to turn new ideas and inventions into products and services responding to client needs. In addition, the European technological landscape is still mainly supply-side oriented partially due to the lack of adequate matching interfaces between the supply and demand for scientific knowledge.

There is a lack of matching interfaces between supply and demand of scientific knowledge in Europe.

Dissemination of created knowledge and commercialisation of IP rights are closely connected to the different phases of growth of technology start-ups. They broadly evolve through the following phases of development from downstream to upstream investment:

- "Technology transfer" phase: from invention and IP generation to business concept, proof-of-concept phase and first customers;
- "Venture" phase: developing a product line, broadening the customer base and establishing a full-fledged business;
- "Expansion" phase: Once the business opportunity is proven, the business needs to expand, distribution channels need to be set up, marketing efforts need to be developed and large-scale production capabilities need to be put in place.

Across Europe, it is often the first and third phases that are most difficult to finance.[2]

2. Converting research into products

Technology transfer (TT) can be broadly defined as the process of converting scientific findings from research organisations into useful products by the commercial sector. TT is also known as "knowledge transfer or knowledge sharing". This is the process whereby an enterprise converts scientific findings from research laboratories and universities into products and services in the marketplace.[3] TT can take three main channels (Figure 1):

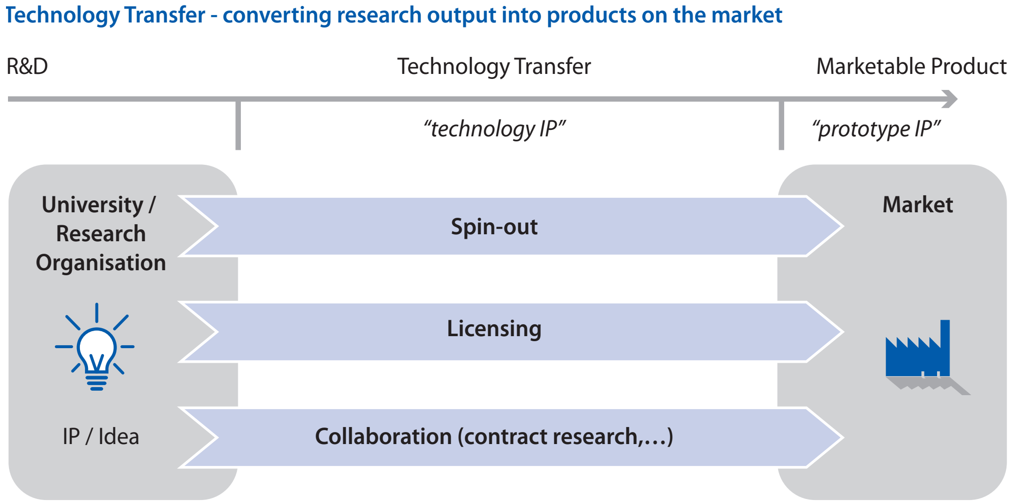
- The creation of new companies (spin-outs), which often involves some transfer of personnel (mobility of researchers);
- Collaboration between universities, research organisations and industry notably via research contracts; and/or
- Licensing of IP.

TT presents specific features discussed in this paper. Many such features are also found in other areas of "upstream investing" (Business Angels, Clusters, pre-seed, seed investments).

2 Other related market segments like pre-seed and seed investments, Business Angel investing and clusters/incubators face similar challenges.

3 See also: http://ec.europa.eu/enterprise/policies/finance/index_en.htm.

Figure 1. The idea of TT from universities/research centres to the market

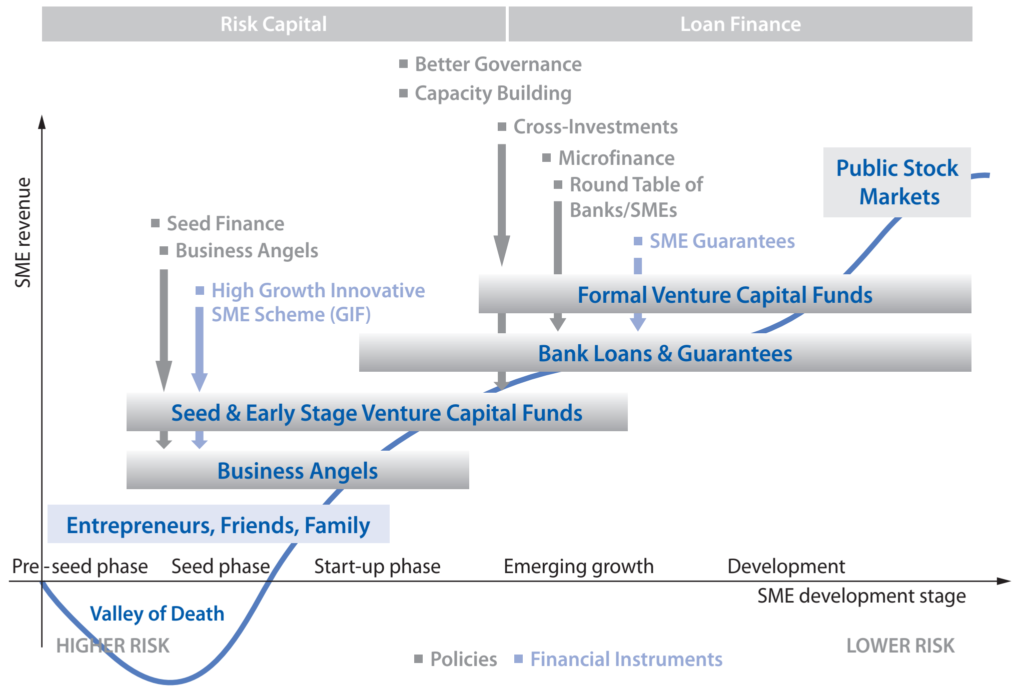


Source: EIF

Technology transfer is most relevant in the early stages of an innovative company's life-cycle.

Figure 2 below summarises the SME life cycle and the related financing needs. TT is to be seen on the left hand side of the graph. But this only captures technology transfer incompletely. TT or the commercialisation of research also takes many other forms than the SME life cycle (licensing, corporate venture *etc.*). Box 1 provides a more elaborate presentation of the importance of licensing.

Figure 2. Positioning of TT in the company/spin-off market segment



Source: European Commission (2009a)

Box 1. Exploiting patents through licensing[1]

Various types of licensing are practiced, including unilateral licensing, cross-licensing and patent pools, all of which involve an agreement by the owner of a patent (licensor) to allow another party (licensee) to make, sell and use the patented invention on an exclusive or non-exclusive basis, without transferring ownership of the patent. Usually, a licensor receives financial rewards in exchange for the licence, typically in the form of royalty payments. Licensing is therefore one suitable mechanism for transferring technology between licensors who want to leverage their technological assets and licensees who want to complement their internal technological capabilities. The advantages and disadvantages of licensing can vary from one case to another. In some cases, a patent licence itself is not sufficient to enable a licensee to bring a new product or service to the market because additional know-how is needed, in the form of documentation, software, samples, training and consulting services.

Table B1. Advantages and disadvantages of patent licensing

	Inward-licensing
Advantages	• Licence payments tend to be less costly than in-house R&D • Payment can be used to control risks by prudent design of payment scheme • Shortens the time required for R&D and bringing new products into markets • Lower risks when an invention has already been commercialised
Disadvantages	• Some restrictions in licensing agreements may raise antitrust concerns
	Outward-licensing
Advantages	• High profitability, although revenue streams are uncertain • Allows multiple licensees at the same time • Less risky than Foreign Direct Investment (FDI) • Simplicity if licensee does not need technical advice (only contract drafting needed) • Especially for SMEs, lowers risk by eliminating need for downstream production facilities
Disadvantages	• Potentially creates rivals in downstream markets who could erode future profits • Total profit is usually smaller than with successful internal development • Returns depend on capability of licensees to develop and market the invention

Source: Kamiyama *et al.* (2006)

As will be explained in Section 3, the size and evolution of technology licensing markets is difficult to measure. Accounting rules do not require firms to disclose patent licensing revenues as a separate item in corporate reports, and although most OECD countries have regulatory requirements for reporting licensing contracts, these are mostly related to cross-border transactions, and data are published only at an aggregate level. As a result, disclosure of patent licensing activity depends largely on firm policy. Even though disclosure of information on

1 This box is based on Kamiyama *et al.* (2006).

licensing revenues has been shown to have a positive effect on investors, most firms choose not to make such information public. Hence, available data on patent licensing is limited, scattered, and lacking in uniformity in spite of demand for more systematic data by policy makers, investors and academics.

One of the most direct benefits of patent licensing is generating revenue for the patent holder. In recent years, a number of firms have been able to generate considerable royalties from outward licensing of technology. IBM Corp., which started to more actively manage its IP rights in the late 1990s and obtained more than 3,000 US patent grants per year on average between 2000 and 2004, received more than USD 1 billion in annual revenues from licensing royalties and sales of IP rights; about half of these revenues came from licensing. Other technology-intensive firms also report significant amounts from patent licensing.

Licensing appears to be concentrated in high-technology sectors. In an OECD survey, respondents from the ICT sector were the most likely to report increases in outward licensing (about 80 percent of respondents), suggesting that outward-licensing has become an important source of revenue for ICT firms. In contrast, respondents from the pharmaceutical industry were most likely to report increases in inward-licensing (about 80 percent of respondents), reflecting the trend of licensing-in from small biotechnology firms. International licensing also appears to be on the rise and accounts for a significant share of total patent licensing. Receipts from world-wide licensing appear to have grown steadily since the mid-1980s. While receipts remain considerably higher in the United States than in the EU or Japan, growth rates in the latter have been equal or faster over the past 20 years.

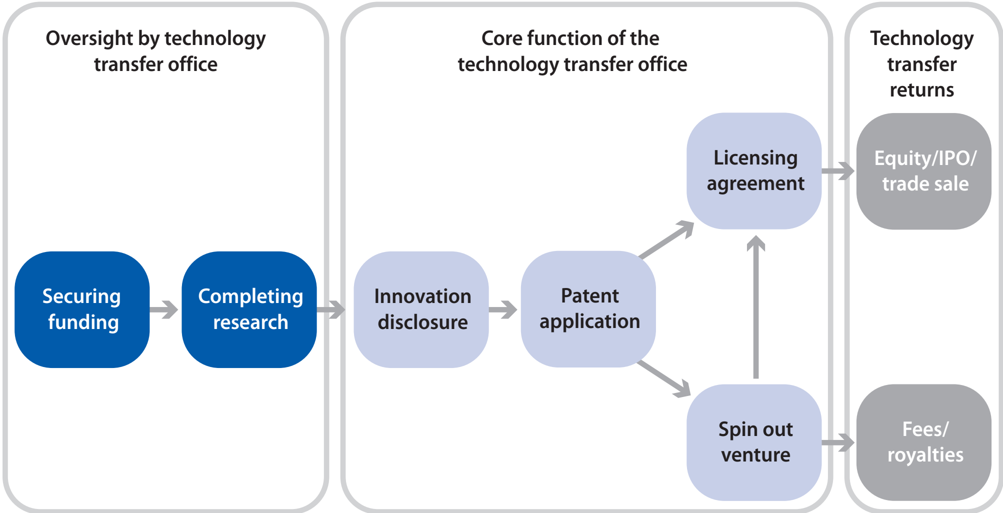
At the national level, indicators of technology licensing also show significant increases. In European countries, OECD data on receipts from international licensing and transfers of patents show steep increases in France and Germany during the 1990s. In France receipts increased by more than a factor of seven between 1990 and 2003 from EUR 330 million to EUR 2.4 billion (not taking into account inflation), while in Germany they doubled from EUR 1.3 billion to EUR 2.7 billion. In contrast, receipts remained relatively flat in Italy at roughly EUR 200m to EUR 300m per year.

Technology transfer often involves a formal transfer of rights to use and commercialise new discoveries and innovations resulting from scientific research to another party. The TT process also covers funded research, innovation disclosure, patents, licensing and sometimes new start-up ventures. Returns on TT are primarily in the form of licensing royalties, but also include sponsored research, one-off transactional fees and new venture equity. Figure 3 summarises the TT process from the securing of funding to the generation of TT returns, considering the core functions of a technology transfer office (TTO).

When early-stage funds dry up and late-stage funds are not yet available, companies face a funding gap.

The TT "funding gap" describes a situation in the life-cycle of a start-up/project whereby typical sources of early-stage funding dry up while late-stage sources of funding are not yet available. The TT "funding gap" thus generates a disconnection between early basic research and downstream development. Typically basic research and early target discovery are mainly funded by government grants (sometimes also through philanthropic research funds). Once a technology has reached the proof-of-concept stage, in late preclinical testing in the case of biotech for instance, venture capital (VC) and licensing funds become available and are supplemented by private equity, public offerings and late stage licensing as the technology progresses towards commercialisation. The “funding gap” arises in between, the point where government and philanthropic funds begin to run out but the technology’s risk profile still discourages VC and licensing investments.

Figure 3. Technology transfer process



Source: Seget (2008).

The funding gap has been magnified in the current crisis.

The TT funding gap has been around for some time, but was magnified after the stock market and VC downturn in 2001 and also in the current crisis. Generating a successful initial public offering (IPO) or trade-sale exit for a venture capitalist has become more difficult, which in turn has put increased pressure on associated royalty rates and spin-out terms. As venture capitalists have become more conservative, moving new technologies from public funding to proof of concept has become more challenging.

With regard to the financial gap between the R&D patenting stages and the development (of prototypes, test series *etc.*) and the stage of commercialisation, the difficulty to assess the value of patents limits the advance toward the production stage. To adequately quantify the value of patents and patent portfolios, the licensing potential needs to be analysed. However, selling and buying technology is not costless; for example, initial investment is frequently needed to screen and identify a licensee, an outlay which patent holders are rarely willing to make due to uncertainty on their licensing potential. Patent Value Funds attempt to uncover both the financial gaps faced by the IP holders and their licensing potential. These are institutional funds that invest in patent portfolios, acting as intermediaries, making IP sellers and buyers meet and pulling off contracting easier to both parties.[4]

Therefore, TT can be envisaged as an intermediary institution for technologies and innovations aimed at facilitating the commercialisation and use of IP generated mainly in the research sector. The development of innovation networks linked to major companies and of technology markets, notably around IP exchange platforms creates new opportunities for adequate intermediary structures for innovation. New forms of commercialisation of IPs should be supported by appropriate financial instruments.

4 IP can also be securitised. Names mentioned in the literature in relation to monetisation and securitisation are, for example, Intellectual Ventures, ThinkFire, Capital Value Partners, Ocean Tomo Capital Fund, Microsoft Intellectual Property Ventures. IP can also be transferred via public auctions; a company offering a marketplace is *e.g.* Ocean Tomo Intellectual Capital Equity.

3. A review of the technology transfer market

Data for Europe on the commercialisation of public science have not been available until recently. Information about patenting and licensing is opaque. The size and evolution of technology licensing markets – in general and not only with regard to commercialisation of public science – is difficult to measure because of a lack of robust statistics. This has been confirmed in discussions with leading experts. Most patent licensing is based on private contracts that are subject to confidentiality agreements, meaning that comprehensive time-series data on patent licensing are not available. The TT market is sizeable, also against the background of the EU's innovation strategy. Despite the funding gap TT is a fast growing market. One proxy for the growth in the TT market is to track EU patent applications at the European Patent Office, which experienced a growth of 40 percent between 1997 and 2007 overall, and more than 70 percent for patents owned by universities (OECD 2008).

Compared with licensing, spin-outs play a more important role in Europe than in the US.

The number of university start-ups has started being used as an indicator of TT success, particularly in Europe. However, such a measure ignores the eventual success of such activity and whether or not it is preferable to other forms of TT. This criticism, that undue focus on spin-out companies has negatively affected other transfer mechanisms such as technology licensing, is discussed in the literature but there is little empirical evidence. From various surveys it appears that in comparison with licensing, spin-outs play a more important role in Europe than in the US. But there is no evidence of an optimal spin-out level or an optimal licensing level. According to another line of argument, it is difficult for European TTOs) to find licensing partners for their technologies and they are instead progressing via spin-outs. In a way, European TT offices might be constrained to create the institutional partners (companies) that they do not find readily on the market.

Only a few studies have analysed the success of TT and TTOs. The recent literature analyzing the efficiency and determinants of university TT focuses on studying American universities (*e.g.* Jensen and Thursby 2001; Lach and Schankerman 2008). This is mainly because of their longer history in the commercialisation of academic research and the availability of university-level datasets containing rich information on universities' TT activities. The main findings from recent empirical studies (*e.g.* Proton 2008; ASTP 2008; Business Insights 2008 and Milken Institute 2006) may be summarized as follows:

Technology transfer policies and strategies matter. Studies have underlined the importance of adopting an institutionalized and strategic approach towards the commercialisation of research activities by universities. Such institutional strategies may cover institutional procedures, organizational structures or management processes that allow universities to exploit their R&D portfolio without hampering the fundamental university mission of teaching and research. Maximising TT to industry is not necessarily in conflict with the mission of universities to perform basic research – indeed the opposite can be argued. Several studies (notably by van Looy *et al.* 2006) have shown that researchers who patent more are also those who publish more in scientific journals, controlling for their seniority, field of research *etc*. Survey evidence for the US shows that researchers often lack the interest to participate in TT (Siegel *et al.* 2003; Thursby *et al.* 2001). Theoretical work by Jensen and Thursby (2001) and Macho-Stadler *et al.* (1996) shows that well-defined licensing contracts can help in this respect by providing the right incentive mechanisms to ensure inventors' cooperation in the disclosure of an invention and its later commercialisation. Lach and Schankerman (2008) find strong empirical support for this intuition and show the importance of well-devised inventor royalty sharing rules for university performance in terms of licensing.[5] Based on a panel of US universities they find that universities giving

5 But university patents are not only about creating financial or market value. For example, university patents play an important role in creating knowledge spillovers, building networks with other academics and venture capitalists and catalysing university-industry recognition (Striukova 2009b).

a higher share of royalties to the inventor generate more inventions and higher licensing income. This incentive effect appears to work both by inducing the sorting of scientists across universities and by increasing scientists' efforts. TT outcomes are also a function of commercialisation strategies. Licensing provides the most common mechanism for TT but spin-out companies have become increasingly popular. Licensing agreements tend to work best in established TT offices with access to well-funded research projects. By contrast, spin-out ventures tend to be more prevalent in markets where research funds are more limited and where commercial licensing partners are less willing to share risk on academic research discoveries. However, licensing statistics have to be read carefully – survey results of higher licensing income can be attributed to the higher average age of (US-) university license portfolios. In addition, in the US, licensing income is highly concentrated, with a small number of universities, both private (Harvard, Stanford) and public (the University of California system) making the bulk of the market.

Universities giving a higher share of royalties to inventors generate more inventions and licensing income.

The key role of the intermediary structure. Successful TT not only depends on the quality of the research and the involvement of the inventor, but crucially also on the size and the experience of the TTO. Among others, Siegel *et al.* (2003) find that larger TTOs generate more TT outcomes. TTO experience in the transfer of technology is also important. Friedman and Silberman (2003) and Lach and Schankerman (2004) find that older TTOs execute more licenses, and suggest that efficiency gains arise as TTOs gain experience in the management of university TT. Friedman and Silberman (2003) further suggest that the TTO's age matters because to be successful TTOs need to build a qualitative portfolio of inventions, which takes time. On average, TTOs in the US benefit from larger research endowments and have had more time to develop than their European, Canadian and Australian counterparts. The TT function involves significant time-lags. It is only as TT offices are given the time to develop and mature that they begin to generate sustainable income streams and as a result are able to justify further investment. The ability to build strong relationships with both university faculty and external commercial partners also benefits from time and experience. According to a study by UNU-Merit (Arundel and Bordoy 2006) the key differences between TT practices across countries can be explained by the size of the respective research budgets and the maturity (experience) of the TT function. Moreover, geographical differences in regulations[6] and location contexts have a significant impact on TT practices and results.

The characteristics of public research institutions. A number of recent empirical studies have found that the size of the university, as measured by the number of academic staff is positively related with the amount of TT (*e.g.* Belenzon and Schankerman 2008). Besides size, previous research finds that the research quality of the university also matters. Universities producing higher-quality research, as measured by the quality of their doctoral programmes, generate more licenses and higher licensing income as shown by Chukumba and Jensen (2005). Thursby and Kemp (2002) further suggest that the portfolio of disciplines present at the university could also play a distinctive role as some sciences are more likely than others to produce research that can be transferred to industry. Recent empirical studies find support for this hypothesis and show that the presence of biomedical and engineering faculties appear to be associated with higher levels of patenting and licensing activity (*e.g.* Lach and Schankerman 2008). Moreover, a number of studies have shown that private universities are more efficient, as measured in terms of scientific publications and various outcomes of TT activity (Adams and Griliches 1998; Siegel *et al.* 2003). Beyond these differences in the level of efficiency Lach and Schankerman (2008) show that scientists at private institutions are more responsive to royalty incentives. The wealth of private universities (endowment) and different criteria for the selection of researchers could explain this difference in responsiveness.

6 An interesting tool to compare various national IP regimes can be found here: http://www.eutechnologytransfer.eu/compare.php.

Clusters, proximity and openness still matter. Existing research suggests the importance of geographic concentration for successful university-industry relations (Agrawal and Cokburn 2003) and the relevance of spillovers of academic research (Jaffe 1989; Jaffe *et al.* 1993; Henderson *et al.* 1998). For instance, Mansfield (1998) who explores the relationship between academic and industrial R&D suggests that universities are more likely to license technology to firms located nearby as the further development of the technology often requires further collaborative efforts: TT is often a proximity activity, requiring much face-to-face interaction. The development of open innovation set-ups is expected to strengthen the role of proximity notably to deal with commercialisation of IPs based on tacit knowledge and requiring trust between partners. That said, new communication technologies also enable collaboration among individuals or entities based in different locations.

Is Europe so different from the US? US TTOs are more effective in generating invention disclosures, patent applications and grants than their European peers. However, European TTOs appear to require a smaller level of research expenditure to generate licensing agreements and start-ups than their US peers. The share of licensing revenue for university TT as a percentage of research expenditure is around 1 percent in Europe but closer to 3 percent in the US. One explanation for the lower licensing returns is a greater reliance on start-ups in Europe.[7] Higher start-up activity and relatively low licensing activity in Europe is also to be put in relation with the lower royalties available for academic inventors in Europe compared with the US. A second explanation could be the advanced market-readiness of projects in the US: Projects at US universities are better financed and further developed towards their relevant markets than in Europe.

There is a significant potential for specialized investment vehicles focusing on technology transfer.

Improving the commercialisation of IP and filling the gap with the US, notably in terms of shifting from research and proof-of-concept grants towards commercial funding, will require access to adequate financial instruments. Financial instruments in the TT segment are not well developed to date. Discussions with market participants in different industry sectors make it clear that a very significant potential exists for specialized investment vehicles focusing on the TT segment.

The change in the innovation process has led to the emergence of new collaborative mechanisms such as patent pools[8] or innovation platforms requiring appropriate intermediate mechanisms for the commercialisation of IP. Knowledge exploitation appears as a key issue in open innovation strategies especially in the upstream phase. New forms of joint IP or IP sharing require adequate management tools and alignment of incentives not always developed in research organisations.

The notion of "Technology market" encompasses a range of different mechanisms by which buyers and sellers trade various forms of knowledge: Buyers and sellers can pool or trade IP, data, information, contacts and know-how. Intellectual property exchanges and patent pools, consortia, networking, matching or brokering services, clearing houses, knowledge warehouses and auctions enter into this broadly defined concept. The current market situation (market needs, unused high-tech potential,

7 The Lambert Review criticises too little licensing and too many unsustainable spin-outs (for the UK): „… there are signs that the pendulum has swung too far and that too many spin-outs are now being created, some of low quality. … Despite a fall in 2002, many more spin-outs are created as a proportion of research expenditure than in the US and Canada. … but these spin-out rates come at a cost to licensing. … nine new university technologies are licensed for every spin-out that is formed in US, compared to only four in the UK." (Lambert Review of Business 2003, p. 58f.) However, the Lambert Review's criticism, that undue focus on spin-out companies has negatively affected technology licensing, has been addressed in an article by Ederyn Williams (Warwick Ventures). He shows that the poorer performance of UK universities in generating licensing income can be entirely attributed to the higher average age of US university license portfolios (Library House, 2007).

8 A patent pool can provide an incentive for further innovation by enabling its members to share the risks associated to R&D. Patent pools can also increase the likelihood that a company will recover some, if not all, of its investment in R&D (Striukova, 2009).

funding gap between basic research and commercialisation, funding gap of exploiting the whole range of technology) leads to many opportunities to develop innovative funding, both SME-related and project-related instruments.

The financial instruments in these markets – and these are not the standard VC tools – are not yet fully developed. However, discussions over the last years with market players from different sectors have made it clear that a sizeable potential for specialized investment companies exists. This is true for the seed stage, but also for the full exploitation of IP.

The financial crisis has further intensified the "traditional" funding issues for the exploitation of R&D. In general, there has been (and still is) a sharp decline in private-equity fundraising activities; early-stage VC is currently more stable than other phases, but also at a much lower level than before. Reasons for the sharp slowdown of fundraising activities are mainly uncertainty due to the ongoing crisis, the strong level of activity in previous years (2005 to 2007), and also uncertainty about the impact on valuations. According to private-equity statistics (*e.g.* Deloitte, EVCA 2009) many VCs are optimistic about their future funds – however, VCs are looking to governments as their financial partners because they see their traditional investor base – commercial banks, investment banks, corporate operating funds, insurance companies and public pension funds – to be drying up.

With the financial crisis, VC funds have turned to governments as financial partners as their traditional investor base has dried up.

4. Key lessons learnt from the EIF experience

As outlined above, TT can take various routes which sometimes differ in substantial ways from better-known financial instruments such as debt/guarantees and equity investments. This section summarises key lessons from EIF's experience in TT investing. An overview of EIF's operational activities is given in the Annex.

4.1 Financial design: Privileged access to deal flow and "Bears' hugs"

TT operations are often organised in partnership with research centres, universities or other structures. In this context, successful operations often benefit from privileged access to spin-outs originating from such innovation centres. Fostering and maintaining privileged relationships with those centres does not always make it possible (let alone desirable) to press for the typical governance/structuring features of VC, such as arms' length principles, conflict of interest parameters *etc.*

This is a departure from standard structuring features and requires a specific approach and skills for successful implementation. In fact, the further upstream the project in the investment spectrum, the less certain standard features of equity investing are applicable – they can even become outright damaging, much like debt standards when applied to equity. The issue is about risk: At this intermediate stage, technology is more developed than basic knowledge but it is not developed enough yet for its market applications to have the degree of certainty that standard capital providers require. Appropriate solutions must be found which address the specifics of this market segment rather than trying to superimpose solutions which work in other environments.

4.2 Implementation issues - private co-investors

TT investing is an emerging area within finance. Consequently, it is not an established asset class among "market-oriented investors" – to an even more significant extent than technology VC which itself is increasingly shunned by the private sector.

TT financing may require a high share of the public investor, significant development efforts and long time horizons – for often modest amounts per deal.

As regards structuring, limits in the level of public investment at first closings of funds are often an obstacle. Typically this specific rule is a legacy of VC or other private-equity investment guidelines, which is *ceteris paribus* applied to TT as if it was the same market segment. At the time of writing, market conditions are such that EIF and similar investors are often led to take up to 50 percent of first closings in their VC and private-equity investments. Therefore, an emerging area such as TT could greatly benefit from a similar approach.

4.3 Business development effort and lead-time

This is an emerging market, which lacks existing teams periodically submitting well-structured investment proposals. This mirrors the funding gap at this stage. EIF's role is to partner with leading research and innovation organisations in order to develop products and approaches resulting in "investable" operations by EIF and other investors. This resource-intensive, "tailor-made" approach entails a high attrition rate, which is counterbalanced by the fact that it positions EIF as the partner of choice with leading innovation centres.

4.4 Longer time horizons: Average size currently smaller than other areas

Successful TT investing requires a long-term approach, with fifteen, twenty year (and beyond) horizons being sometimes necessary. Also, the average size of investments in this area can be significantly smaller than in the typical private-equity operations.

5. Potential activities to meet market needs

Investing in support of knowledge transfer from universities to industry calls for new financing models which could address both the information and risk patterns of this activity (in-between public and market research). The availability of such instruments is a necessary condition for attracting larger amounts of private capital without which inventions cannot be transformed into innovations. In order to meet the markets' needs, public support should be provided through a flexible tool set, adapted to a variety of situations and needs. The remainder of the section explains potential future options for the EIF.

5.1 Extension of current TT activities

EIF, like other investors, has so far focused on leading European universities/research institutions, ruling out smaller operations. However, public-sector investors like EIF could also address smaller or less prominent universities and research centres. Indeed Europe has a significant number of universities/research centres producing numerous spin-outs. Given the growing number of teams that have professionalised their TT approach over time, this could open up a new market segment for investors if addressed with the right instruments and approach. Another growing trend is the emergence of trans-national operations, creating a critical mass in terms of deal flow, network and competencies.

5.2 Licensing operations

In TT through licensing, the IP developed within a research organisation is "licensed" by the research organisation to a production company. This license can be exclusive or not, is often limited to certain market segments or countries as well as in time. The IP can potentially also be acquired by the company.

Licensing operations can take various forms. Often the IP developed at research organisations is not mature enough to be licensed or sold directly to companies but requires further validation of the technology (*e.g.* by building a prototype or carrying out pre-clinical testing) before it is in a position to attract industrial buyers. Funding for such activities is mostly not in place within research organisations. Licensing TT operations can address precisely this funding gap. What is needed is an investor who could fund the further development of the technology by paying for the activities required to make the IP more mature. In return, the TT Operation receives a share of the IP and the associated revenue streams in case the IP is licensed out or sold. Financing of this kind is of great value as it ensures that valuable technologies are not left unused within academia. This type of operation is complementary to that of seed and early-stage funds, which invest in companies (not in projects or IP assets) and which only partially address the TT process.

Funding the development of commercial applications out of academic inventions in exchange for a share in the IP is a possible area of future development.

Licensing operations can take other forms such as Project Funds, IP Funds, Royalty Funds, IP Line Extension and IP Live Extension Projects, IP carve out projects *etc.* A more detailed description can be found in Table 1. on the following page.

Because of the portfolio aspects as well as long lead times, "licensing" or "royalty" market segments lend themselves to complex financial engineering encompassing securitisation techniques and secondary approaches, which can be a more efficient form of funding than equity.

5.3 Corporate venturing and larger commercial TT operations

Corporate venturing or corporate VC can be defined as the practice whereby a large firm takes an equity stake in a small innovative or specialist firm to which it may also provide management and marketing expertise. The objective of corporate VC is to gain a specific competitive advantage as well as to achieve a return. Corporate funds focusing on early-stage investments can be used as a tool to gain access to new technologies, often developed in the research organisations relevant to the industries on which the corporate venture fund focuses. In some cases the fund may also invest in companies spun out of the parent organisation, for instance to commercialise IP in an industry segment not relevant to the parent organisation. Corporate venture funds can be managed by teams which are still strongly linked to the parent company or by teams held at arms length. Some corporate funds attract third-party investors at fund level. The individual ticket size of this type of transaction is larger than for the other TT activities described in this section.

5.4 University seed funds

Another area of development consists in supporting numerous university (pre)-seed funds. These funds are often in collaboration with a single university and managed by a small local team. In this area, the return expectations are very limited. However, these funds play an important role in the creation of numerous technology spin-outs and, hence, significantly contribute to the commercialisation of academic research. This approach could be taken to a higher level, through operations bringing together several universities in order to create more sizeable spin-out funds – such funds could operate in physical or virtual clusters possibly extending across different EU countries.

Table 1. Different types of licensing operations

Profile	Comments
"Licensing" operations	The IP developed within a research organisation is "licensed" to a(n industrial) company. License is exclusive or not, with often limited coverage (market segments, countries, and time). See the discussion in Section 5.2 of the main text. Note that existing or planned initiatives in this area are often either supported by non-EU private groups (*e.g.* Royaltypharma 2009 using a securitisation angle; Paul Capital 2009 following a secondaries strategy; and Intellectual Ventures 2009 with a translational lab focus), or by national public groups without a European remit (*e.g.* the initiative by CDC to establish an organisation to commercialise patents from public-sector research).
Projects funds	Shares some features with upstream VC. However, investments are made not in a company but in projects. Overhead costs are initially low because it can be decided at a later stage whether to commercialise the IP through licensing or through a spin-out. The ownership of the IP developed within these projects needs to be contractually agreed upfront. Similar to some existing university proof-of-concept funds.
IP funds	Investments are made into individual IP assets (*e.g.* patents), which have a potential to be commercialised. Different investment strategies can be applied. One strategy consists in buying portfolios of existing but (nearly) unused patents, often in batches at reduced prices. Grouping individual patents into "patent families" (or bundles) can be valuable to potential buyers (or licensors) of the technology by allowing them to fully protect their use of key technologies. Another strategy consists in selectively acquiring clusters of patents and building project teams around these technologies to further develop them to the point where they are attractive to commercial buyers. Such funds contribute to transferring existing IP assets into the commercial world.
Royalty funds	Fund buys the rights to the future royalty streams linked to a specific patent of or pools of patens. This is applicable for patents that are already commercialised (or close to commercialisation). By doing so, the fund increases the liquidity of the markets for patents.
IP line extension projects	Project financing is needed to develop further products on existing and already commercialised IP. The commercial use of existing IP-protected technologies can be extended with the development of tailored products for specific markets and customer profiles. Example: Schwarz Pharma asked for the financing of a clinical study in order to get market approval of a molecule already on the market for another indication. As a result, Schwarz would have been able to double revenues on their existing IP with only some minor IP extensions. An investor such as EIF could finance (part of) these developments in the form of project finance (also on a portfolio basis).
IP carve out projects	Spin-off or licensing-out of specific IP families that protect a potential new product from existing companies. Main driver is the lack of financing for second-line products which often bear higher potential than the first line but have more onerous product development. The cost of product development could then be addressed through TT financing, *e.g.* in the form of an SME or a special-purpose vehicle (SPV).
Secondary use of IP	Most (major) innovative companies manage their IP portfolio actively, often maintaining IP portfolios which are not in the (new) focus of the company. Also, stressed (tech) companies struggling for survival try to sell their IP when the underlying product development is at a too early stage but IP, know-how, skilled staff and results are in place. Acquiring the necessary IP and creating a new appropriate structure is a potential target of a TT transaction.

6. Conclusion

Global policy discussions[9] increasingly focus on innovation and the knowledge economy as a driver of long-term growth. In parallel, new forms of innovation processes are emerging, notably open innovation and innovation networks, stressing the importance of links and connections between the various stakeholders. Older business and innovation models do not hold anymore, and likewise new financing models have to emerge. Investment in supporting innovation calls for new financing models, particularly in knowledge commercialisation and diffusion. Direct support to TT, Pre-seed and Seed, Business Angels, and incubators are important instruments, notably through a more active commercialisation of intellectual property. IP management has to be integrated in these strategies from the outset, as IP is a major instrument for transferring knowledge and generating revenue.

New innovation processes call for new business and financing models.

Scaling up TT as a policy measure to support the commercialisation of research is a separate area within the financing arena, with its own characteristics requiring a targeted approach and dedicated financial products and approaches. Financial engineering in this market segment must be flexible and blend financial products as needed (certainly equity but also guarantees, lending etc.) to share the risk between universities, inventors, entrepreneurs and investors appropriately and to maximise the potential value of IP so as to make this IP a powerful attractor for further capital.

9 See *e.g.* Executive Office of the President (2009) and European Commission (2009b).

Annex: EIF's TT activities so far

Profile	Examples	Comments
Spin-off portfolio	IP Venture Fund	A GBP 32 million co-investment fund in which EIF invested GBP 14 million and which reached its first close in September 2006. The fund systematically co-invests 25 percent of the financing round of spin-outs originating from the 10 universities with which IP group has commercialisation agreements. These include Oxford Chemistry, Oxford Engineering, Queen Mary College, King's College London, Southampton, Bath, Bristol, Leeds, Glasgow, York, and Surrey universities.
Next-generation licensing	Leuven/CD3	CD3, the Centre for Drug Design and Discovery financed jointly by EIF (EUR 4 million) and the University of Leuven (EUR 4 million) in 2006, finances early-stage drug development projects, bridging the gap between academic research and the point where large pharma companies are willing to get involved. A successor fund is under consideration.
University seed fund	UMIP Premier Fund	The UMIP Premier Fund is a GBP 32 million fund, closed in April 2008, corner-stoned by EIF with a GBP 9 million investment. The fund is dedicated to spin-out companies originating from the University of Manchester and performs investments ranging from proof-of-concept, seed and A/B rounds. The fund is managed by MTI partners, a technology VC.
University / Incubator fund	University X (name deleted) Innovation	The University X (name deleted) Innovation Seed Fund is a EUR 10.5 million fund, sponsored by EIF with EUR 5.25 million. EIF worked together with the University and the incubator in the structuring and set-up of the fund. The fund reached its first close in July 2008 and has since already performed five investments in promising start-up companies. The fund invests in start-up companies originating from the university and other innovative centres in the Gothenburg region.
Two-step spin-off portfolio	University Y (name deleted), under completion	EIF envisages an investment in partnership with the University Y (name deleted) Institute in the life sciences sector to finance spin-outs in Sweden and the Nordic region. EIF would invest into a dedicated structure, the University Y Co-Investment Fund, in which it would be the main or a major investor and which would systematically co-invest alongside University Y Development at a fixed ratio. The fund would provide seed financing to newly created spin-out companies as well as follow-on financing to the existing portfolio of approximately 40 companies created by University Y Development since 2003.

References

Adams, J. and Griliches, Z. (1998). "Research Productivity in a System of Universities". *Annales D'Economie et de Statistique*, No. 49/50.

Agrawal, A. and Cockburn, I. (2003). "The Anchor Tenant Hypothesis: Exploring the Role of Large, Local, R&D Intensive Firms in Regional Innovation Systems". *International Journal of Industrial Organization*, (21), pp. 1227-1253.

Aho, E. (2006). "Creativing an innovative Europe". Report of the Independent Expert Group on R&D and Innovation appointed following the Hampton Court Summit and chaired by Esko Aho, 2006.

Arundel, A. and Bordoy, C. (2006). "Developing internationally comparable indicators for the commercialization of publicly-funded research". United Nations University, Maastricht, The Netherlands.

Belenzon, S. and Schankerman, M. (2008). "The Impact of Ownership, Incentives and Local Development Objectives on University Technology Transfer Performance". *Journal of Law and Economics* (forthcoming).

Chukumba, C.O. and Jensen, R.A. (2005). "University Invention, Entrepreneurship, and Start-Ups". NBER Working Paper No. 11475.

Deloitte, EVCA (2009a): "Global trends in venture capital". 2009 Global Report.

European Commission (1994). "Growth, Competitiveness, Employment", White Paper, Brussels.

European Commission (2007b). Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions improving knowledge transfer between research institutions and industry across Europe: embracing open innovation, Brussels, 04.04.2007.

European Commission (2009a). "Cyclicality of SME finance". Study by EIM Business & Policy Research, May.

European Commission (2009b). "Reviewing Community innovation policy in a changing world". COM (2009) 442 final, Brussels, 02.09.2009.

Executive Office of the President (2009). "A Strategy for American Innovation: Driving towards sustainable growth and quality jobs". Washington D.C., September 2009. http://www.whitehouse.gov/assets/documents/sept_20__innovation_whitepaper_final.pdf

Friedman, J. and Silberman, J. (2003). "University Technology Transfer: Do Incentives, Management and Location Matter?". *Journal of Technology Transfer,* (28), pp. 17-30.

Gambardella, A., Giurib, P. and Luzzic, A. (2006). "The Market for Patents in Europe". Laboratory of Economics and Management, Sant' Anna School of Advanced Studies, Pisa, Italy.

Guellec, D. and Sachwald, F. (2008). "Research and entrepreneurship: a new innovation strategy for Europe", in Conference of the French Presidency of the European Union, *Knowledge intensive growth: European Strategies in the Global Economy*; Toulouse, France, 07.-09.07.2008. Conference Paper.

Henderson, R., Jaffe, A. and Trajtenberg, M. (1998). "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting 1965-1988". *Review of Economics and Statistics*, (80:1), pp. 119-127.

Intellectual Ventures (2009). http://www.intellectualventures.com/about.aspx

Jaffe, A. (1989). "Real Effects of Academic Research". *American Economic Review*, (79:5), pp. 957-970.

Jaffe, A., Trajtenberg, M. and Henderson, R. (1993). "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations". *Quarterly Journal of Economics*, (108:3), pp. 577- 598.

Jensen, R. and Thursby, M. (2001). "Proofs and Prototypes for Sale: The Licensing of University Inventions". *American Economic Review*, (91:1), pp. 240-259.

Kamiyama, S., Sheehan, J. and Martinez, C. (2006). "Valuation and exploitation of intellectual property". OECD STI Working Paper 2006/5, 30.06.2006.

KfW (2006). "Innovationen im Mittelstand", in *Mittelstands- und Strukturpolitik* (37) KfW-Research, Frankfurt/M., Germany.

Lach, S. and Schankerman, M. (2004). "Royalty Sharing and Technology Licensing in Universities". *Journal of the European Economic Association,* (2:2-3), pp. 252-264.

Lach, S. and Schankerman, M. (2008). "Incentives and Inventions in Universities". *The Rand Journal of Economics,* (39:2), pp. 403-433.

Lambert Review of Business – University Collaboration, Final Report, Her Majesty's Stationery Office, Norwich, December 2003.

Library House (2007): *Spinning out quality: University spin-out companies in the UK*, ed. 2, London.

Macho-Stadler, I., Martínez-Giralt, X. and Pérez-Castrillo, D. (1996): "The role of information in licensing contract design". *Research Policy*, (25), pp. 43-57.

Mansfield, E. (1998). "Academic Research and Industrial Innovation: an Update of Empirical Findings". *Research Policy*, (26), pp. 773-776.

Milken Institute (2006): *Mind to Market: A Global Analysis of University Biotechnology Transfer and Commercialization*, September.

OECD (2008): Compendium of Patent Statistics, Paris, 2008.

Paul Capital (2009). http://www.paulcapital.com/InvestmentPlatforms/Healthcare/Default.aspx

Proton (2008): The Proton Europe Fourth Annual Survey Report (fiscal year 2006).

Royalty Pharma (2009). http://www.royaltypharma.com

Schumpeter, J.A. (1951). "The Theory of Economic Development". Cambridge, USA.

Seget, S. (2008). "Technology Transfer Strategies, Maximizing the returns from new technologies". *Business Insights*, London.

Siegel, D.S., Waldman, D. and Link, A. (2003). "Assessing the Impact of Organizational Practices on the Relative Productivity of University Technology Transfer Offices: an Explanatory Study". *Research Policy*, (32:1), pp. 27-48.

Striukova, L. (2009a). "Corporate value creation through patent governance structures", in *International Journal of Intellectual Property Management*, (3:3), pp. 223-237.

Striukova, L. (2009b). "Value of university patents as a determinant of technology transfer", in *Interational Journal Technology Transfer and Commercialisation*, (8:4), pp. 379-391.

Thursby, J.G., Jensen, R. and Thursby, M. (2001). "Objectives, Characteristics and Outcomes of University Licensing: a Survey of Major US Universities". *Journal of Technology Transfer*, (26: 1-2), pp. 59-72.

Thursby, J.G. and Kemp, S. (2002). "Growth and Productive Efficiency of University Intellectual Property". *Research Policy*, (31:1), pp. 109-124.

Van Looy, B., Debackere, K., Martens, T. and Bouwen, R. (2006). "Exploring Requisites and Antecedents of Continuous Innovation", KU Leuven, Belgium.

ABSTRACT

Financing constraints have been discussed as a major obstacle to innovation. *Small and medium-sized enterprises and start-ups are particularly concerned by such impediments. Venture capital has emerged as a partial solution in some countries, but is only available for start-up firms with major growth potential. Recently, new intermediaries have attempted to provide external finance to innovative firms based on the firms' patent portfolios. Patents have been used as collateral or as assets assembled in patent funds seeking to commercialize the patent rights. Patent auctions are indicative of a nascent market for patented technology. This paper presents an overview on the role of patents and licenses, both in the classical sense and as instruments for financing innovation. It also discusses implications of these developments for public policy and the design of patent systems.*

Dietmar Harhoff (harhoff@lmu.de) is Professor of business administration at the Ludwig-Maximilians-Universität (LMU) Munich and Director of the Institute of Innovation Research, Technology Management and Entrepreneurship (INNO-tec) at LMU.

The author would like to thank previous and present co-authors for helpful discussions and suggestions. He would also like to thank Alfonso Gambardella, Bronwyn Hall and Stuart Graham for numerous discussions on the topic of this article and Rosemarie Wilcox for assistance with preparing the manuscript. The usual *caveat* applies.

The role of patents and licenses in securing external finance for innovation

1. Introduction

Dietmar Harhoff

The economic literature has analyzed a number of problems that stand in the way of an efficient allocation of resources to R&D and innovation in a market economy. Among them are the well-known externalities that emerge from knowledge having characteristics of public goods. Moreover, it has been suggested in theoretical and empirical studies that there are financing constraints for particular types of firms and activities, such as research and development. These constraints limit the extent to which firms engage in R&D and innovation, even if no knowledge externalities are present. A more recent literature has focused on a third problem and argues that the market for intermediate outputs of the innovation process (such as ideas, patents, licences, blue-prints, prototypes, etc.) is incomplete. The first two problems lead to inefficiently low investment in innovation. The third one leads to inefficiently low extent in the division of labour, since the market for technology (defined as the aforementioned intermediate outputs) is not transparent and does not function well at this point. Transactions have to be internalized, and gains from specialization are lost.

This paper is mostly concerned with the latter two problems which are intricately linked.[1] At the root of them lies the same phenomenon – the idiosyncratic nature of technology, largely following firm-specific paths of development, coupled with asymmetric information on alternative uses, substitutes and values. If a market for intermediate results of innovation processes existed, then the financing constraints of innovative firms would probably be less pronounced. Intermediate results could be licensed, sold, leased or become part of other financial transactions, which would relax the financing constraints problem. The topic of this paper is the role that patent rights do or could play in the establishment of such markets for technology and as an instrument to support the financing of innovation.

The following sections develop these thoughts in some detail. First, a brief summary of the classical theoretical arguments pertaining to financing constraints, pecking orders and cost of capital is given. In Section 3, classical uses of patents and licenses are summarized and discussed. Section 4 discusses relatively novel uses of patents as instruments for securing external finance. Section 5 provides a discussion of how modern patent systems are or could be designed to support the financial functions of patents. Section 6 concludes.

2. Theoretical and empirical evidence on financing gaps

Hidden information, hidden action and incompleteness of contracts impact debt and equity finance. The following sections briefly review how these market imperfections lead to financing problems – in particular for small and young firms and for innovative enterprises.

2.1 Asymmetric information and pecking orders

The impact of asymmetric information on financing has been studied in particular detail for debt finance. Credit markets differ from standard commodity markets in that the lender delivers a loan on

1 The material presented here builds on earlier work with Carolin Haeussler and Elisabeth Mueller, as well as work with Karin Hoisl, Georg von Graevenitz and Stefan Wagner.

the borrower's promise to pay back the loan and interest. The lender's evaluation of the borrower's capability to pay back is crucial for the lending decision. Equilibrium quantity rationing emerges endogenously due to asymmetric information (the lender knows less about the borrower than the borrower himself) and incompleteness of contracts (contractual agreements to control all aspects of borrower behaviour are infeasible). In the case of rationing, the lender will decide not to grant a loan to the borrower, even if the borrower offers a higher interest rate than is observed in the market for loans. Thus, the supply of loans does not equate the demand at the market interest rate.

The underlying cause for all credit rationing phenomena can be traced back to selection and incentive effects imposed by interest rates. Adverse selection occurs, since the average quality of borrowers will be a decreasing function of the interest rate charged by the lender. Moreover, as the interest rate increases a borrower will be tempted to undertake riskier projects unless the loan is fully collateralized. As a consequence, either some lenders are not able to obtain any loan, or the loan size will be below the one demanded by the borrower (Bester and Hellwig 1987). If collateral is in short supply for firms, then the firm may have projects that would be worth financing, but cannot be pursued because of the lack of debt finance. As we discuss later, this is particularly likely in innovation projects which largely produce intangible assets as intermediate output.

Firms prefer internal finance over debt and debt over new shares, reflecting capital costs.

In response to a lack of debt finance, firms may want to issue equity. But asymmetric information and moral hazard may prevent managers from doing so as Myers and Majluf (1984) show. They analyze the effects of asymmetric information if managers have privileged knowledge about the true value of investment projects and the firm's other assets while investors (or lenders) only know the joint distribution of these values until the *ex ante* random characteristics of the projects are revealed. Managers are assumed to act on behalf of "old" shareholders. Issuance of new shares will occur only if this is not to the disadvantage of old stockholders, *i.e.*, if the market's evaluation of the new stock is above the respective value for the old stockholders. Thus, managers will only issue shares for investment with less than expected value. Consequently, issuing shares will be seen by the new investors as a bad signal. Anticipating this, the firm will not issue new shares even if the projects have positive net present value. Thus, in the Myers/Majluf model, financing constraints have negative welfare effects. Variations of the fundamental theme of the Myers and Majluf paper have been developed in large numbers, but the basic idea is the same in these extensions. Given that management acts in the interest of existing shareholders, firms will prefer internal finance over debt financing, and debt financing over the issuance of new shares. This prediction has found some empirical support (*e.g.* see the review in Thakor 1993, p. 461).

As a result of some of these arguments, Myers and Majluf (1984), *inter alia*, have postulated a financial "pecking order" model. In this model there is no well-defined optimal capital structure as it exists in the static Modigliani-Miller model with taxation, but a well-defined ranking of capital costs. Once slack resources are exhausted, the firm will have to borrow to satisfy its capital needs. The most expensive type of capital will be new equity. In some cases, the firm will rather forego an investment opportunity than to issue debt or equity. Exogenous variations in cash flow will lead to more or less investment in such a situation.

2.2 Different types of investment: Capital goods versus intangibles

Can financing constraints be particularly important for investment in research and development (R&D) or innovation projects? There are a number of reasons why investment in physical capital and investment in knowledge capital should be affected differentially by financing constraints, and why obtaining external finance for innovation and R&D projects may be more costly than obtaining such funding for capital investment. At the same time, fundamental technological differences with respect to the adjustment costs of investment and R&D and differences in tax treatment may work against extensive sensitivity of R&D spending to transitory shocks in cash flow. Finally, the impact of uncertainty needs to be taken into account.

For the purpose of the present discussion, let us first assume that contrary to most capital investment goods (plant, property, and equipment), R&D results such as a new prototype, a design or a patent cannot be used as collateral. This is largely still the rule, but there are important exceptions which will be considered in Section 4 below. The reasoning behind this assumption is simple: The investment share of R&D expenditure is of the order of 10 percent of total R&D expenditure, and most inputs to the innovation process are likely to be firm-specific or specific to the new product or process to be developed. Under these conditions there is no liquid market where the collateral could be liquidated in the case of insolvency. Thus, external financiers cannot expect to recover a significant share of their funds from collateralized intangibles.

R&D firms may be reluctant to reveal their R&D efforts – which adds to the cost of external funds.

Second, for obvious reasons firms may be hesitant to reveal the content and objectives of their R&D efforts since this knowledge may leak out to competitors.[2] Strategic considerations of this kind will tend to maintain and reinforce informational asymmetries. But even without secrecy undermining the incentives to share information about R&D projects, the evaluation of long-term risky projects by external financiers may be more costly than the assessment of more short-term oriented ones. Thus, if providers of finance face greater uncertainty and longer planning horizons with respect to R&D than capital investment projects, they will require a higher "lemon's" premium for the former type of investment. Hence, even without rationing behaviour on behalf of banks and other financial institutions, there will be a premium to be paid for obtaining external funding for R&D projects. If lenders cannot control which type of project will be financed by the loan, then the cost of capital will reflect the financiers' assessment of average project risk. Taken together, these results suggest that R&D-intensive firms face a larger difference between capital costs for internal and for external funds than firms with few R&D projects.

The cost of capital for investment and for R&D projects may also be affected differentially due to the tax treatment of R&D and intangibles. Traditionally, R&D had to be expensed. This is a preferential treatment (full depreciation in the year of investment) when compared to capital investment but only so if the firm does have a tax debt which can be reduced by the expensed R&D. Young firms with extended periods in which no positive tax debt occurs will not profit from this treatment. Moreover, carrying the tax losses forward does not fully compensate this disadvantage, either because the value of the tax loss declines over time or because some taxation regimes limit the extent to which firms can off-set current profits with past losses. An example is the minimum taxation principle in the current German tax code which effectively limits the off-setting of profits against losses that have been carried forward. Hence, while a young firm may not be able to derive much benefit out of the classical tax treatment of R&D, there are actually dangers coming with it. Since the firm does not capitalize its intangibles, it runs an increased risk of ending up over-indebted. New taxation and accounting rules have therefore tried to address this issue. The US General Accounting Principles (GAP) have included a limited right to choose between capitalization and expensing for some time. Such an option is now available in most accounting and taxation systems, *e.g.* under the International Accounting Standards IAS 38 and IAS 39. To summarize, for most young firms the R&D expensing rule did not generate any advantages in the past, and the current trend towards explicitly listing some intangible assets (but only the development component) on the asset side of the balance sheet does not create a particular advantage for R&D.

2 See Mansfield (1985) for some evidence on the speed of information dissemination. Theoretical models of knowledge dissemination are presented by Bhattacharya and Ritter (1985) and Bhattacharya and Chiesa (1994).

Taken together, these theoretical arguments suggest that finance for R&D and innovation will be more constrained and thus more susceptible to cash-flow variations than capital investment.

Despite heavy reliance on own cash flow, R&D is relatively smooth over time due to high adjustment costs.

However, there are other considerations that run counter to this conclusion. For one, adjustment costs are likely to be higher for R&D than for physical investment. Indeed, it is likely that the R&D process cannot be delayed or accelerated to the extent to which this may be possible for capital investment. Scientists cannot be fired and rehired without substantial loss of human capital to the firm (and potential gains to competitors), and resources employed in R&D cannot simply be used in production (or *vice versa*). This effect will actually dampen the long-term response of R&D to cash flow variation. But since the marginal cost of capital is increased – not reduced – by higher marginal adjustment costs, firms with high marginal adjustment costs are likely to show more stable R&D expenditure – albeit at a lower average level – than firms with low adjustment costs.

The recent economic crisis has triggered new studies on the relationship between uncertainty, the business cycle and R&D. Bloom (2007) develops a real-options model in which he analyzes the reaction of capital investment and/or R&D to changes in the level of uncertainty. He finds that there have been (and currently are) strong fluctuations in economic uncertainty. Higher uncertainty tends to reduce aggregate investment, hiring and productivity growth because decision-makers seek to delay important decisions. As to R&D, Bloom shows that higher uncertainty reduces the responsiveness of R&D to changes in demand conditions and increases the persistence of R&D over time. Nabar and Nicolas (2009) study R&D investment behaviour during the Great Depression. They develop a model in which firms differ with respect to the precision of their beliefs about the future development of demand. Firms with imprecise prior beliefs react more strongly to sector-specific signals than firms with more precise information. Their empirical investigation yields interesting insights as well. Their data suggest that learning and updating were important determinants of R&D decision making between 1930 and 1932, but not in the subsequent years till 1936. Access to liquidity was not sufficient to let firms engage in R&D – even financially unconstrained firms were apparently not willing to engage in countercyclical innovation. The results confirm that uncertainty may seriously undermine R&D and innovation – even if financial constraints are not a problem.

The arguments described in the previous sections (and in some cases countervailing ones) have by now been tested in a large number of empirical studies. I will not review this evidence in detail, but will largely point to survey results instead, in particular to the overview presented by Hall (2002).[3] Summarizing a large number of empirical studies, she concludes that the empirical evidence regarding financing constraints or "funding gaps" is fairly clear by now. In particular, there is strong empirical evidence in favour of the view that relatively small and young firms (SMEs and start-ups) attempting to undertake innovation face relatively high costs of capital. Classical financing institutions are not well-prepared to support the financing of innovation in these firms. It is much harder to find convincing empirical evidence for the existence of financing constraints in large, established firms. While it may still be the case that R&D and innovation in these firms are subject to important externalities (such as knowledge spillovers), funding gaps appear to be limited to SMEs and young firms.

2.3 External equity and the emergence of the venture capitalist

The literature summarized above considered debt and public equity markets, but not private equity (PE). For the purpose of this study, the most interesting form of PE is venture capital which explicitly

3 See Hall (2009, in this issue) for an updated overview article.

addresses the financing needs of young firms with strong growth prospects, but no assets that could be collateralized. Venture capital (VC) is equity or equity-based investment in private companies with high potential for growth (see Gompers and Lerner 2000; Kaplan and Strömberg 2003). VC is typically organized as a limited partnership. The limited partners – wealthy individuals and institutional investors – enter a partnership with experienced venture capitalists (VCs) who act as general partners. The partnership typically lasts for about ten years. The funds are then invested in young firms in return for preferred stock. VCs also receive important special rights which allow them to influence the management of the start-up even if they hold a minority share. Venture capital emerged first at the end of WWII but gained in importance in the US during the 1980s when a clarification of the Employee Retirement Income Security Act's 'prudent-man' rule allowed pension funds to invest in high-risk assets, including VC. While VC has seen a dramatic development in the US, it has not been successful in a broad set of countries, with the UK, Israel, Canada and New Zealand being the exceptions. The lack of an initial-public-offering (IPO) exit channel is presumably one of the most important impediments for the emergence of a functioning VC market in Europe. The emergence of VC can be interpreted as evidence that other financing institutions – in particular banks and public markets – have not been able to address the financing problems of young firms. It is all the more sobering that the majority of European countries and the European Union have not been able to establish a strong VC financing channel for young firms.

Venture capital addresses financing constraints of young companies with little collateral – but only of very fast-growing ones.

The positive role of VC in supporting innovation is well established by now (Kortum and Lerner 2000). But one needs to point out that VC is restricted in scope – it addresses the financing need of a very important, yet small segment of start-ups with particularly high growth potential. Even with a working VC market in Europe, a much larger segment of innovative small and medium-sized enterprises (SMEs) would continue to experience financing problems.

2.4 A summary

To summarize, funding gaps exist, and they are particularly problematic for SMEs and young firms. The emergence of the venture capitalist, a new type of intermediary in the 1960s and 1970s and its subsequent success (at least in some countries and regions) can be taken as evidence that the financing needs of innovative SMEs and young firms in Europe are not being met by existing institutions and players. While these insights are relatively clear cut, many questions are still unresolved at this point. As Hall (2002) points out, little is known about the effectiveness of various government policies pertaining to institutions such as incubators, pre-seed and seed funding (as in the case of the German *Hightech Gründerfonds*) and other forms of subsidies for start-ups. There is also a lack of information as to how corporate-governance regimes and regulation interact with different types of information problems that lie at the root of financing constraints for innovation. It will be important to analyze how these factors affect innovation. Unfortunately, history has shown that policy discussions frequently neglect this aspect and focus on capital investment and issues of depreciation. That focus appears more and more outdated – the design of accounting and taxations systems should increasingly be concerned with its impact on innovation and training, rather than the installation of fixed capital.

Moreover, as the next sections will show, there is a host of relatively new financing arrangements that have not received detailed attention in the academic discussion while some innovative financial firms and investors are already betting considerable sums on these new arrangements. There is an open question if and how the emergence of these new institutions and players should be supported by governments. To delineate these novel financing instruments from more classical uses of patents and licenses, the next section first summarizes what is known about the "old world" of intellectual property.

3. Classical functions and uses of patents

Patents can be valuable assets to firms because they protect inventions and their transformation to innovative products (Cohen *et al.* 2000 and Dechenaux *et al.* 2008). Patents may protect the company's competitive position by virtue of their exclusion power. This is essentially saying that patents carry private value.[4] The most convincing evidence in favour of this view comes from event studies analyzing the market response to critical events such as the loss of patent rights in litigation or attacks on patent rights in opposition proceedings. Given that litigation cases are usually surprising news, these studies come close to an experimental setting. For example, in a study by Marco (2001) the impact of patent litigation outcomes on stock prices is analyzed (413 patents of 158 US corporations). These events have a significant impact on stock prices. Whenever the validity of patents is confirmed in court rulings, stock prices increase by 1 percent on average. "Bad news" (a revocation or narrowing of claims) leads to a reduction of stock prices by 0.7 percent on average. More evidence on the contribution of patent rights to a corporation's market value comes from Hall *et al.* (2005 and 2007) for the US and Sandner (2009) for Europe. Haeussler *et al.* (2009) analyze the impact on share prices of opposition, *i.e.*, a formal request by a third party to have the patent revoked. They find that the stock market reacts to patent oppositions. Historically, such oppositions lead to a revocation in one third of all cases, and in another third of cases they lead to a restriction of the patent right. Hence, oppositions are a real threat to the patent-holder. Haeussler *et al.* (2009) find that stock market reactions are particularly strong in the case of oppositions against highly-cited (presumably valuable) European patents, but that stocks appreciate if the opposed patent was deemed to be "academic", *i.e.*, if the patent is associated with a large number of prior art references to the scientific literature. While patents can be valuable, there is considerable dispersion in the patent value distribution. As a rule of thumb, 90 percent of the value in a patent portfolio is accounted for by only 10 percent of the patents (Scherer and Harhoff 2000). Litigation and opposition are usually directed at the more valuable patents (Lanjouw and Schankerman 2001).

Patents convey survival advantages to firms and allow operating at higher margins.

The asset character of patents can be traced back to the fact that they provide protection against full competition. In markets with elastic demand, this allows firms to operate at higher margins. Moreover, patents convey survival advantages to firms. Cockburn and Wagner (2007) investigate the effect of patenting on the survival chances of 356 internet firms that went public at the peak of the stock market bubble of the late 1990s. They find that by March 2005, about 66 percent of these firms had delisted from the NASDAQ exchange. Fewer than half of the firms in the sample had obtained patent protection. Those firms that had done so had significantly longer survival spans than firms without patent protection. As the authors show in a detailed econometric analysis, patenting is positively associated with survival. Interestingly, this positive result does not appear to hold for business method patents, for which no survival advantage was apparent in the estimates.

Even if patents had no asset value (in the sense that they could be subject to transactions), they may serve an important purpose in supporting economic transactions such as co-operation on the development of an improved technology. Patents safeguard the right of the technology owner and allow parties to write contracts based on a well-defined ownership title. A sophisticated version of this argument has been put forth by Merges (2005). In Merges' view, property titles support pre-contractual liability and thus grant some protection for disclosure of sensitive information in the period leading up to contract formation. Moreover, property provides enforcement flexibility after a contract is signed since a property right grants its holder many important advantages in the course of enforcement. Property thus supports transactions and would support the emergence of a more transaction-rich economy populated with specialized firms.

4 That alone is not sufficient to justify patent systems from a normative perspective. But the lack of conclusive evidence on the welfare balance of the patent system continues to vex economists. See Section 5 for comments on this problem.

While patents are not required to license technology, many technology-licensing contracts are based on patent rights. The exact extent of licensing is subject to some uncertainty, but most surveys arrive at the conclusion that up to 10 percent of patents are licensed. See Motohashi (2008), Nagaoka and Kwon (2006), and Gambardella *et al.* (2007) for further important studies. Thus a modest volume of transactions is taking place already. However, the conditions at which licensing takes place are difficult to assess. For example, patents may form complex "thickets" when individual patent rights have overlapping and uncertain scope. Patent owners and technology users cannot determine with precision which rights they may be infringing upon or if other parties infringe upon their own patents. Rather than carrying the legal conflicts to court, firms may choose to cross-license parts of their portfolios or even form a pool of patents. In such a situation, patents form the currency for coming to an agreement that substitutes for costly resolution in court. In some cases, the cross-licensing arrangement will be accompanied by compensatory payments to those parties who contribute a particularly large share of patent rights. Cross-licensing differs conceptually from licensing of specific patents since it is used to avoid legal controversy, not to trade technology rights.

Licensing is a way of trading technology rights while cross-licensing mainly serves to avoid legal controversy.

Patents also serve other purposes, such as demonstrating the technological prowess of the applicant or as a visible sign of technical competence of the inventor named on the patent. These functions should not be belittled. Given that patent offices offer their search services at subsidized fee levels, some corporations even use the patent system as an evaluation device of their corporate R&D staff.

In the PatVal-EU survey, inventors named on EPO-granted patent rights were asked whether their patents were used for commercial or industrial purposes, or if they were licensed (Giuri *et al.* 2007). They were also asked to rate the importance of different motivations for patenting (on a 1-5 scale), including licensing, cross-licensing and strategic reasons like blocking competitors. The survey distinguishes between the following six uses of the patents:

- Internal use. The patent is exploited internally for commercial or industrial purposes, it can be used in a production process or incorporated in a product;
- Licensing. The patent is not used internally by the applicant, but it is licensed out to another party;
- Cross-licensing. The patent is licensed to another party in exchange for another patented innovation;
- Licensing & use. The patent is both licensed to another party and used internally by the applicant organisation;
- Blocking patent. The patent is used neither internally nor for licensing, and was applied for to block competitors; and
- Sleeping patents. The patent is not employed in any of the uses described above. It may still have option value to the holder as an asset protecting a completely different technical approach, but it unfolds no blocking effect with respect to competitors.

The analysis by Giuri *et al.* (2007) shows that slightly more than half of the patents were exploited by the applicant organisation for industrial and commercial purposes. About 36 percent were not used, with about half of them being blocking patents and the other half sleeping patents. Finally, 6.4 percent of the patents were licensed, 4 percent were both licensed and internally used, and 3 percent were used in cross-licensing agreements.

Of particular interest are differences between large firms and SMEs. Overall, the small firms licensed out 26 percent of their patents and left 18 percent unused. This is in contrast to large firms which licensed out only 10 percent of the patents and left 40 percent of their patents unused. Hence, firm size and firm type explain a large part of the variation in the extent to which patents are used or licensed. As shown in earlier contributions (*e.g.* Mowery *et al.* 2001), public or private research organisations and universities license a large fraction of their technologies and do not use them internally.

Even if part of the results may be accounted for by the fact that large firms have lower marginal costs of patenting and thus maintain some share of patents in their portfolio for merely strategic reasons, these results are in line with the notion that SMEs will seek to license technology in order to open a source of financing for their enterprises, and that SMEs would profit more from a functioning market for licenses than larger firms. There is strong agreement on this point in the literature. More support for it has recently come from studies undertaken by the OECD (Zuniga and Guellec 2009) and by a team of US researchers (Graham *et al.* 2009).

4. Patents as financing tools

4.1 The market for technology

Market exchanges of non-embodied technology are still at a modest level but gathering pace.

Recent research following the work by Arora *et al.* (2004) has emphasized the importance of a market for technology. This notion refers to the market exchange of non-embodied technology. Most of the economics literature has followed the assumption that trading non-embodied technology, *e.g.* ideas, know-how and patents, is considerably more difficult than trading the embodiment of such knowledge, for example, in the form of machines and other artefacts. The classical argument points at the low rates of licensing and patent trade. As the above sections have shown, licensing is indeed relatively rare, although many patents are not utilized.

The overall monetary volume of licensing transactions has been the subject of some research and of speculation. It is important to note that licensing (in the sense of granting access to technology) occurs for a number of reasons, some of which have little to do with genuine market exchange. For example, within multi-national enterprises (MNEs) licensing can be used to shift profits towards a low-tariff tax jurisdiction. Given the intangible nature of intellectual property, the transfer of a patent right to a subsidiary in a low-tax country could be followed by high royalty payments from the high-tax to the low-tax location of the MNE. A large share of international trade occurs within MNEs (Maskus 2000). The use of intangibles for "tax optimization" purposes should therefore be an important aspect in the empirical picture, but its extent is unknown. Furthermore, licensing is difficult to separate from conceptually different activities, such as cross-licensing for the purpose of avoiding litigation. In this case, there is no genuine trade or transactions indicative of a market, but merely an avoidance of legal confrontation.

Arora *et al.* (2004) estimate that the world market for technology has had a volume of about USD 35-50 billion in the mid-1990s. The estimate includes licenses and the transfer of know-how as well as transfers based on other forms of collaboration such as production and marketing. Athreye and Cantwell (2007) employ data from the IMF balance of payments statistics and from the World Development Indicators database to compute global licensing revenues. Their time series indicates that worldwide royalty and licensing revenues amounted to about USD 10 billion in 1980, and about USD 80 billion in 1998 (Athreye and Cantwell 2007, Figure 2). It is unclear which share of this growth is accounted for by within-MNE transactions and to what extent transfer pricing issues have been relevant. A 2005 special issue of the Economist included an estimate for technology licensing revenues at around USD 100 billion in 2005. Slightly less than half of this figure (USD 45 billion) is estimated for licensing and royalties in the USA alone. Survey evidence (as in Zuniga and Guellec 2009, p. 16) points to increases in the frequency of licensing and of licensing revenues. Their survey data are particularly telling since they restrict the analysis to licensing transactions with unaffiliated firms. Hence, while there is still a need for more precise figures, there is some evidence that the market for technology is growing. Despite this evidence, if less than one tenth of all patents are licensed (see Section 3 above) then this points to a rather incomplete market.

Another component of technology markets might be the outright sale of patent rights. However, the sparse evidence available on patent trade supports the argument that markets for technology are not liquid. Recent studies by Serrano (2008) and Burhop (2009) confirm that there is a moderate degree of patent trade, probably even larger than many economists had thought. Burhop (2009) finds that about 8.3 percent of all patents granted by the German Imperial Patent Office between 1884 and 1913 were transferred to other owners. Serrano (2008) finds that the rate of transfers in the US has been 13.5 percent between 1983 and 2002. In both contexts, the share of patents ever traded during their statutory lifetime is small, confirming that there may be a high degree of illiquidity in the market. One reason for the low degree of trade may lie in the idiosyncratic nature of technology. Many patents protect inventions that firms pursue on firm-specific development paths. At the same time, the lack of trade may simply reflect the high degree of asymmetric information which may lead to a market failure.

Establishing a market for technology would be equivalent to allowing firms to trade intermediate inputs and outputs of the innovation process. This would have advantageous effects. First, specialized firms may emerge that focus and specialize on particular stages of innovation, for example the design stage. Hall and Ziedonis (2001) study the relevance of patents for the emergence of specialized design firms in the semiconductor industry. Leaving aside economies of specialization, a liquid and transparent market for technology would also alleviate financing constraints by allowing firms to shorten the time period from first investment to arriving at an output that can be taken to a market. Financing needs for the intermediate steps would be smaller so that the likelihood of financing these steps internally would increase. Moreover, with a market at hand loans could possibly be collateralized, opening the path to more debt finance. Finally, the likelihood of obtaining private equity finance would also be enhanced since the start-up can be liquidated more quickly. The highly illiquid nature of private equity currently translates into high premia for the investor, and thus into high costs of finance.

A more liquid market for technology would enable firms to specialize on specific stages of innovation and open paths to debt finance.

Markets for technology are not a magical cure. As Gambardella (2002) points out, they may introduce new forms of market failures while alleviating others. In particular, they may generate externalities related to the complementarity of intermediate inputs to innovation processes. Much more needs to be learned about markets for technology, but for present purposes a focus on the positive properties seems appropriate.

Moreover, patents can contribute to the growth of markets for technology in manifold ways. They can safeguard the value of assets, lower the costs of transactions, facilitate licensing and technology trade, serve as collateral or provide important signals to investors. As Epstein and Pierantozzi (2009) point out, patents will also help to recover value in the case of distress or bankruptcy – which will again lower the *ex-ante* cost of capital. These aspects are discussed in the subsequent sections.

4.2 Hybrid business models and "financial bootstrapping"[5]

Growth-oriented firms are subject to highly cyclical financial environments. Venture capital supply and demand have seen strong fluctuations over time. It is not surprising that firms have tried to survive periods of scarce finance by somehow reverting to their own means. One strategy has been referred

5 This section builds on Haagen *et al.* (2007).

to as "bootstrapping" – the start-up seeks to slow its growth to the rate that can be supported with the financial means at hand. "Bootstrapping" can be supported by the performance of R&D services. This allows the firm to maintain a functioning R&D group which can switch back to working on own development targets once financial conditions have improved.

Slowing firm growth to a pace that is sustainable with own funds circumvents financing constraints but may not be optimal.

In this context, even the promise of the future delivery of know-how and patented inventions may serve to support the financing of start-ups. In the 1990s, biotechnology firms developed hybrid business models which allowed them to survive extended periods of under-financing by engaging in contract R&D for larger firms, mostly from the pharmaceuticals sector. Pharmaceuticals producers have been eager to replenish their product pipelines which were threatened by expiring patents and low incidence of new clinical entities (NCEs). Rather than internalizing the costly search for NCEs, large firms have increasingly sought co-operation with smaller biotechnology firms in the early phases of drug development.

Haagen *et al.* (2007), in a comparative assessment of British and German biotechnology firms, evaluate the extent to which firms make use of such approaches. They show that start-ups in a VC-poor country (Germany) engage more often in hybrid models, presumably because other means of finance are not available in sufficient volume. Firms with a hybrid business model offer contract research or services to third parties in order to finance the company's own research and development activities. In essence, the contractual relationship between firms is that of *ex-ante licensing.* 63 percent of the German firms as compared to 55 percent of British firms follow this 'bootstrapping' mode of finance. Focusing on the subgroup of firms that are younger than five years, Haagen *et al.* find that 66 percent of German firms compared to 60 percent of British firms pursue a hybrid business model. Nearly half of German firms' personnel resources are devoted to conducting contract research or services to finance the company's own research. Somewhat unexpectedly, the proportion of British firms' personnel committed to contract research or services is also relatively large at about 45 percent.

The bootstrapping approach may be in conflict with the rapid development of the firms' own products and technologies. After all, firms pursuing a bootstrapping approach choose a form of finance that reduces external control, but may delay the growth of the start-up. This may not be optimal. In fact, there are often very large rewards for early entrants in large but immature markets. The dominance of US firms in emerging technology markets may be due to the fact that they have access to financial channels, which allows them to grow quickly. This is presumably not the only reason for the (relative) scarcity of fast-growing European high-technology firms, but it may contribute significantly to the phenomenon.

4.3 Patents as signals and attractors of external equity finance

The relevance of patents for companies attempting to obtain financial resources, especially in their early stages, has been noted repeatedly in the literature (Hayes 1999; Lemley 2000). An important source of finance for innovation in high-growth start-ups is external equity which is often supplied by venture capitalists (VCs). A product that is proprietary or can otherwise be protected is an important selection criterion for VCs (MacMillan 1985). Hence, companies in need of capital will try to obtain patents if the cost of doing so is not too high for them.

Patents increase appropriability and thus provide incentives for innovation. In addition, patents facilitate the licensing of technology (*e.g.* Gans *et al.* 2002). They increase the attractiveness of companies as acquisition targets (Cockburn and Wagner 2007) and enable VCs to recover a salvage value from failing companies. However, scholars have also documented that "patent strength" varies between industries in that in most industries patents are less featured than other means of protecting innovations, such as first-mover advantages or secrecy (Levin *et al.* 1987). But on average, patents matter for VCs. Baum and Silverman (2004) examine selection criteria used by VCs and subsequent company performance. They find a positive association between patent applications at the US Patent Office (USPTO) and pre-IPO financing defined as VC financing and private placements. Interestingly, patent grants have a positive but smaller effect than patent applications.

The signaling function might be more valuable to the patent holder than the substance of the rights.

While a large strand of literature has investigated the traditional view of patents as a means of protecting intellectual property, Long (2002, p. 625) notes that scholars have overlooked the informational function of patents which "may be more valuable to the rights holder than the substance of the rights". Moreover, the information that is relevant to a financier may not just come from the grant event, but from other aspects of the patenting process. Recently, a few scholars have shed light on some aspects of the role of patents for VC financing. Hsu and Ziedonis (2008) find a positive effect of patents on investors' estimates of company value for a sample of VC-financed semiconductor start-ups. They find larger effects for early funding rounds, where information asymmetry is at its largest. In addition, patents are particularly valued by more prominent VC investors. Lerner (1994) also documents a positive influence of patents on company valuation.

VCs need to make their investment decisions under a high degree of uncertainty. Technology start-ups are difficult to evaluate since they do not have a track record which outsiders can use to evaluate their potential, they are often years away from first revenues, their assets are mostly intangible and they are plagued by a high failure rate. These perils have led VCs to spend a great deal of effort in seeking and assessing signals of ventures' growth potential (Amit *et al.* 1990; Hall and Hofer 1993) and have driven entrepreneurs to undertake symbolic action to gain legitimacy (Zott and Huy 2007).

The value of signaling lies in the reduction of information asymmetries (Spence 1973) and of information costs (Long 2002). In general, the literature has identified three broad categories of signals that are relevant for technology-based start-ups. Signals of the first type include educational background as well as founder history (Eisenhardt and Schoonhoven 1990; Burton *et al.* 2002; Shane and Stuart 2002). The second group includes signals in the form of attributes of parties affiliated with a person or organization (*e.g.* Stuart *et al.* 1999). The third category includes previous accomplishments of the start-up company. Patent grants and even patent applications may be considered as such an accomplishment, signaling a company's technical abilities.

The value of signals generated during the patenting process is that they reduce information asymmetries between VCs and the new and unproven company seeking capital, and that they minimize information costs for the financiers. Even a patent application which has not been approved yet by a patent office may constitute such a signal. The preparation of patent applications requires effort and time, since applicants have to follow strict guidelines and need to include technical information in a structured manner. This may allow individuals familiar with the patent application requirements to quickly assess the strengths and weaknesses of an invention and of the technology employed by the start-up.

The notion that patents facilitate the acquisition of VC is quite intuitive. From an investor's perspective, a start-up with strong patent rights should be preferred since the patent protects the start-up's market position by allowing it to exclude others from using its proprietary technology. Moreover, should the start-up fail the patent may allow VCs to obtain some salvage value. In this regard, patents may both serve as valuable assets that enhance the value of the investment in the case of success *and* in the case of failure, and also as signals which certify to some extent that the start-up has at its avail a novel and inventive technology. In the latter case, the patent's function is mainly to act as a seal of quality, possibly reducing the information problem on the investor's side. Both functions are complementary, but the second one could even work for industries in which patent protection is not effective, as long as the patent office's assessment contains new information for the venture capitalist.

Patenting activity is positively correlated with company value and other success measures.

Several contributions in the empirical literature suggest that patents can indeed work in the two ways just described. Mann and Sager (2007), building on a qualitative study by Mann (2005), investigate the relationship between patents and VC availability. They show that there is a significant positive correlation between various success measures (number of financing rounds, overall investment, exit status, acquisition of late-stage financing and survival span) and measures of patenting activity. They also demonstrate that in the software industry, only few start-ups ever have patents (hence, they are a relatively scarce asset), that patenting behaviour varies strongly, and that the size of the patent portfolio does not matter as much as a simple indicator of patenting activity. Mann and Sager (2007) do not have strong evidence in favour of a causal relationship; hence, the results could be caused by "good start-ups" being active in patenting and simultaneously being favoured by VC investments without a causal impact of patent rights on the financing decision.

Hsu and Ziedonis (2008) bring a new aspect into the discussion and treat patents as quality signals for entrepreneurial ventures which have to fight the liabilities of smallness and youth. They find that patent filings have a strong association with investor estimates of company value – a doubling of the stock of applications is associated with a 28-percent increase in value. Patents are particularly important in early financing rounds, valued more highly by prominent VCs, and positively correlated with the likelihood of an IPO. Theoretical considerations would predict that founders with more experience should profit less from the signalling effect than less experienced ones, but this expectation cannot be confirmed. While the authors also estimate panel models (over financing rounds, including an IPO round), the claim that the effects of patent filings are causal remains tentative (as in other studies as well). Moreover, it seems that the results could be reconciled with the notion that on average, the firms simply own valuable assets, and that the VC valuation reflects that.

Haeussler *et al.* (2008) accept the notion that patents might be signals, but point to a weakness in the argument. Usually, the VC investment decision precedes the patent grant considerably. Hence, the signal (if there is any) cannot lie in the grant decision of the patent office itself, but must reside in other information generated in the course of patent examination. In the US patent system, patents are usually taken to be patent grants, since the application used to be unknown to the public. Conversely, the European Patent Office (EPO) data used by Haeussler *et al.* (2008) can be employed to trace unsuccessful applications as well as successful ones. The European patent system thus affords a much more detailed view of the patenting process, since applications, search reports, grants, oppositions and communications between applicant and examiner are observable. This allows the authors to test if VCs react more strongly to patents that become – much later on – highly cited and to patent oppositions.

Using the timing of events to identify effects, Haeussler *et al.* (2008) find that in the presence of patent applications, VC financing occurs earlier. The results also show that VCs pay attention to patent quality, financing those ventures faster which later turn out to have high-quality patents. Patent oppositions increase the likelihood of receiving VC, but ultimate grant decisions do not spur VC financing, presumably because they are anticipated. The empirical results and additional interviews with VCs suggest that the process of patenting generates signals which help to overcome the liabilities of newness faced by new ventures. However, it is not the patent application or patent grant *per se* which certify the start-up's quality. It is a diverse set of events which taken together allow VCs sufficiently familiar with the patent system to assess the quality of the firm in their portfolio.

Taken together, these studies suggest that patents have an important but complex function for start-ups to secure external finance from VC channels. Patents may in part reflect enhanced appropriability, but they may also act as signals which would be hard to obtain in the absence of a patent system. Since these functions of patents have only been investigated in the recent literature, there is still no quantitative measure of how strongly the institution contributes to the financing of new firms.

4.4 Patents as collateral in debt finance

Researchers have studied the nexus of finance and innovation for more than thirty years now. The financing-gap problem has already been described. Venture capital provides a solution in some of the cases, but in all likelihood, there are a large number of firms which are subject to financing constraints for R&D and innovation, but most of them are unlikely to receive VC. Reasons could be that the growth prospects of the firm's projects – although substantial – are not as high as required from a VC's point of view. Moreover, the entrepreneur or owner may not wish to give up their independence.

Difficult valuation issues and the risk surrounding the liquidation values limit the use of patents as collateral.

In these cases, innovative firms typically tend to lack tangible capital that could be used as collateral to obtain external finance. Why can they not make use of their intangible assets to provide collateral? In the presence of liquid markets for intellectual property such as patent rights and with some certainty given their scope and value, managers could resort to using patents as collateral in debt financing transactions. The literature states that there are two reasons why the use of intangibles as collateral in debt finance has been limited (*e.g.* Lev 2001). The first one is that it is often exceedingly difficult to come up with an objective valuation of such assets, even from the proprietor's perspective. Even if a valuation existed, asymmetric information could make it hard to communicate the assessment to the financier. The second is that in the case of the loan going defunct, the bank will find it typically very difficult to sell the asset or commercialize it in some other way. Markets for intellectual property are still not well-developed. In other words, the collateral will not provide the intended function as an asset that can compensate the bank for the loss from the defunct loan.

Several authors have suggested that the classical view needs to be amended and that extending debt finance against intellectual-property (IP) collateral is becoming more common. The argument is in line with the "markets-for-technology" view which states that technology is increasingly being traded in some form of market transactions. While there is some systematic evidence of the latter, there is no comprehensive statistical data that would capture the extent to which loans are granted in exchange for IP collateral. As an upper bound, a recent KfW survey of 4,300 German SMEs yielded the result that in 2007, only 2.2 percent of the surveyed firms used intangible assets as collateral (KfW 2007). Given that these assets may include trademarks, copyright, patents and other IP rights, the share of firms using patents as collateral is likely to be less than one in a hundred.

The phenomenon should nonetheless not be belittled. It is true that only few specialist financiers offer such services today, and the use of patents for collateral is still largely experimental and non-standard. But this form of financing innovation has true potential and could make a major contribution in improving overall conditions for innovation. To get a flavour of such transactions consider the example of ESKA Implants GmbH & Co KG, a producer of joint replacements reported in Schlemvogt (2009). The company needed capital for expanding its product range and service network to complete a turn-around. The main bank was willing to accept patents as collateral. An external valuation specialist identified 320 relevant patent rights which were valued at EUR 3.5 to 5.0 million. The bank then accepted the respective portfolio (with a risk adjustment of 30 to 50 percent) as collateral. The company remained the owner of its patents in these transactions.

Several factors are currently counteracting the use of patents as collateral. Banks are still highly sceptical, and loan officers typically point to the lack of expertise in dealing with complex IP issues. The inclusion of IP specialists is likely to raise the costs of such transactions. Moreover, the high risk regarding the liquidation value of the collateralized IP also reduces the extent to which it can be used. It is not uncommon that the collateral value of IP in such debt finance transactions is below ten percent of its value to the proprietor. Nonetheless, even such a low valuation may provide the firm with sufficient credit to perform sizeable innovation activities. As a consequence, an increase in innovation activity would be the consequence of past inventive activities.

Better valuation techniques, greater IP-market liquidity and financial innovations would boost debt finance for innovative firms.

It is too early to assess the relevance of these developments and to give predictions about the future potential of IP-collateralized debt finance for innovation. With improvements and standardization in valuation techniques, with greater liquidity in markets for patents and licenses, and with greater openness towards innovative financing instruments on behalf of banks, a significant financing branch could emerge. Some banks could evolve into specialists handling such transactions and become lead debt-holders in syndicated transactions. Debt transactions of this type could be handled either by "house banks" with the support of patent valuation specialists or by specialist banks which offer valuation and extension of debt in one organization. Clearly, the new form of financing requires both relational as well as transactional competencies.

Offering this option as an additional source of finance would be welfare-improving since the extent of funding gaps (in particular for SMEs) could be reduced. Yet, there are important obstacles. A significant shift towards this form of financing would necessitate that loan officers in banks have technical expertise as well as legal and business training. Clearly, this would constitute a major change. Moreover, there is an open question if temporary support *via* public banks (*e.g.* the KfW in Germany), government support or coordinated EU-wide measures could accelerate the development of a new and stable private financing mechanism for innovation. These questions will be discussed below.

4.5 Patent funds

Patent funds are one of the most interesting types of commercialization vehicles. While IP funds are not a recent invention,[6] they have been rising in importance recently. Some US patent funds have gained an ambivalent reputation for extorting license payments by making intensive use of legal threats or full-fledged litigation (*e.g.* see Business Week 2006). The European situation is different, presumably because the litigation system does not grant the kind of strategic opportunities available in the US system. There are other differences as well. While US commercialization of patents is usually undertaken by stock-listed firms, European patent funds are typically closed investment funds which require investors to hold on to their investments for a time period of four years or more. Investors are compensated for the illiquidity of the investment with relatively high returns – most patent funds announce return expectations between approximately 10 and 20 percent after taxes.

Two types of funds have been set up in recent years – "blind pools" and "asset pools".[7] In blind pools,

6 Less recent examples include the British Technology Group (BTG) which was founded in 1995. BTG seeks to commercialize patent rights in the field of pharmaceutical and medical inventions. BTG has been expanding its portfolio by several large-scale acquisitions, *e.g.* in 2000 when Siemens AG transferred a portfolio of about 1800 patents to BTG.

7 Deutsche Bank has set up three asset-pool funds, starting with Patent Select I in 2006, while Credit Suisse established a blind-pool fund in 2004/2005 already. Euram Bank has set up three blind-pool patent funds, starting in 2007. Little is known about fund performance to date; returns from the first fund are supposed to be distributed in 2009/10. Fund volume has been increasing, and minimum investments have been declining from 50,000 EUR in 2005 to 10,000 EUR in 2008. The total fund volume is currently of the order of 300 million EUR and is expected to grow further. For a practitioner's view on these funds, see Lipfert and Ostler (2008).

the patent portfolio to be commercialized has not been selected yet – the performance of the pool rides mostly on the fund managers' talent in detecting, acquiring and commercializing patents. In asset pools, the intermediary makes an up-front investment in selecting the patent portfolio and then invites investors to fund the subsequent commercialization process. Asset pools are considerably less risky for the investor than blind pools, but the intermediary will have to be compensated for the set-up costs and shifting of risk and returns are lower than in the case of blind-pool funds. While the first generation of European patent funds was privately placed, subsequent funds have been marketed as investments to a broader group of investors.

Patent funds come as 'blind pools' (portfolio yet to be chosen) and 'asset pools' (intermediary buys portfolio up-front).

From an analytical perspective, investments in patent funds are still largely unknown entities, and more research is needed to describe their characteristics reliably. Understandably, the information provided by fund managers themselves tends to veer to the optimistic side. The claim made by fund managers that patent fund investments are largely uncorrelated with investments in other asset classes (*e.g.* Lipfert and Ostler 2008, p. 265 and BIT 2008, p. 51 and p. 71) have not been substantiated in independent research. Moreover, the performance expectations appear to be relatively high at this point, and may be seriously affected by the current economic crisis. How patent funds will weather the current decline in IP activity and the trend towards a more restrictive granting of such rights remains to be seen. Despite these sceptical remarks, this new form of IP monetization can support the financing of innovative companies. It should therefore be welcome. The setup of funds whose commercialization strategy relies heavily on litigation and threat of litigation is likely to receive a more critical assessment. The discussion of these practices is taken up in the next section.

5. Patent systems and the financing of innovation

5.1 Parameters of patent system design

The rules of the patent system are important determinants of the new financing and exchange institutions that are currently springing up. Given the focus of this paper, the central question is how the patent system should be designed to facilitate the financing function of patents and licenses. If it is true that patents make it easier for innovative firms to obtain finance or to license their inventions, then a well-functioning patent system also has a positive effect on innovation through this channel. This is a welfare component of the patent system that has only recently found attention and that still needs further study.[8] If patents facilitate the emergence of new markets or even the competitive entry of new firms into existing markets with innovative products, then the simple juxtaposition of welfare losses due to exclusion rights (market power) and of welfare gains due to innovation does not hold. To stretch the argument somewhat, absent the patent there would be no entry (*i.e.*, competition) and no innovation.

Various questions need to be answered in this context. Is there a trade-off between what is good for financing innovation and social welfare maximisation of patent systems more broadly? Is a poorly designed patent system an impediment for innovation finance? And is the European Patent System conducive to allowing the use of patents to procure external finance?

The main aspect to be considered when answering these questions is the extent of uncertainty about patent rights. It should be recalled that patent rights can support the financing of innovative companies since they may help to reduce informational asymmetries. But if patent rights themselves are highly

8 To the best of my knowledge Bronwyn Hall has been the first to make this point. Hall (2007) contains a detailed discussion of the role of patents for start-up firms and for competition.

uncertain regarding the scope of the concomitant exclusion right, then their effect in reducing informational asymmetries is likely to be small. Moreover, with uncertain patent rights it will be difficult to establish liquid and transparent markets for patents and licenses. Hence, for a patent system to support the emergence of new financing channels, it needs to provide well-delineated patent rights. Finally, the granting and scope decision should come quickly in order to support firms in the initial stages of innovation, when financial constraints are particularly pronounced.

A full-fledged discussion of patent system design is well beyond the scope of this paper. Instead, I will focus on a limited number of parameters which are particularly important for achieving reasonable trade-offs. These are the timing of decisions, the quality and precision of the examination and the cost of patenting (as perceived by the applicant). Aspects of the patent-litigation system are discussed in the next sub-section. These characteristics are strongly related – higher quality and faster examination are likely to require more resources than low-quality, slow decision-making.

Patent system policy faces a trade-off between duration/costs and the precision of granting decisions.

From the perspective of any stakeholder, the optimal patent system would simply arrive at precise and reliable decisions almost immediately and at almost no cost to the applicant or society at large. Obviously, this ideal system does not exist due to trade-offs between precision, duration and costs. Consider the issue of precision first. To simplify somewhat, decisions by patent authorities are subject to two types of errors. An error of type I consists in not granting a patent to an applicant with a truly novel and inventive technology. Conversely, an error of type II occurs when a patent is granted to an undeserving application, *e.g.* when the technology already exists or the inventive step is too small to deserve patent protection. Clearly, minimizing the likelihood of any error will require resources. Moreover, it may require time – irrespective of resources. Some information is simply generated by time passing by and cannot be replicated easily by investing more private resources. Hence, an immediate examination would not be optimal, especially in new technical fields. This argument has been made by Regibeau and Rockett (2007).

Since efforts to avoid errors will tend to increase the duration and costs of patent examination, it is clear that a patent system supportive of the new financing functions will involve complex trade-offs. A look at the empirical literature supports this view. There is strong evidence that (i) longer time lags in patent examination create uncertainty (Schankerman and Galasso 2007; Gans *et al.* 2008); (ii) some applicants seek to increase uncertainty for their rivals and therefore delay examination proceedings (Harhoff and Wagner 2009); (iii) quick decisions are typically less precise than slower ones, in particular in new technical fields (Regibeau and Rocket 2009); (iv) systems which allow applicants to delay examination (deferred examination) lead to a significant reduction of the examination workload; and (v) systems with a large inflow of "marginal" applications create additional uncertainty for all players because the state of the art can no longer be determined reliably (McGinley 2008 and Opperman 2009).

The current situation of the European Patent Office (EPO) and of the national patent offices in Europe and beyond is not satisfactory. The EPO has accumulated a major backlog of applications. Moreover, applicants are increasingly resorting to tactics of delay and artificial complexity in their filings (McGinley 2009). After some time period in which the EPO had tried to accommodate the quantity objectives of its "clients", the office has now switched to a quality-oriented approach. It has established practices towards "raising the bar" which will result in lower grant rates and sanctions (higher fees) for abusive practices. This approach needs to be supported by policy makers in Europe, and by the leadership of national patent offices. The reform measures undertaken at the EPO need further support. This conclusion is not new, and it is broadly supported in the academic literature – see Harhoff (2006) and Guellec and van Pottelsberghe (2007) for further comments and references. Yet some stakeholders such as legal representatives see private value in an ever-expanding patent system. Furthermore, patent offices themselves may be "self-interested". After all, these are organizations with legal and implicit commitments to their employees who would wish to see secure pension funds, high degrees of job security and comparatively high salary levels. Complex issues of fairness, labour market competition and long-term incentives in the patent office need to be considered. The political economy of patent systems may therefore be far more complex than the optimization of these systems in terms of welfare and efficiency. It is probably the most neglected aspect in the current academic discussion.

While it is clear that patent office operations should be as efficient as possible, there is no reason to believe that the price of patenting should necessarily be as low as the marginal costs of operating a patent office (which should be as low as possible in order to have patent offices work efficiently). The cost of patenting (as perceived from the applicant) is a screening device that will deter applicants with low-value, marginal applications. Thus, a low-price system is likely to invite a large number of marginal applications which would clog the patent system, with subsequent problems for examination quality. Even some US practitioners are now conceding that this has been the fate of the US patent system (Oppermann 2009). Fees and filing costs are an important determinant of actual applicant behaviour – they should therefore be considered appropriate instruments of patent policies. A policy of providing patent protection at the lowest possible cost to the applicant without considering the implications for filing volumes is seriously misguided.

A low-price patent system invites many low-value applications that clog the patent system, affecting examination quality.

Finally, the backlogs at the major patent offices create uncertainty with respect to the state of the art and the scope of protection. If granting decisions cannot be produced quickly, then the patent system should generate precise information that allows knowledgeable experts to arrive at reasonably precise estimates of subsequent decisions at later stages. In that regard, the European system does well since the written communication between applicant and examiner is made public in the EPO's file inspection system.

5.2 Patent litigation

Despite the infrequent occurrence of patent litigation (in particular at appeal levels), the patent litigation framework has a particularly important impact on patenting practice, patent office behaviour and on emerging markets for technology. Patent-litigation cases occur in two basic forms: either as revocation proceedings challenging the validity of patents granted by the respective patent authority or as infringement proceedings seeking to enforce patent rights. The likelihood of a patent being involved in litigation at some point during its term is estimated at between 1 and 3 percent in most patent systems, with some variation across technical domains, industries and countries. It is particularly high in the US and still relatively low in Europe. Patent litigation is known to occur particularly frequently (i) for valuable patents; (ii) as assessments of case quality become more divergent; and (iii) as the distribution of information becomes increasingly asymmetric. Patent litigation is "the tail that wags the dog of the patent system" – litigated cases provide legal precedence and important signals to patent holders, potential infringers and third parties seeking to steer free of patent conflicts. A well-designed litigation system is therefore the capstone of any patent system. Conversely, a flawed litigation system may effectively counteract any welfare gains from the system or cause welfare losses of its own.

The "ascendancy of intangibles", as Lev (2001) has termed recent developments, has led to the emergence of new types of players and intermediaries. The so-called "patent troll" has become the most notable one. Using the patent litigation system to extort license payments has been referred to in the literature as "trolling" which is not an illegal practice, but seeks to exploit structural and procedural weaknesses of the patent and judicial system to earn rents. See Reitzig *et al.* (2007) for a detailed analysis of the "troll" business model. Since these rents may not be compensated by welfare gains, trolling is likely to be welfare-reducing.

Various features of the US patent and litigation system may contribute to the widespread occurrence of trolling in the US. The following aspects have been named as supportive of patent trolling:

- High costs of legal proceedings;
- Cost allocation rules in court (both parties bear their own costs);
- Contingency fee payments for lawyers, creating incentives for lawsuits;
- High damage awards and risk of treble damages in the case of "wilful infringement";
- Pro-patentee posture of US courts and juries;
- Low examination quality creating uncertainty about the scope of protection;
- General and broadly defined extension of patentable subject matter to software and business methods; and
- Quick and indiscriminate availability of injunctions[9] which can be used to create economic pressure.

Patent trolls who exploit weaknesses of the litigation system to extort license payments are more widespread in the US than in Europe.

The exact extent of "trolling" in Europe is unknown. Certainly, the practice has not played the prominent role that is has in the US. On the other hand, several patent funds have purchased several thousands of patents, and the first court actions by "trolls" may already be pending in Europe. The weaker presence of "trolls" is presumably due to the fact that the patent system in Europe deviates from the US system in several crucial points. In Europe, (i) court proceedings are much less costly; (ii) cost allocation favours the winning party; (iii) damage awards are not excessive; (iv) most courts have sought a careful balance between the rights of the parties and have not followed a systematic pro-patent posture; (v) injunctions are not issued automatically; and (vi) the quality of patent examination has been considerably better than in the US, despite some weakening. However, one should not assume that the European system is "troll-proof".

Current efforts to transform the fragmented European patent litigation system into a unified court need to take these and other considerations into account. A patent litigation system in which parties duplicate their controversies in national courts is no longer appropriate for the European economy. But the reform towards the unified system needs to assure that the current balance of power between parties is maintained. The Czech EU Presidency, in Working Document 5072/09 (Draft Agreement on the European and Community Patents Court and Draft Statute, dated January 8th, 2009) has put forth a new proposal for a unified Patent Court, to be named "European and Community Patents Court". Essentially, the proposal foresees the establishment of a unified patent court which will cover both European patents and future Community patents. This proposal has revived the policy discussion. It describes a good starting point for creating a unified system without creating loopholes that could be exploited by patent trolls. A more detailed discussion is given in Harhoff (2009).

Most importantly, patent litigation should occur at relatively low cost for litigants. As a US judge once noted, high litigation costs distort patent trade and the patent system.[10] They would be dangerous to an emerging market for technology and new financing channels.

---

9 In May 2006, the US Supreme Court decided to put and end to quasi-automatic injunctions in the US litigation system. These were one of the major instruments used by trolls to exert pressure on presumed infringers. See eBay Inc v. MercExchange, L.L.C., 547 U.S 388(2006).

10 Ellis (2000): "(…) It is, simply put, that the escalating, indeed skyrocketing litigation costs of the 1970's and 1980's have distorted patent markets and patent economics." This comment concerns the development in the United States.

6. Conclusions and policy implications

It has long been known that innovation activity may not only be impeded by classical knowledge externalities, but also by financing constraints. These arise due to informational asymmetries that are particularly pronounced in the early stages of innovative processes and technology creation. Traditional debt finance and public equity markets cannot close these funding gaps, and relatively new forms of private equity, such as venture capital, reach only the small portion of start-up firms which are likely to generate a particularly high rate of return.

New forms of innovation finance are emerging, however. While these do not play a major role at this point, policy makers and managers should pay attention to these new developments. Supported by changes in valuation techniques and accounting regulation, it seems likely that patent rights will increasingly be used as collateral in debt finance. Moreover, patent funds may become an important source of finance for owners of patents. When intermediate outputs of the innovation process become increasingly tradable for financing reasons, a more liquid and transparent market for technology will emerge.

Greater availability of finance and markets for technology are complementary and require appropriate design of patent systems.

The two developments – enhanced availability of finance and improved markets for technology – are complementary, but they depend crucially on the appropriate design of patent systems. The more uncertain patent rights are, the less likely is it that the new forms of finance will play a major role, and the more will markets for technology be impacted by information asymmetries that drive up the cost of innovation finance. Thus, the trend towards high quantities of low-quality patents needs to be stopped. The pro-quantity stance of some patent offices needs to give way to a strategy in favour of well-delineated and reasonably secure property rights. There is even the possibility of a virtuous cycle in which high-quality patent rights lead to an improvement of the financing situation for SMEs and young firms, and ultimately to more research, innovation and high-quality inventions. Paradoxically, the path towards the virtuous cycle will require cutting the number of patent grants from currently inflationary to much lower future levels, with a concomitant improvement of inventive step and value. Policy-makers need to learn that patent offices are not the modern analogue of the alchemist who promises the transmutation of common metals into gold. They are more like central banks – printing too much money may lead to inflation and uncertainty, and thus undermine growth.

These comments are of course partly speculative. To advise policy makers more objectively, there is a need for more reliable and objective data and sober analysis. In future research, a comprehensive annual survey of banks could help to measure the extent to which patents are already being employed as collateral in debt financing. More detailed data on licensing and patent transfers are required to study the development of markets for technology. Moreover, a Europe-wide listing or collection of information on patent funds would be helpful to describe the state of the emerging fund market more reliably. It is also clear that further policy interventions should support the emerging markets. The market for licenses is in dire need of more transparency. Such transparency might be achieved by changing the reporting requirements for licensing transactions as proposed by Lemley and Myhrvold (2007). But the issues are complex – in some cases the emergence of a market for technology will benefit from allowing for anonymous transactions in order to avoid situations in which a party showing interest in a license is immediately threatened with litigation in order to drive up prices.

Summing up, there are promising signs of a positive scenario of markets for technology and improved innovation financing, in particular when measures are taken to make these exchanges more transparent and less prone to opportunistic rent extortion. Such a development would reduce informational asymmetries and quasi-rents, yield lower prices for technology, allow for greater specialization and lower capital costs for innovative firms. All of this would be welcome news for European entrepreneurs, managers and policy makers alike.

References

Amit, R., Glosten, L. and Muller, E. (1990). "Entrepreneurial ability, venture investments, and risk sharing". *Management Science*, (36), pp. 1232-1245.

Arora A., Fosfuri, A. and Gambardella, A. (2004). *Markets for technology: The economics of innovation and corporate strategy*, MIT Press, Cambridge, Mass., USA.

Athreye, S. and Cantwell, J. (2007). "Creating competition? Globalisation and the emergence of new technology producers". *Research Policy*, (36), pp. 209-226.

Baum, J.A. and Silverman, B.S. (2004). "Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology start-ups". *Journal of Business Venturing*, (19), pp. 411-436.

BIT (Beteiligungs- & Investitions-Treuhand AG) (2008). Prospect for Alpha Patent Fund 3. http://basisplusweb.bit-ag.com/6YXN-NYAD-674Y-PX89/de/beteiligung/downloads/alpha_patentfonds_prospekt.pdf

Bloom, N. (2007). "Uncertainty and the Dynamics of R&D". *American Economic Review*, (97:2), pp. 250-255.

Bond, S., Harhoff, D. and Van Reenen, J. (2006). "Investment, R&D and financial constraints in Britain and Germany". Centre of Economic Performance, Discussion Paper No. 0595, London School of Economics. Forthcoming in *Annales d'Économie et de Statistique*.

Burhop, C. (2009). "The transfer of patents in imperial Germany". Preprints of the Max Planck Institute for Research on Collective Goods No. 2009/26, Bonn. http://www.coll.mpg.de/pdf_dat/2009_26online.pdf

Business Week (2006). "Inside Nathan Myhrvold's mysterious new idea machine", http://www.businessweek.com/print/magazine/content/06_27/b3991401.htm?chan=gl

Cockburn, I. and MacGarvie, M. (2007). "Patents, thickets and the financing of early-stage firms: Evidence from the software industry". National Bureau of Economic Research, Working Paper No. 13644.

Cockburn, I. and Wagner, S. (2007). "Patents and the survival of Internet-related IPOs". National Bureau of Economic Research, Working Paper No. 13146.

Cohen, W.M., Nelson, R.R and Walsh, J.P. (2000). "Protecting their intellectual assets: Appropriability conditions and why U.S. manufacturing firms patent (or not)". National Bureau of Economic Research, Working Paper No. 7552.

Dechenaux , E., Goldfarb, B., Shane, S. and Thursby, M. (2008). "Appropriability and commercialization: Evidence from MIT inventions". *Management Science*, (54), pp. 893-906.

Eisenhardt, K.M. and Schoonhoven, C.B. (1990). "Organizational growth: Linking founding team, strategy, environment, and growth among U.S. semiconductor ventures, 1978-1988". *Administrative Science Quarterly*, (35), pp. 504-529.

Ellis, T.S. (2000). "Distortion of patent economics by litigation costs: Proceedings of the 1999 Summit Conference on intellectual property". University of Washington, Seattle, USA. CASRIP Symposium Publication Series, (5), pp. 22-26. http://www.law.washington.edu/CASRIP/Symposium/Number5/pub5atcl3.pdf

Epstein, R. and Pierantozzi, M. (2009). "Obtaining maximum value from distressed patent assets". *American Bankruptcy Institute Journal*, (28), pp. 48-51.

Galasso, A. and Schankerman, M. (2008). "Patent thickets and the market for innovation: Evidence from settlement of patent disputes". Centre for Economic Policy Research, Discussion Paper No. 6946, London.

Gambardella, A. (2002). "Successes and failures in the markets for technology". *Oxford Review of Economic Policy*, (18), pp. 52-62.

Gambardella, A., Giuri, P. and Luzzi, A. (2007). "The market for patents in Europe". *Research Policy*, (36), pp. 1163-1183.

Gans, J.S., Hsu, D.H. and Stern, S. (2002). "When does start-up innovation spur the gale of creative destruction?". *RAND Journal of Economics*, (33), pp. 571-586.

Gans, J.S., Hsu, D.H. and Stern, S (2008). "The impact of uncertain intellectual property rights on the market for ideas: Evidence from patent grant delays". *Management Science*, (54), pp. 982-997.

Giuri, P., Mariani, M., Brusoni, S., Crespi, G., Francoz, D., Gambardella, A., Garcia-Fontes, W., Geuna, A., Gonzales, R., Harhoff, D., Hoisl, K., Lebas, C., Luzzi, A., Magazzini, L., Nesta, L., Nomaler, O., Palomeras, N., Patel, P., Romanelli, M., Verspagen, B. (2007). "Inventors and invention processes in Europe: Results from the PatVal-EU survey". *Research Policy*, (36), pp. 1107-1127.

Gompers, P. and Lerner, J. (2000). *The Venture Capital Cycle*, MIT Press, Cambridge, Mass, USA.

Graham, S., Merges, R., Samuelson, P., and Sichelman, T. (2009). "High-technology entrepreneurs and the patent system: Results of the 2008 Berkeley patent survey". http://ssrn.com/abstract=1429049.

Guellec, D. and van Pottelsberghe, B. (2007). *The economics of the European patent system: IP policy for innovation and competition*, Oxford University Press, Oxford, UK.

Haagen, F., Haeussler, C., Harhoff, D., Murray, G. and Rudolph, B. (2007). "Finding the path to success – The structure and strategies of British and German biotechnology companies". AGBO Report, LMU München.

Haeussler, C., Harhoff, D. and Schirge, M. (2008). "Stock market reactions to patent oppositions in biotechnology and pharmaceutical", Working Paper, Ludwig-Maximilians Universität Munich, mimeo.

Haeussler, C., Harhoff, D., and Mueller, E. (2009). "To be financed or not … - The role of patents for venture capital financing,". Centre for Economic Policy Research, Discussion Paper No. 7115, London.

Hall, B.H. (1992). "Investment and research and development at the firm level: Does the source of financing matter?". National Bureau of Economic Research, Working Paper No. 4096.

Hall, B.H. (2002). "The financing of research and development". *Oxford Review of Economic Policy*, (18), pp. 35-51.

Hall, B.H. (2007). "Patents and innovation (and competition)", in OECD (eds.), *Competition, patents and innovation*, Directorate for financial and enterprise affairs, Competition committee, pp. 243-251.

Hall, B.H. (2009). "The financing of innovation". *EIB Papers*, (14:2), in this issue.

Hall, B.H., Jaffe, A. and Trajtenberg, M. (2005). "Market value and patent citations". *RAND Journal of Economics*, (36), pp. 16-38.

Hall, B.H., Thoma, G. and Torrisi, S. (2007). "The market value of patents and R&D: Evidence from European firms". National Bureau of Economic Research, Working Paper No. 13426.

Hall, B.H. and Ziedonis, R.H. (2001). "The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry 1979-1995". *RAND Journal of Economics*, (32), pp. 101-128.

Hall, J. and Hofer, C. (1993). "Venture capitalists' decision criteria in new venture evaluation". *Journal of Business Venturing*, (8), pp. 25-42.

Harhoff, D. (2006). "Patent quantity and quality in Europe – Trends and policy Implications," in Kahin, B. and Foray, F. (eds.): *Advancing knowledge and the knowledge economy*, MIT Press, Boston, USA, pp. 331-350.

Harhoff, D. (2009). "Economic cost-benefit analysis of a unified and integrated European patent litigation system". Final Report, Tender No. MARKT/2008/06/D.

Harhoff, D. and Körting, T. (1998). “Lending relationships in Germany: Empirical results from survey data”. *Journal of Banking and Finance*, (22), pp. 1317-1353.

Harhoff, D., Narin, F., Scherer, F.M. and Vopel, K. (1999). “Citation frequency and the value of patented inventions”. *Review of Economics and Statistics*, (81), pp. 511-515.

Harhoff, D. and Reitzig, M. (2004). “Determinants of opposition against EPO patent grants – The case of biotechnology and pharmaceuticals”. *International Journal of Industrial Organization*, (22), pp. 443-480.

Harhoff, D. and Wagner, S. (2006). “The duration of patent examination at the European Patent Office”. Discussion Papers in Business Administration No. 1256, University of Munich. Forthcoming in *Management Science*.

Hayes, D.L. (1999). “What the general intellectual property practitioner should know about patenting business methods”. *Computer Lawyer*, (16), pp. 3-18.

Hsu, D.H. (2006). “Venture capitalists and cooperative start-up commercialization strategy”. *Management Science*, (52:2), pp. 204-219.

Hsu, D. and Ziedonis, R.H. (2008). “Patents as quality signals for entrepreneurial ventures”. Academy of Management Best Paper Proceedings.

Kaplan, S. and Strömberg, P. (2003). ”Financial contract theory meets the real world: An empirical analysis of venture capital contracts”. *Review of Economic Studies*, (70), pp. 281-315.

KfW (Kreditanstalt für Wiederaufbau) (2007). “Immaterielle Vermögenswerte und Unternehmens-finanzierung“, KfW-Research, Sonderband “Innovationen im Mittelstand”, (37), pp. 149-165. http://www.kfw.de/DE_Home/Research/Publikatio94/Mittelstan45/Mittelstnd99/Per_39_Periodikum_immat_Sicherheiten_071030_final_online.pdf

Kortum, S. and Lerner, J. (2000). “Assessing the contribution of venture capital to innovation”. *RAND Journal of Economics*, (31), pp. 674-692.

Lanjouw, J.O. and Schankerman, M. (2001). “Characteristics of Patent Litigation: A Window on Competition”. *RAND Journal of Economics*, (32), pp. 129-151.

Lanjouw, J. O. and Schankerman, M. (2004). “Protecting Intellectual Property Rights: Are Small Firms Handicapped?”. *Journal of Law and Economics*, (47), pp. 45-74.

Lemley, M.A. (2000). “Reconceiving patents in the age of venture capital”. *Journal of Small and Emerging Business Law*, (4), pp. 137-148.

Lemley, M.A. and Myhrvold, N. (2007). “How to make a patent market”. Stanford Law and Economics, Olin Working Paper No. 347.

Lerner, J. (1994). The importance of patent scope: An empirical analysis. *RAND Journal of Economics*, (25), pp. 319-333.

Lev, B. (2001). *Intangibles – management, measurement, and reporting*, Brooking Institution Press, New York, USA.

Levin, R.C., Klevorik, A.K., Nelson, R.R. and Winter, S.G. (1987). “Appropriating the returns from industrial research and development”. *Brookings Papers on Economic Activity*, (1987:3), pp. 783-820.

Lipfert, S. and Ostler, J. (2008). “Patentverwertungsfonds als effiziente Intermediäre zwischen Kapital- und Patentmarkt”. Mitt. Heft, (6), pp. 261-266.

Lipfert, S. and von Scheffer, G. (2006). “Europe’s first patent value fund”. Intellectual Asset Management, (December/January), pp. 15-18.

Long, C. (2002). “Patent signals”. *University of Chicago Law Review*, (69), pp. 625-679.

MacMillan, I.C., Siegel, R. and Subbanarasimha, P.N. (1985). "Criteria used by venture capitalists to evaluate new venture proposals". *Journal of Business Venturing*, (1), pp. 119-128.

Mann, R.J. (2005). "Do patents facilitate financing in the software industry?". *Texas Law Review*, (83), pp. 961-1030.

Mann, R.J. and Sager, T.W. (2007). "Patents, venture capital, and software start-ups". *Research Policy*, (36), pp. 193-208.

Maskus, K. (2000). Intellectual property rights in the global economy, Institute for International Economics.

McGinley, C. (2008). "Taking the heat out of the global patent system," IAM Magazine, July, http://www.iam-magazine.com/issues/ Article.ashx?g=6a2efdac-2023-4f35-956b-a9577cd908b9

Merges, R. (2005). "A transactional view of property rights". *Berkeley Technology Law Journal*, (20), pp. 1477-1520.

Motohashi, K. (2008). "Licensing or not licensing? An empirical analysis of the strategic use of patents by Japanese firms". *Research Policy*, (37), pp. 1548-1555.

Myers, S.C. and Majluff, N.S. (1984). "Corporate financing and investment decisions when firms have information that investors do not have". *Journal of Financial Economics*, (13), pp. 187-221.

Nabar, M. and Nicolas, T. (2009). "Uncertainty and innovation during the Great Depression". Working paper. http://people.hbs.edu/tnicholas/UI16_Revised2.pdf

Nagaoka, S. and Kwon, H. (2006). "The incidence of cross-licensing: A theory and new evidence on the firm and contract level determinants". *Research Policy*, (35), pp. 1347-1361.

Opperman, C.P. (2009). "The elephant in the room". *Intellectual Asset Magazine*, July/August, pp. 53-59.

Regibeau, P. and Rockett, K. (2007). "Are more important patents approved more slowly and should they be?". Centre for Economic Policy Research, Discussion Paper No. 6178, London.

Reitzig, M., Henkel, J. and Heath, C. (2007). "On sharks, trolls, and their patent prey – Unrealistic damage awards and firms' strategies of 'being infringed'". *Research Policy*, (36), pp. 134-154.

Scherer, F.M. and Harhoff, D. (2000). "Policy implications for a world with skew-distributed returns to innovation". *Research Policy*, (29), pp. 559-566.

Serrano, C. (2008). "The dynamics of the transfer and renewal of patents," National Bureau of Economic Research, Working Paper No. 13938.

Spence, M. 1973. "Job market signalling". *Quarterly Journal of Economics*, (87), pp. 355-374.

Stuart, T.E., Hoang, H. and Hybels, R.C. (1999). "Interorganizational endorsements and the performance of entrepreneurial ventures". *Administrative Science Quarterly*, (44), pp. 315-349.

Thakor, A.V. (1993). "Information, investment horizon, and price reaction". *Journal of Financial and Quantitative Analysis*, (28), pp. 459-482.

The Economist (2005). "A market for ideas." Special section, October 22nd, pp. 3-6.

Zott, C. and Huy, Q.N. (2007). "How entrepreneurs use symbolic management to acquire resources". *Administrative Science Quarterly*, (52), pp. 70-105.

Zuniga, M. and Guellec, D. (2009). "Who licenses out patents and why? Lessons from a business survey". Organisation for Economic Co-ordination and Development, STI Working Paper 2009/5, Paris.

Economic and Financial Reports*

Report 2008/01 **Christoph Memmel, Christian Schmieder & Ingrid Stein,** "Relationship Lending – Empirical Evidence for Germany"

Report 2007/04 **Atanas Kolev & Armin Riess,** *"Cost-benefit rules for new-technology renewable energy projects"*

Report 2007/03 **Frédéric Blanc-Brude, Hugh Goldsmith & Timo Välilä,** *"Public-Private Partnerships in Europe: An Update"*

Report 2007/02 **Andreas Kappeler & Timo Välilä,** *"Composition of Public Investment and Fiscal Federalism: Panel Data Evidence from Europe"*

Report 2007/01 **Eric Perée and Timo Välilä,** *"A Primer on Public Investment in Europe, Old and New"*

Report 2006/03 **Rien Wagenvoort,** *"Comparing Distributions: The Harmonic Mass Index: Extension to m Samples"*

Report 2006/02 **Rien Wagenvoort,** *"Does the hedge fund industry deliver alpha?"*

Report 2006/01 **Frédéric Blanc-Brude, Hugh Goldsmith and Timo Välilä,** "Ex Ante *Construction Costs in the European Road Sector: A Comparison of Public-Private Partnerships and Traditional Public Procurement"*

Report 2005/03 **Gerti Dudkin and Timo Välilä,** *"Transaction Costs in Public-Private Partnerships".*

Report 2005/02 **Eric Perée and Timo Välilä,** *"Fiscal Rules and Public Investment".*

Report 2005/01 **Timo Välilä and Aaron Mehrotra,** *"Evolution and determinants of public investment in Europe".*

Report 2004/02 **Alfred Steinherr, Ali Tukel and Murat Ucer,** *"The Turkish Banking Sector: Challenges and Outlook in Transition to EU Membership".*

Report 2004/01 **Federico Galizia,** *"Systemic credit risk in the presence of concentration".*

Report 2003/02 **Federico Galizia,** *"Measuring the "financial gap" of European corporations: an update".*

Report 2003/01 **Rien Wagenvoort,** *"Bank Survey evidence on bank lending to SMEs in the European Union".*

Report 2002/02 **A. Rossi, G. Bichisao & F. Campolongo,** *"Hedge accounting within IAS39".*

Report 2002/01 **Luisa Ferreira de Almeida & Patrick Vanhoudt,** *"Catching the Celtic tiger by its tail".*

Report 2001/03 **Eric Perée & Alfred Steinherr,** *"The euro and capital markets: A new era".*

Report 2001/02 **Federico Galizia & Dermot O'Brien,** *"Do capital expenditures determine debt issues?"*

Report 2001/01 **Federico Galizia with Thomas Steinberger,** *"The "savings gap" of European Corporations: A first look at the available data".*

Report 2000/02 **Christopher Hurst & Kristian Uppenberg,** *"Investment issues in south-eastern Europe".*

Report 2000/01 **Dermot O'Brien & Rien Wagenvoort,** *"Some empirical findings on the characteristics of cost-efficient credit institutions".*

Report 99/P3 **Carsten Sprenger,** *"Direct investment and the eastern enlargement of the EU".*

Report 99/P2 **Daniel Piazolo,** *"The credibility and growth effects of EU institutions for Eastern Europe".*

Report 99/P1 **Hendrik Hassheider,** *"Private sector investment as a means of financing Trans-European Networks".*

Report 99/02 **Rien Wagenvoort & Paul Schure,** *"The recursive thick frontier approach to estimating efficiency".*

Report 99/01 **Paul Schure & Rien Wagenvoort,** *"Economies of scale and efficiency in European banking: New evidence".*

Report 98/05 **Daniel Ottolenghi,** *"Walking a tightrope: Financial liberalisation in Mediterranean countries".*

Report 98/04 **Christian Keuschnigg,** *"Venture capital: A case for investment promotion".*

Report 98/03 **Roman Arjona, Pascale Viala & Rien Wagenvoort,** *"Small business finance and the European financial environment: Some empirical evidence".*

Report 98/02 **Alfred Steinherr & Roman Arjona,** *"The impact of European Monetary Union on the development of the Mediterranean zone".*

Report 98/01 **Marco Buti, Lucio R. Pench & Paolo Sestito,** *"European unemployment: Contending theories and institutional complexities".*

Economic and Financial Reports are preliminary material circulated to stimulate discussion and critical comment.

*As from 2004, EFRs are available in electronic format only.

The above publications are available free of charge from:

European Investment Bank
Economic and Financial Studies

98-100, boulevard Konrad Adenauer
L-2950 Luxembourg

infoefs@eib.org (+352) 4379-82154 (+352) 4379-68895

www.eib.org/efs

EIB Papers 2008 – 2009

Volume 14, Number 2, 2009: R&D and the financing of innovation in Europe. Financing innovative firms

Bronwyn B. Hall, *"The financing of innovative firms"*
Laura Bottazzi, *"The role of venture capital in alleviating financial constraints of innovative firms"*
Jacques Darcy, Helmut Krämer-Eis, Dominique Guellec & Olivier Debande, *"Financing technology transfer"*
Dietmar Harhoff, *"The role of patents and licenses in securing external finance for innovation"*

Volume 14, Number 1, 2009: R&D and the financing of innovation in Europe. Stimulating R&D, innovation and growth

Kristian Uppenberg, *"Innovation and economic growth"*
Christian Helmers, Christian Schulte & Hubert Strauss, *"Business R&D expenditure and capital in Europe"*
Bart van Ark, Janet X. Hao, Carol Corrado & Charles Hulten, *"Measuring intangible capital and its contribution to economic growth in Europe"*
Kieran Mc Morrow & Werner Röger, *"R&D capital and economic growth: The empirical evidence"*
Dirk Czarnitzki, *"The virtue of industry-science collaborations"*
Damien Ientile & Jacques Mairesse, *"A policy to boost R&D: Does the R&D tax credit work?"*
Jérôme Danguy, Gaétan de Rassenfosse & Bruno van Pottelsberghe de la Potterie, *"The R&D-patent relationship: An industry perspective"*

Volume 13, Number 2, 2008: Infrastructure investment, growth and cohesion. The economics of regional transport investment

Gianmarco Ottaviano, *"Infrastructure and economic geography: An overview of theory and evidence"*
Achim Kemmerling & Andreas Stephan, *"The politico-economic determinants and productivity effects of regional transport investment in Europe"*
Riccardo Crescenzi & Andrés Rodríguez-Pose, *"Infrastructure endowment and investment as determinants of regional growth in the European Union"*
Diego Puga, *"Agglomeration and cross-border infrastructure"*
David Brown, Marianne Fay, John Felkner, Somik Lall & Hyoung Gun Wang, *"The death of distance? Economic implications of infrastructure improvement in Russia"*

Volume 13, Number 1, 2008: Infrastructure investment, growth and cohesion. Public investment: Composition, growth effects and fiscal constraints

Juan Gonzalez Alegre, Andreas Kappeler, Atanas Kolev & Timo Välilä, *"Composition of government investment in Europe: Some forensic evidence"*
Richard Jong-A-Pin & Jakob de Haan, *"Time-varying impact of public capital on output: New evidence based on VARs for OECD countries"*
Armin Riess, *"The economic cost of public funds in infrastructure investment"*
Gerd Schwartz, Ana Corbacho, Qiang Cui, Giovanni Ganelli & Paolo Manasse, *"Macro-fiscal policy challenges and public investment in new EU member states"*

The above publications are available free of charge from:

European Investment Bank
Economic and Financial Studies

98-100, boulevard Konrad Adenauer
L-2950 Luxembourg

infoefs@eib.org (+352) 4379-82154 (+352) 4379-68895

www.eib.org/efs

EIB Papers 2006 – 2007

Volume 12, Number 2, 2007: An efficient, sustainable and secure supply of energy for Europe. Meeting the Challenge

Shimon Awerbuch & Spencer Yang, *"Efficient electricity generating portfolios for Europe: maximising energy security and climate change mitigation"*
Machiel Mulder, Arie ten Cate & Gijsbert Zwart , *"The economics of promoting security of energy supply"*
Franz Hubert, *"Strategic investment in international gas transport systems"*
Joachim Schleich, *"The economics of energy efficiency: barriers to profitable investments"*
Dominique Finon, *"Pros and cons of alternative policies aimed at promoting renewables"*
Atanas Kolev & Armin Riess, *"Environmental and technology externalities: policy and investment implications"*

Volume 12, Number 1, 2007: An efficient, sustainable and secure supply of energy for Europe. Global and European policy perspectives

Atanas Kolev & Armin Riess, *"Energy – revival of a burning matter"*
Dieter Helm, *"European energy policy: meeting the security of supply and climate change challenges"*
Coby van der Linde, *"The art of managing energy security risks"*
Mark Jaccard, *"Fossil fuels and clean, plentiful energy in the 21st century: the example of coal"*
Juan Alario, *"EU policy objectives and energy investment decisions"*
Bassam Fattouh, *"The drivers of oil prices: the usefulness and limitations of non-structural models, supply-demand frameworks, and informal approaches"*

Volume 11, Number 2, 2006: An industrial policy for Europe? From concepts to action

Timo Välilä, *"No policy is an island – on the interaction between industrial and other policies"*
Andreas Strohm, *"Competition policy at war with industrial policy?"*
Otto Toivanen, *"Innovation and research policies: two case studies of R&D subsidies"*
Jordi Gual & Sandra Jódar, *"Vertical industrial policy in the EU: an empirical analysis of the effectiveness of state aid"*
Ha-Joon Chang, *"Industrial policy in East Asia – lessons for Europe"*
Christopher Allen, Didier Herbert & Gert-Jan Koopman, *"The European Commission's new industrial policy"*

Volume 11, Number 1, 2006: An industrial policy for Europe? Context and concepts

Armin Riess & Timo Välilä, *"Industrial policy: a tale of innovators, champions, and B52s"*
James Foreman-Peck, *"Industrial policy in Europe in the 20th century"*
Olivier Debande, *"De-industrialisation"*
Elie Cohen, *"Theoretical foundations of industrial policy"*
Charles Edquist & Cristina Chaminade, *"Industrial policy from a systems-of-innovation perspective"*
Richard Baldwin & Philippe Martin, *"Coordination of industrial policy in the European Union"*

The above publications are available free of charge from:

European Investment Bank
Economic and Financial Studies
98-100, boulevard Konrad Adenauer
L-2950 Luxembourg
infoefs@eib.org (+352) 43 79-82154 (+352) 43 79-68895

www.eib.org/efs

EIB Papers 2004 – 2005

Volume 10, Number 2, 2005: Innovative financing of infrastructure - the role of public-private partnerships. Lessons from the early movers

Armin Riess, *"Is the PPP model applicable across sectors?"*
Paul A. Grout, *"Value-for-money measurement in public-private partnerships"*
Patricia Leahy, *"Lessons from the Private Finance Initiative in the United Kingdom"*
Rui Sousa Monteiro, *"Public-private partnerships: some lessons from Portugal"*
Andreas Brenck, Thorsten Beckers, Maria Heinrich, Christian von Hirschhausen, *"Public-private partnerships in new EU member countries of Central and Eastern Europe"*
Campbell Thomson, *"Public-private partnerships: prerequisites for prime performance"*

Volume 10, Number 1, 2005: Innovative financing of infrastructure - the role of public-private partnerships. Infrastructure, economic growth, and the economics of PPPs

Timo Välilä, Tomasz Kozluk, & Aaron Mehrotra, *"Roads on a downhill? Trends in EU infrastructure investment"*
Ward Romp & Jakob de Haan, *"Public capital and economic growth: a critical survey"*
Christophe Kamps, *"Is there a lack of public capital in the European Union?"*
Timo Välilä, *"How expensive are cost savings? On the economics of public-private partnerships"*
Mathias Dewatripont & Patrick Legros, *"Public-private partnerships: contract design and risk transfer"*

Volume 9, Number 2, 2004: The internationalisation of production in Europe. Case studies of foreign direct investment in old and new EU members

Frank Barry, *"Export-platform FDI: the Irish experience"*
Thierry Mayer, *"Where do foreign firms locate in France and why?"*
Magdolna Sass, *"FDI in Hungary: the first mover's advantage and disadvantage"*
Gábor Hunya, *"FDI in small accession countries: the Baltic states"*

Volume 9, Number 1, 2004: The internationalisation of production in Europe. Causes and effects of foreign direct investment and non-equity forms of international production

Armin Riess & Kristian Uppenberg, *"The internationalisation of production: moving plants, products, and people"*
Zbigniew Zimny, *"Long-term trends in international production"*
Kristian Uppenberg & Armin Riess, *"Determinants and growth effects of foreign direct investment"*
Jozef Konings, *"The employment effects of foreign direct investment"*
Ari Kokko & Patrik Gustavsson, *"Regional integration, FDI, and regional development"*

The above publications are available free of charge from:

European Investment Bank
Economic and Financial Studies

98-100, boulevard Konrad Adenauer
L-2950 Luxembourg

infoefs@eib.org   (+352) 4379-82154   (+352) 4379-68895

www.eib.org/efs

EIB Papers 2002 – 2003

Volume 8, Number 2, 2003: Europe's changing financial landscape. The financing of small and medium-sized enterprises

Rien Wagenvoort, *"SME finance in Europe: introduction and overview".*
Rien Wagenvoort, *"Are finance contraints hindering the growth of SMEs in Europe?".*
Ulrich Hommel & Hilmar Schneider, *"Financing the German Mittlelstand".*
Michel Dietsch, *"Financing small business in France".*
Luigi Guiso, *"Small business finance in Italy".*

Volume 8, Number 1, 2003: Europe's changing financial landscape. Recent developments and prospects

Eric Perée & Armin Riess, *"The transformation of finance in Europe: introduction and overview".*
Thorsten Beck, *"Stock markets, banks, and economic development: theory and evidence".*
Graham Bishop, *"The role and development of EU capital markets".*
E. Philip Davis, *"Institutional investors, financial market efficiency, and financial stability".*
Arnoud Boot, *"Restructuring in the banking industry with implications for Europe".*

Volume 7, Number 2, 2002: The financial integration of an enlarged EU. Macroeconomic interlinkages

Robert A. Feldman & Nancy Wagner, *"The financial sector, macroeconomic policy and performance".*
Paul De Grauwe & Marianna Grimaldi, *"Exchange rate regimes and financial vulnerability".*
Willem Buiter & Clemes Grafe, *"Anchor, float or abandon ship: exchange rate regimes for the Accession countries".*

Volume 7, Number 1, 2002: The financial integration of an enlarged EU. Banking and capital markets

Armin Riess, Rien Wagenvoort & Peter Zajc, *"Practice makes perfect: A review of banking in Central and Eastern Europe".*
Dana Hájková, Jan Hanousek & Libor Němeček, *"The Czech Republic's banking sector: Emerging from turbulent times".*
Éva Várhegyi, *"Hungary's banking sector: Achievements and challenges".*
Peter Zajc, *"Slovenian banks a decade later".*
Erich Hampel, *"Successful banking in an enlarged EU".*
Jens Köke & Michael Schröder, *"The future of Eastern European capital markets".*

The above publications are available free of charge from:

European Investment Bank
Economic and Financial Studies

98-100, boulevard Konrad Adenauer
L-2950 Luxembourg

infoefs@eib.org   (+352) 4379-82154   (+352) 4379-68895

www.eib.org/efs

EIB Papers 2000 – 2001

Volume 6, Number 2, 2001: The 2001 EIB Prize

First Prize; Erich Gundlach & Luder Wößmann, *"Better schools for Europe"*.
Second Prize; Jan Fidrmuc, *"Democracy in transition economies: Grease or sand in the wheels of growth"*.
Third Prize; Gilles Duranton & Vassilis Monastiriotis, *"The evolution of the UK North-South divide: Should we mind the gap?"*.

Volume 6, Number 1, 2001: European economic growth. The impact of new technologies

Christopher Hurst & Kristian Uppenberg, *"Wonders will never cease: Prospects for a new economy in Europe"*.
Paul David, *"Productivity growth prospects and the new economy in historical perspective"*.
Patrick Vanhoudt & Luca Onorante, *"Measuring economic growth and the new economy"*.
Danny Quah, *"ICT clusters in development: Theory and evidence"*.
Hermann Hauser, *"Nothing ventured, nothing gained"*.
Andrew Gillespie, Ranald Richardson & James Cornford, *"Regional development and the new economy"*.
Luc Soete & Bas ter Weel, *"Computers and employment: The truth about e-skills"*.
Harald Gruber, *"The diffusion of information technology in Europe"*.

Volume 5, Number 2, 2000: Regional convergence in Europe. Theory and empirical evidence

Daniel Mouque, *"A survey of socio-economic disparities between the regions of the EU"*.
Angel de la Fuente, *"Convergence across countries and regions: Theory and empirics"*.
Jacques-François Thisse, *"Agglomeration and regional imbalance: Why? And is it bad?"*.
Philippe Martin, *"The role of public policy in the process of regional convergence"*.
Patrick Vanhoudt, Thomas Mathä & Bert Smid, *"How productive are capital investments in Europe?"*.

Volume 5, Number 1, 2000: Regional development in Europe. An assessment of policy strategies

Christopher Hurst, Jacques-François Thisse & Patrick Vanhoudt, *"What diagnosis for Europe's ailing regions?"*
Yannis Ioannides & George Petrakos, *"Regional disparities in Greece: The performance of Crete, Peloponnese & Thessaly"*.
Rodolfo Helg, Giovanni Peri & Gianfranco Viesti, *"Abruzzo & Sicily: Catching up and lagging behind"*.
Andrés Rodríguez-Pose, *"Economic convergence and regional development strategies in Spain: The case of Galicia & Navarre"*.
Margarethe Quehenberger, *"Lessons from Eastern Germany"*.
Bertrand Rossert, *"Contributing to regional development through project selection"*.

The above publications are available free of charge from:

European Investment Bank
Economic and Financial Studies
98-100, boulevard Konrad Adenauer
L-2950 Luxembourg
infoefs@eib.org (+352) 4379-82154 (+352) 4379-68895

www.eib.org/efs

EIB Papers 1998 – 1999

Volume 4, Number 2, 1999: The 1999 EIB Prize

First Prize; Philippe Martin, *"Are European regional policies delivering?"*.
Second Prize; Rudi Dornbusch & Francesco Giavazzi, *"Hard currency and sound credit: A financial agenda for Central Europe"*.
Third Prize; Jordi Gual, *"Deregulation, integration and market structure in European banking"*.
Special Topic Prize; Jens Verner Andersen & Jørn Henrik Rasmussen, *"Solving the unemployment puzzle in Europe"*.

Volume 4, Number 1, 1999: European banking after EMU

Christopher Hurst & Rien Wagenvoort, *"European banking after EMU"*.
Martin Brookes, *"The impact of EMU on portfolio management"*.
Graham Bishop, *"New capital market opportunities in Euroland"*.
Colin Mayer, *"European capital markets: Competition between systems"*.
Luigi Spaventa, *"Comments on the future of the EMU capital markets."*
Daniel Gros & Karel Lannoo, *"The structure of financial systems and macroeconomic instability"*.
Clas Wihlborg, *"Supervision of banks after EMU"*.
Christopher Hurst, Eric Perée & Mireille Fischbach, *"On the road to wonderland? Bank restructuring after EMU"*.
Rien Wagenvoort & Paul Schure, *"Who are Europe's efficient bankers?"*.
Philip Molyneux, *"Increasing concentration and competition in European banking: The end of anti-trust?"*
Jean Dermine, *"The case for a European-wide strategy"*.
Ingo Walter, *"Financial services strategies in the euro-zone"*.

Volume 3, Number 2, 1998: International financial institutions in the 21st century

Christopher Hurst & Eric Perée, *"Only a mid-life crisis? The future for IFIs in an integrated world"*.
Michael Klein, *"One hundred years after Bretton Woods: A future history of the World Bank Group"*.
Jannick Lindbaek, Guy Pfeffermann & Neil Gregory, *"The evolving role of multilateral development banks: History and prospects?"*.
Jean-François Rischard, *"Multilateral development banks and global public networks: Speculations for the next century"*.
Pasquale Scandizzo, *"The purpose, management and governance of IFIs: A case study of ambiguity"*.
Nicholas Stern & Hans Peter Lankes, *"Making the most of markets: The role of IFIs"*.
Joseph Stiglitz, *"IFIs and the provision of international public goods"*.
A discussion between Alfred Steinherr & Jacques Attali.

Volume 3, Number 1, 1998: Employment in Europe

Christopher Hurst, *"A discussion of the papers and an overview of the role of investment"*.
Jørgen Elmeskov, *"The unemployment problem in Europe: Lessons for implementing the OECD Jobs Strategy"*.
Gilles Saint-Paul, *"Does technical progress create unemployment?"*.
Michael Burda, *"The consequences of EU enlargement for Central and Eastern European labour markets"*.
José Viñals & Juan Jimeno, *"The impact of EMU on European unemployment"*.
Jacques Drèze, Alain Durré & Henri Sneessens, *"Investment stimulation, with the example of housing"*.
Ole Rummel & Thomas Schröder, *"The employment effects of investment projects"*.
Pascale Viala, *"Financing young and innovative enterprises in Europe: Supporting the venture capital industry"*.

The above publications are available free of charge from:

European Investment Bank
Economic and Financial Studies

98-100, boulevard Konrad Adenauer
L-2950 Luxembourg

infoefs@eib.org (+352) 4379-82154 (+352) 4379-68895

www.eib.org/efs

EIB Papers 1996 – 1997

Volume 2, Number 2, 1997: The 1997 EIB Prize

First Prize; Bernadette Frédérick & Peter Vanden Houte, "*What is the optimum strategy for freezing exchange rate parities at the start of EMU*".
Second Prize; Jean Dermine, "*Eurobanking, a new world*".
Joint Third Prize; Daniel Gros, "*The dynamics of European integration*".
Joint Third Prize; Martin Kolmar, "*On the efficiency of national social security systems in the European Union*".
Awards for Authors under 30 for essays by Pablo de Andrés Alonso & Félix J. Lopez Iturriaga; Volker Köllmann & Andri Kopperschmidt; and Jérôme Vacher.

Volume 2, Number 1, 1997: Banking in an uncertain world

Edward Gardener & Philip Molyneux, "*The too-big-to-fail doctrine revisited*".
Agnès Belaisch, "*High real interest rates: A long-term risk?*".
Pier-Luigi Gilibert, "*Expected loss as a credit risk measure*".
Jacques Girard & Christopher Hurst, "*The capital structure of private infrastructure projects and the risk of default*".
Kristian Kjeldsen, "*Value-at-risk and capital adequacy: The challenge for financial regulation*".

Volume 1, Number 1, 1996: Special Issue on EMU

Daniel Gros, "*The steeple chase towards EMU*".
Ole Rummel, "*On the feasibility of EMU with diverse European economic transmission mechanisms*".
Bernhard Winkler, "*Is Maastricht a good contract?*".
Paul de Grauwe, "*How to fix conversion rates at the start of EMU*".
Luis Gonzalez-Pacheco & Alfred Steinherr, "*A proposal to stabilise the value of the ECU*".

The above publications are available free of charge from:

European Investment Bank
Economic and Financial Studies

98-100, boulevard Konrad Adenauer
L-2950 Luxembourg

infoefs@eib.org (+352) 4379-82154 (+352) 4379-68895

www.eib.org/efs

EIB Papers • Volume 14 • No2 • 2009

European Investment Bank • European Investment Bank • European Investment Bank • European Investment Bank • European Investment Bank

European
Investment
Bank

Economic and Financial Studies

98-100, boulevard Konrad Adenauer
L-2950 Luxembourg
www.eib.org/efs

ISBN 978-92-861-0990-4

QH-PA-14-002-EN-C

ISSN 1830-3676