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The problem of private under-investment in innovation: a policy mind map

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Abstract

This paper reviews the major finance-related causes of private under-investment in innovation and the consequent alternative choices for public policy. The focus is on (i) incentive-based arguments that address the problem of limited appropriability of new knowledge, and (ii) the lacking access to external sources of finance caused by imperfections in the capital market. Drawing a policy mind map, which aims to enhance the mutual awareness and coordination of policy makers at the crossroads of technology and corporate finance, the paper is organised along the following chain of thought: (i) causes and rationales, (ii) aims and targets, (iii) critical constraints, and (iv) the main finance-related instruments of innovation policy.

Key words: technological change, corporate finance, innovation policy, fiscal incentives, venture capital.
JEL codes: O31, O32, O33, G14, H25, H81.

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1. Introduction

Innovation requires the commitment of resources, which in turn need to be financed. The decision to invest in innovation therefore depends on two critical factors, namely the initial *incentive* to allocate resources for innovation and the capacity to raise the necessary *financial means*. Economic theory provides good reasons for public intervention in both respects, and public authorities have applied these arguments to a growing number of policy initiatives. In short, policy attempts to intervene in the investment decisions of firms, because two deficiencies in the pure market-based allocation of resources may cause suboptimal private expenditures on innovation:

- First, the *limited appropriability of new knowledge* frequently causes private returns to fall short of the social returns and thus leads to under-investment in innovation (Nelson, 1959; Arrow, 1962). Since this kind of market failure stems from distorted incentives to innovate, it occurs irrespective of the actual financing capacity of the firm.
- Second, under-investment can result from *capital market imperfections*, which undermine a firm's capacity to raise the external funds required for financing an investment, even when incentives are not distorted.

The plethora of rationales and new programmes, which has expanded rapidly over the past decades, increasingly becomes a source of confusion. This paper therefore aims to provide a coherent general perspective on the various policy channels. Being directed at students of innovation research as well as policy makers at the crossroads of technology and corporate finance, it seeks to compile a selective review of the major arguments in the debate.

The paper is organised along the chain of thoughts displayed in Figure 1. To begin with, the next section identifies in more detail the finance-related causes of under-investment and the corresponding rationales for public intervention. Section 3 addresses the specific targets and objectives at which policy should be aimed. Section 4 then discusses critical constraints on the selection of policy tools. Section 5 elaborates the particular instruments, while Section 6 summarises and concludes.

2. Policy rationales

2.1 Missing markets for knowledge

The first of the two finance-related causes of under-investment in innovation originates in the limited saleability of new ideas. As a public good, knowledge has two critical properties which can seriously reduce its commercial value (Geroski, 1995, 92ff). First, knowledge remains in circulation no matter how many people use it ('non-rivalry' of consumption). Second, as soon as knowledge is disclosed, it becomes difficult to enforce any payment ('non-excludability'). As a consequence, many innovative firms face the following dilemma: *How can they communicate to a potential buyer the value of a new idea, without disclosing the idea itself? And once they have disclosed the idea, why should a potential buyer be willing to pay for it?* Innovative firms must therefore deliberately manage their knowledge flows in a way that maximises their private returns on a given innovation. Geroski (1995) lists a number of strategic options for individual enterprises, among them intellectual property rights, secrecy, lead-time, and embodied knowledge ('sell products, not ideas').

Depending on the particular technology and market characteristics, some strategies will be more effective than others, but overall, an innovative firm cannot expect to fully prevent the unpaid diffusion of new knowledge. Frequently, competitors, suppliers, or customers reap benefits from a new innovation, even though they may have contributed little or nothing to its development. As the above strategic means to appropriate the returns from innovation rise with the nearness to market and saleable products, the overwhelming share of private expenditures on R&D goes to the development part of innovation. Conversely, the more distant to the market the research is, the more difficult it becomes, to fully appropriate the returns.

An adequate policy response can rely on various instruments. One example is the strengthening of appropriability conditions through an effective system of intellectual property rights (Granstrand, 2005). Another policy instrument is the public provision of basic research with the potential to create positive externalities that favour industrial applications over the long run. A third instrument is to offer public subsidies as a form of financial compensation for the additional social returns of innovation.

While the first two examples lie outside the focus of the present paper, the latter directly aims to influence the financing decision of firms and will be discussed in Section 3.

2.2 The 'financing gap'

Imperfections in capital markets are the second finance-related cause of under-investment in innovation. The literature on National Systems of Innovation (NSIs) regularly stresses the importance of mature and well developed capital markets for the allocation of financial resources to innovation activities. To give a few examples, Edquist (2005) and O'Sullivan (2005) offer comprehensive general surveys, while Chang and Shih (2004) compare the distinct systems of China and Taiwan, or Marsh (2003) investigates the particular case of the biotech industry in New Zealand.

The basic function of capital markets is to channel financial resources to their most profitable uses. Thereby, investment decisions are based on expectations about future returns; they rely on incomplete information describing possible future outcomes and thus involve uncertainty. The financing decision is subject to two potential types of error: the financing of projects that fail and the denial of financing to projects that would have been profitable. In this situation, the accuracy of the allocation of resources depends on two critical factors: (i) the availability of *information*; and (ii) the ability to interpret information properly, i.e. *knowledge*.

In the ideal state of perfect capital markets, all projects are funded purely according to their own merits; a firm's size, the availability of collateral, or the firm's equity ratio play no role whatsoever. Since riskier projects call for higher rates of interest, markets can clear in equilibrium. In practice, however, interest rates are rarely used to discriminate between projects, and firms without sufficient collateral face credit constraints. This situation can be linked to two distinct problems resulting from the asymmetric availability of information to the entrepreneur and the investor. First, *adverse selection* is the problem of properly identifying the quality of a project. The entrepreneur has better information about expected costs and returns, which he cannot credibly communicate to the investor, who has difficulties discriminating between good projects and bad. The investor denies credit rather than raising the interest rate, because the latter would generally attract the riskier projects (Stiglitz and Weiss, 1981). Secondly, *moral hazard* is an incentive problem. In this case, the entrepreneur may alter

her behaviour at the cost of the investor. Examples are the reduction of own effort, the pursuit of growth instead of returns to the investor, and the increases in the risk profile of a project. When the costs of monitoring the entrepreneur become too high, the investor must deny financing even though the project may have otherwise been profitable.

Some enterprises are more affected by restricted access to external financing than others. For *small* enterprises, the effort on an accurate risk assessment and other transaction costs can be very high relative to the required volume of finance. Additional problems arise for *young* (start-up) companies, which have not accumulated a steady cash-flow and typically lack not only collateral, but also a track record establishing their good reputation among creditors. Furthermore, investors must take into account the statistical fact that many young enterprises fail (Hölzl et al., 2007; Kaniovski and Peneder, 2008). Finally, the burden of being small and new is further aggravated when the investment is on *innovation* (see, e.g., Carpenter and Peterson, 2002):

— For innovative and technologically complex projects, the need for expert knowledge grows hand in hand with the development of new uncertainties and the increasing asymmetry of information;

— More specifically, adverse selection increases as entrepreneurs become more reluctant to disclose information due to the confidential nature of innovation (fear of imitators);

— Moral hazard may also increase if the investor has difficulties distinguishing between lacking effort on the side of the entrepreneur and inherent risk as a cause of failure;

— Innovative firms tend to have few tangible assets that can be used as collateral. Instead, they rely more on intangible assets, such as highly qualified (but equally mobile) personnel or the ‘present value of growth options’ that reside in an innovative idea.

As a consequence, the optimal (or feasible) capital structure typically changes over time, as a firm increases in size and age (Berger and Udell, 1998; Myers, 2001). Due to the high degree of informational opacity and the associated problems of asymmetric information, young and small start-up companies initially rely most on ‘insider funds’ (i.e., private savings of the business’s founder, family members and friends). Access to intermediated funds increases as firms grow, successfully

strengthening their reputations and accumulating other tangible assets. With a growing number of options available, the conventional 'pecking order hypothesis' posits that firms prefer (i) internal financing from their own cash-flows and retained earnings in favour of external financing and (ii) issuing debt before equity, in the case that internal funds are exhausted. Internal financing is the cheapest method, because it avoids the problems of governance linked to asymmetric information. Debt financing is generally the favoured source of external financing, thanks to lower issuing costs and the entrepreneur's preference to maintain ownership and control.

Empirical observations generally support the stylised pecking order hypothesis. For example, in a study of small and medium sized enterprises in the German machinery sector, Harhoff et al (2001) report that more than 2/3 of expenditures on product innovations were raised from the businesses own cash-flow, followed by bank finance and public subsidies. Similarly, in a study on Belgian technology-based small firms, Boskaya and van Pottelsberghe de la Potterie (2004) observe that personal funds of the founders are the primary source of seed-financing, bank loans and government play an important role in the early stages of technology development, and business angels or venture capital play a greater role in the later stages. They conclude that the financial structure changes as firms grow older, with the share of external finance first increasing during start-up, peaking in early growth, but then gradually decreasing in the later stages of development.

However, other studies with a focus on highly innovative companies draw a different picture. For example, Hall (2002, p. 45) concludes in her survey of the empirical literature that "there is solid evidence that debt is a disfavoured source of finance for R&D investment." Similarly, Hyytinen and Pajarinen (2003) observe a "partially reversed" pecking order in their sample of Finnish SMEs. They show that innovative companies exhibit lower debt ratios and rely more on equity from the principal owner. Moreover, they find that venture capital is the most important source of external equity for firms with the highest R&D intensities, while business angels are the major external source of equity for SMEs with "some but low" innovative activity. Finally, Hogan and Hutson (2005) conclude in a study of Irish software companies that the entrepreneurs in their sample were willing to forfeit independence and control in order to pursue innovation and maximise the value of their companies – eventually, for the potential future sale of their businesses.

In short, while studies uniformly point at the predominance of internal financing, the relative weight of external equity and debt depends on how innovative the firm is. Entrepreneurs can overcome the 'financing gap' by continuously building-up their leverage through steadier and stronger cash-flows and the strengthening of their reputations. However, the lack of sufficient access to external financing is particularly prevalent when they face extraordinary growth opportunities. Inadequate access to financial resources is felt most urgently when firms face an opportunity for a rapid expansion of their activities. What follows from these considerations, is that the 'financing gap' affects only a limited number of firms, but it is precisely these companies that bear the highest potential to drive economic development through radical innovations.

3. Aims and targets

Analytically, both forms of market failure are independent causes of under-investment. In practice, however, they can interact and reinforce each other. This is the case, for instance, when the full appropriation of returns on an innovation depends on the exploitation of *first-mover advantages* (e.g., through launching costly advertising campaigns, or expanding distribution networks). In the presence of capital market imperfections, innovative start-ups typically lack the necessary funds to expand their operations rapidly enough and thereby keep competitors at a comfortable distance. Conversely, external investors may be reluctant to provide funds, particularly when they are not certain whether the entrepreneur will successfully ward off the activities of potential imitators, thus protecting the future returns on her/his innovation.

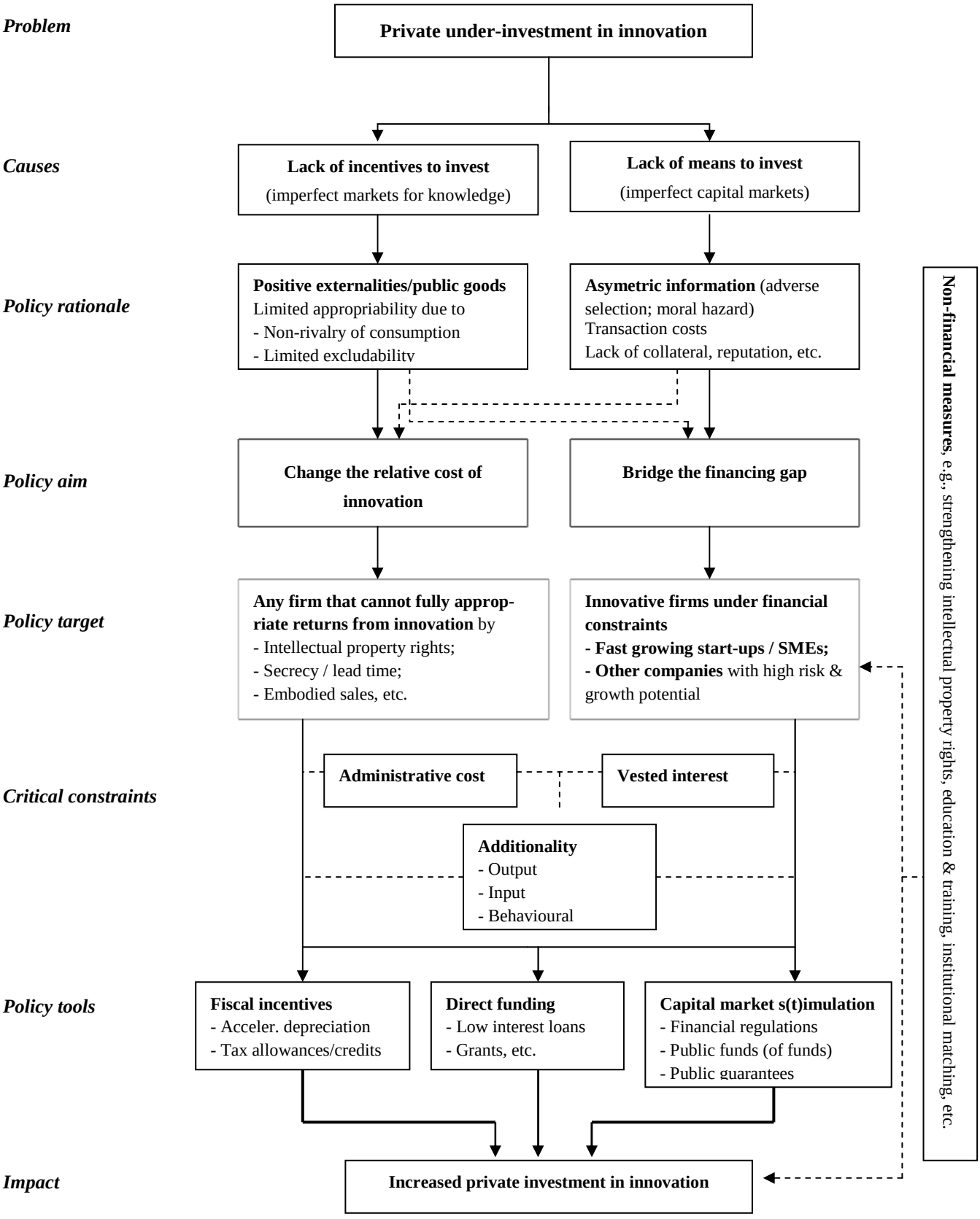
Despite such interdependencies, the analytical distinction between the two causes of under-investment is important when identifying the appropriate objectives of different policy instruments. For example, the strengthening of intellectual property rights is a non-financial policy measure, which intends to increase the 'saleability' of new ideas and thereby directly tackles the problem of appropriability. Conversely, finance-related policies aim to compensate for positive externalities, thereby increasing the private incentives for the entrepreneur to commit own resources through the change in the relative cost of innovation.

Ideally, the size of the subsidy must depend on the specific appropriability conditions. For example, this implies that firms should receive less compensation, the better they are able to protect their innovations by means of intellectual property rights, secrecy, or embodied sales. However, such criteria should apply only to specific markets and technologies, and not to different firms within the same market (say, large as opposed to small enterprises), since the subsidy would then distort the competitive process precisely to the disadvantage of those firms that have learned to manage their knowledge flows best – which is not a desirable outcome of public intervention.

In contrast, innovation policies that try to compensate for the lack of access to financial resources require a more selective approach, targeting the specific group of firms that are most likely to fall into the 'financing gap' (for reasons other than inferior technological or management capabilities). Like other investments, innovative activities are predominantly financed by internal sources, i.e. from the current cash-flow and retained earnings. External financing is needed when investment opportunities are higher than the firm's capacity for self-financing. Even then, large and established companies with a proven record of saleable products can easily turn to financial intermediaries or public equity markets, in the case that the scope of new investments exhausts their capacity for self-financing. As explained in Section 2, the 'financing gap' due to capital market imperfections is a specific concern of young and small enterprises, particularly those which pursue an innovation and try to expand fast enough for the timely appropriation of its returns.

In short, while positive externalities constitute a general rationale for public support, and this public support is primarily conditional upon the merits of a particular project (or technology) and not upon specific qualities of the firm, insufficient access to financing calls for policies that specifically target a certain type of enterprise, with the overall aim of bridging the 'financing gap'. Thereby the central concern is to enable and foster the 'deal flow' from the early invention of novel ideas, e.g., in a university lab, to business plans (see, e.g., Durao et al., 2005) and their initial realisation in a start-up company, and ultimately, to the subsequent growth and expansion of a new high-tech enterprise.

Figure 1: The financing of innovation: a policy 'mind' map



4. Critical constraints

Any kind of economic policy operates under a certain number of critical constraints.[1] To name only two of the most common examples, one must take into account the administrative costs of running a policy and its exposure to manipulations by 'vested' interests. In general, one might expect that policies which barely discriminate between potential beneficiaries are also less prone to the attempted manipulations of the selection process. Overall, one would also expect them to incur fewer administrative costs. However, their downside is that they are also less effective in targeting particular policy aims.

In the latter regard, the general objective of public financial aid to innovation is *output additionality*, which requires the generation of additional social returns through the subsidy. However, the overriding concern in policy design is the question of 'leverage' versus 'displacement' effects, i.e. whether and how public subsidies affect private investments in innovation. In this regard, the basic criterion is *input additionality*, which means that private expenditures rise at the very least by an amount that is equal to the cost savings from the public subsidy. Positive leverage is achieved, if private investments rise by more than the amount of the subsidy (for instance, because it improves the bargaining power of the R&D department within an organisation, or, in the case of constraints on liquidity, because it is perceived by external investors as a sign of quality). Conversely, if 'crowding-out' occurs, the subsidies displace (part of the) private investments that firms would have financed themselves. The foregone opportunity to direct public resources in a better direction (with positive leverage) then constitutes the social cost of policy failure.

One must suspect that in practice, these 'windfall-gains' are quite common. The system may support companies which just substitute the public funding for their own expenditures, leaving the actual amount of innovation activities unaffected, for two reasons. First, public authorities are unlikely to withhold their support precisely from the most promising innovation projects, which in turn are most likely to be undertaken anyway. David et al. (2000) cite two explanations for this situation: (i) the

[1] See, e.g., Pichler, Stampfer and Hofer (2007) for an elaborate historical account of public research funding within the specific context of Austrian institutions and policy.

pressures within public agencies for high 'success rates'; and (ii) the pressure from vested interests, which tends to increase with the size of prospective private pay-offs.

Second, even if public agencies had the power and the will to deny the financing of the most successful innovative companies, one must also acknowledge that in practice, the principle of additionality remains extremely difficult to define and monitor at an operational level. Even in the *ex post* evaluation of policy programmes, the hypothetical counterfactual of 'what would have happened to the firm, in case of an opposite funding decision', must be established by econometric means, estimating an average impact for a given and sufficiently large sample of comparable firms (see, e.g., Blundell and Costa Dias, 2002; or Heckman et al., 1999). In contrast, at the time of funding, the individual decision by the public agency must be *ex ante* and (depending on experience) is likely to have only a limited number of comparable cases to draw inferences from.

To reconcile theory with policy practice, one may derive some comfort from the consideration that even in the presence of "windfall gains", where the public has little leverage on private expenditures for innovation, public subsidies may well 'reward' innovative companies for generating positive externalities. From a dynamic viewpoint, this may raise the economy's capacity to generate innovations in the long run, even though the short-term allocation of current resources is not welfare efficient. The reason is, that the strengthening of innovative firms may foster structural change and encourage the growth of technological capabilities within the economy.

Alternatively, one may define the success of a policy in terms of other criteria, according to which the objectives go beyond merely increasing the amount of money spent on innovation. Policy can instead address a desired change in the behaviour of firms, which may, for instance, relate to the informal sources of innovation and positive spillovers. Probably one of the earliest research papers on the topic is by Leyden, Link and Bozeman (1989), who provide empirical evidence that public R&D support induces private research laboratories to share more of their innovation-related knowledge. For a more recent discussion, see, for instance, Georghiou (2005) and Falk (2005). Typical tools to foster this kind of '*behavioural additionality*' are grants, which a firm receives conditional to its participation in regional networks, cluster initiatives or some form of co-operation between science and business, where the intention is to raise the social returns on the investments.

5. Policy instruments

5.1 Raising incentives to invest

Public subsidies designed to raise incentives for private investment in innovation can assume one of two different forms:

— fiscal incentives, which allow companies to reduce their tax payments, or

— the direct funding of targeted expenditures.

Several instruments can be distinguished among the *fiscal incentives*. First, countries regularly allow firms to deduct their current expenditures on R&D from their taxable income. Many countries have similar provisions for current expenditures on training or marketing activities. If one interprets these expenditures (which one should) as investments in intangible assets that generate income over a longer period, such provisions amount to a generous subsidy in the form of *accelerated depreciation*. In addition to the immediate depreciation of current expenditures, a number of countries implement rules for the accelerated depreciation of R&D equipment, and some countries even expand these provisions to include buildings that are used for R&D (OECD, 2003). Secondly, *tax allowances* offer firms the opportunity to deduct an additional percentage of expenditures on innovation from their tax base. Third of all, *tax credits* allow firms to deduct a certain percentage of the targeted expenditures directly from their tax liabilities.

Since fiscal subsidy schemes typically relate to corporate income taxes, they can only raise incentives for firms that are profitable. Fiscal subsidy schemes have no impact, for instance, on high-tech start-ups that earn little or no profit. However, these might be firms that have reinvested their entire cash-flow in strategies designed to promote fast growth and place it among the first-movers in the respective market – certainly a worthwile target of public support. A fourth instrument is therefore the *innovation premium*, paid to companies which have not earned a positive taxable income. One may also apply carry-forward or carry-backward rules, which permit the *carry-over* of a claim on certain benefits to a period where the firm is liable to pay taxes on its returns.

Finally, one may consider an *alternative tax base*, as in the case of the Netherlands, where an R&D rebate can be deducted from the employer's part of the wage tax and social security contribution of R&D-related personnel. The fiscal incentives thus apply to firms of all legal status (including self-employed entrepreneurs) and directly link the cost reduction to the activities of the R&D department, which may effectively raise its bargaining power for the allocation of funds within the firm. In addition, this scheme offers special provisions for companies younger than 5 years and favours small and medium sized enterprises through a nonlinear rate that decreases with certain thresholds of firm turnover and also includes an upper limit on the total rebate (Hutschenreiter, 2002).

All these schemes implicitly assume that fiscal incentives have the power to influence the private decision to invest in innovation (additionality). But the actual leverage depends on the price elasticity of investments, i.e. the extent to which cost reduction through subsidisation induces firms to spend more on the targeted class of expenditures. Hall and Van Reenen (2000) survey empirical studies that apply various methods and data sources and consequently produce very diverse results. A majority of the latest estimates is, however, broadly in line with a macro-panel study by Bloom, Griffith and Van Reenen (2002), who report that a 10% fall in the cost of R&D stimulates just over a 1% rise in the level of R&D in the short-run, but about a 10% rise over the long-run. In other words, fiscal incentives increase private expenditures on R&D by an amount that is equal to the loss in tax revenues. On average and over the long-run, fiscal incentives thus fulfil the basic criterion of 'input additionality', i.e. rather than displacing private expenditures, the public resources spent on tax incentives constitute additional investments in innovation.

The actual impact of tax incentives in a particular country can vary considerably, depending on the precise design of its fiscal scheme. One critical choice, for example, is between the level and the increment of the targeted expenditures. Incremental schemes only subsidise expenditures which are above the average of the previous years and thus aim at reducing windfall gains. The goal is to raise the leverage of additional incited investments per unit of public subsidy. However, incremental schemes also have the disadvantage of greater complexity, which may cause additional distortions (e.g., with respect to the timing of investments) and raise the costs of compliance as well as of administration.

Direct funding instruments give governments more scope to make deliberate choices about which projects they want to support. In contrast, fiscal incentives generally leave these decisions to the firms themselves. The higher degree of public intervention in private decision-making is the price direct funding schemes pay for the opportunity to discriminate better between projects. The potential pay-off is higher leverage through the more narrow targeting of public resources, for instance towards projects with particularly high spillovers. But direct subsidies may also target other social objectives, such as the support of small and medium sized enterprises, start-up companies, regional cohesion, or other public 'missions' which are of priority to society at large. Typical tools are either grants or public loans at low rates of interest. Sometimes loans are conditional reimbursable (i.e. repayable only if the innovation is successful). The criteria for the selection of applicants can be very diverse, as are the intensity and standards of monitoring and governance. Competitive allocation is certainly the most transparent procedure; although desirable, it is not universally applied.

In contrast to fiscal incentives, which apply only to those levels of political governance that are empowered to make their own tax laws, any local, regional, national, supra-national or even non-governmental authority can in principle pay direct subsidies (provided that it is not in conflict with international regulations of public aid to private business). Furthermore, innovation policy is a fairly recent agenda (compared, for instance, to other fields such as research-, industrial- or competition policy). Parallel to the increasing awareness of the importance of innovation to the process of economic development, innovation policy has grown dramatically in popularity over the past decades, producing an ever increasing number of agencies and initiatives, which have emerged in immediate response to newly perceived needs (Mowery, 1995; Lundvall ans Borras, 2005). As a consequence, the concern now should be for the increasing fragmentation as a result of too many programmes operating at sub-critical levels and lacking transparency and co-ordination. Admitting that some diversity is rooted in the heterogeneous sources of spillovers and the variety of objectives determined by different levels of governance and political territories, the need for a broad and coherent policy approach is certainly growing (Guellec and van Pottelsberghe de la Potterie, 2004).

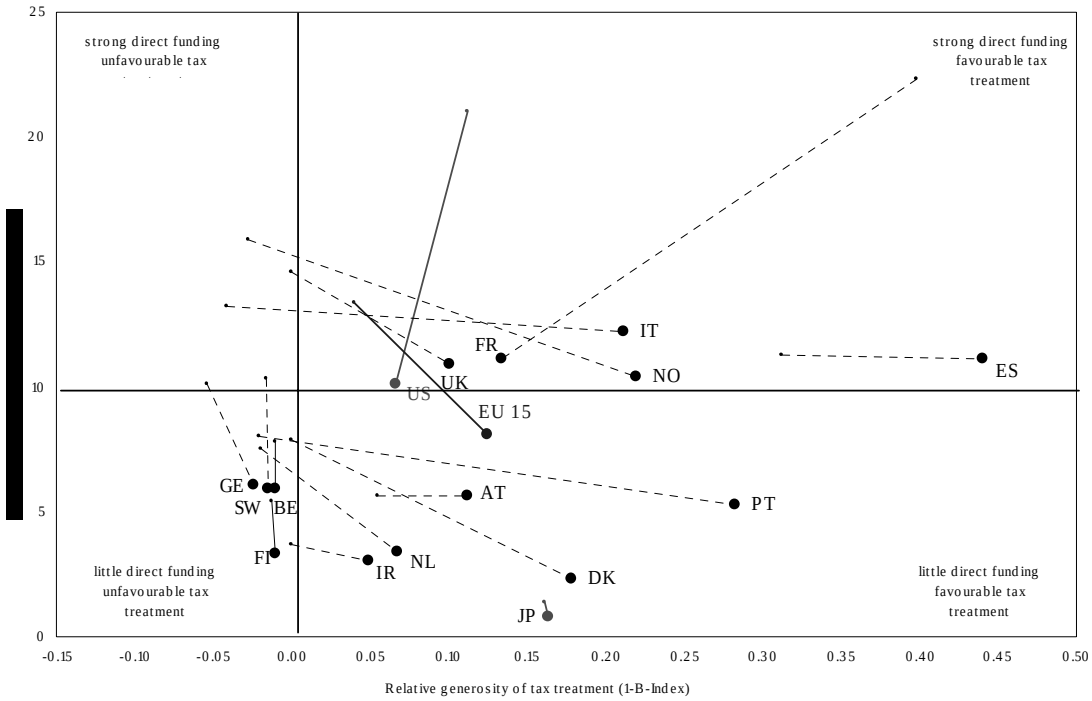
A major barrier to exchanging information on successful policies is the lack of harmonised standards and tools for the evaluation of the manifold programmes and initiatives. It is therefore difficult to

analyse the actual impact on private investment decisions and thereby derive principles of best practice (Fahrenkrog et al., 2002). David et al. (2000, p. 500) survey about 30 different studies; ultimately they stress the diversity in the aims and scope of programmes, as well as in the reported impacts. Referring to the criterion of "input additionality", they draw the cautious but positive conclusion that "at this time, the econometric results obtained from careful studies at both the micro- and macro-levels tend to be running in favor of findings of complementarity between public and private R&D investments." Finally, investigating the aggregate net effect in a panel of 17 OECD countries, Guellec and van Pottelsberghe de la Potterie (2003) report a positive impact of direct public funding and fiscal incentives on business R&D. The relative impact, however, depends on the generosity of the scheme, increasing up to a threshold of about 10% of business R&D, but decreasing beyond. Relatedly, they find that direct and indirect instruments of government support are substitutes in the sense that increasing the generosity of one instrument reduces the impact of the other. Their finding of such interactions between different instruments underscores the need for an integrated approach, where the individual tools become part of a coherent and coordinated policy system.

The above considerations make clear that any 'optimal' combination of fiscal incentives and direct subsidies depends on the particular context, aim and priorities of national innovation policies. Even though a certain degree of international harmonisation is desirable, the diversity of systems also offers an opportunity to learn how effective these instruments are in practice. This opportunity is currently lost, since little systematic data is being collected and the occasional evaluations of particular programs lack a comparable design and methodology (OECD, 2003).

Figure 2 summarises the aggregate trends for direct vs. indirect financial incentives, demonstrating that individual countries choose very different combinations of the two policy instruments. On the vertical axis, the share of business expenditures on R&D funded by the government is a straight-forward measure of the use of direct subsidies in innovation policy. Conversely, the OECD's B-index has become the standard tool for assessing the relative generosity of fiscal incentives (Warda, 2001). The horizontal axis depicts how generous the tax treatment of R & D expenditures is. Each line connects the position of a particular country in the year 1991 and 2002.

Figure 2: Direct vs. indirect subsidies (small dots: 1991; big dots: 2003/2004)



Note: (i) The B-index is defined as the income before tax needed to break even on one dollar of R&D outlay. See Warda (2001) for a detailed explanation. BERD means 'business expenditures on research and development'.

Source: adapted and updated from OECD (2003).

Despite the overall variety in the policy mix of individual countries, we find a general trend of decreasing shares of government-financed business expenditures on R&D. The downward shift has been most pronounced in the United States (from 30% in 1981, and 21% in 1991, to 10% in 2003) and in France (from 25%, and 22%, to 11%, respectively). Most other countries experienced a similar development. For the EU-15 the respective shares declined from 19% in 1981 to about 13% in 1991 and finally 8% in the year 2003. For the EU-25 it declined from about 11% in 1995 to 8% in 2003. While the tax treatment of R&D expenditures became more generous during the same period, the relative importance of the two forms of innovation policies has thus dramatically shifted in favour of fiscal incentives and against direct funding instruments. In part this may be due to growing concerns about the administrative costs of direct funding schemes. Another explanation might be that fiscal incentives do not raise total government spending as a ratio of GDP, which is a performance figure against which governments are frequently benchmarked.

5.2 Access to financial resources

Policies addressing capital market imperfections as a cause of under-investment in innovation typically make their selections from the following menu of instruments:

- The direct funding of firms targeted, for example, to high-tech start-ups and SMEs;
- Fiscal incentives for investors in targeted classes of assets (risk capital);
- The s(t)imulation of capital markets through regulatory reforms, equity programmes, and guarantee schemes.

To begin with, *direct funding schemes* typically offer targeted grants or preferential loans at low interest rates for SMEs and start-up companies. However, as pure subsidies they are constrained in terms of volume and degree of selectivity. Important as they may be for launching innovative projects and helping firms with low to intermediate financing needs, it is unlikely that they will suffice when it comes to backing the expansion of fast growing high-tech start-ups that pursue truly radical innovations.

What policy must aim for in the latter instances, is the mobilisation of private resources that put companies on firm financial footing throughout the full cycle of innovation and novelty-led expansion. One means is to offer *fiscal incentives* to financial investors on the condition that these provide equity to specified ventures. Typical instruments are exemptions from capital gains taxes, tax allowances or income tax credits, the deduction of losses from the income tax bases, investment relief in exchange for corporate taxes, or exemptions from taxes on securities transactions.

Even though fiscal incentives may strengthen a given market by drawing in more investments, public policy needs additional tools to bridge persistent gaps in the financing of high-risk ventures. First, public policy may try to *stimulate* risk capital markets through regulatory reforms, for instance, by revising restrictions on institutional investors (such as pension funds, etc.). Secondly, it may *simulate* the market by substituting private investors with its own, newly launched equity programmes. In this case, the public provides equity either directly to venturesome entrepreneurs, or indirectly in the form of a ‘fund-of-funds’ investor, which spreads resources over a number of private equity companies on the condition that certain rules of behavioural additionality (e.g., focusing on high-tech seed and start-

up companies) be upheld. The big challenge is to find and maintain the delicate balance between bridging persistent gaps in funding but not displacing potential private investors ('crowding-out').

As a third instrument, the public sector can offer *guarantees*, for the case that private markets do not provide insurance, should particular investments result in failure. As they more immediately address the underlying risk of investments as a principal source of the 'financing gap', their potential leverage on private investments is considerable. In most countries, loan guarantee schemes are well established, but they are most often designed as horizontal measures for SMEs, with little discrimination as to the degree of innovation (European Commission, 2003). Equity guarantees are a more recent development, and address either individual investments or the portfolios of equity funds. They can be particularly helpful to allure relatively inexperienced investors to participate in riskier segments of the market. However, guarantees are also afflicted by two major shortcomings: the danger of increasing moral hazard by raising the risk profile of an investment or reducing one's effort to avert failure, and the problem of taking on the risk of investments that would have been undertaken anyway (windfall-gains). In order to mitigate these effects, guarantee schemes should not cover all of the risks involved and they should require that some compensation (insurance premium) be paid by the investor.

At this point, one should also emphasise that financial institutions themselves repeatedly create new means of overcoming inherent limitations and restrictions when it comes to backing potentially profitable ventures (Perez, 2003; Hölzl, 2006). The recent emergence of *venture capital* is perhaps the most remarkable example of the astounding capacity of financial institutions to innovate (Gompers and Lerner, 1999). At the same time, it gives ample evidence of the prominent (but often overlooked) role of public policy in the enhancement of these new markets. Baygan (2003) painstakingly documented venture capital policy in some of the most dynamic markets (among others, the USA, the United Kingdom, Israel, and Korea).

What makes the development of venture capital markets an important means of bridging at least part of the 'financing gap' is not only the focus on firms with high growth potential, but also the intense commitment in terms of the selection and monitoring of projects, which helps to mitigate problems of asymmetric information. Equally important, cash-flow is consistently reinvested, thus building-up company value rather than paying out dividends (Peneder and Wieser, 2002). Even though

investments are of limited duration and investors inevitably must reap their returns through exiting, the episode of venture backed financing is the time during its early history when an innovative company can most ruthlessly pursue first-mover advantages.

There is only little empirical evidence on the impact of policy on the development of venture capital markets. For instance, in a macro-panel study on the determinants of venture capital, Romain and van Pottelsberghe de la Potterie (2003) point at the importance of aggregate growth, technological opportunities (proxied by R&D investments, knowledge stocks and patents), an entrepreneurial environment (captured by the proportion of nascent entrepreneurs and business founders), or low corporate income taxes.

In contrast, the empirical literature on the economic impact of venture capital is rapidly growing (Peneder, 2006). Apart from a few exceptions (e.g., Romain and van Pottelsberghe de la Potterie, 2004), most of the studies focus on the firm-level evidence. For example, Bottazzi und Da Rin (2002) have found that European venture capital financed firms are able to come up with significantly more capital in the IPO process, but have not detected any statistically significant impact of venture capital financing on firm growth. In contrast, Engel (2003) reports significant positive growth effects using a broad sample of German firms provided by the country's leading credit rating agency. Using a propensity score matching, he finds that venture capital financed firms achieve more than double the annual employment growth than firms in the control group. Of related interest, Engel and Keilbach (2007) examine the impact of venture capital on the number of patent applications. They find that innovative firms are more likely to receive venture capital, but once they have received financing their patent output does not differ significantly from that of other firms. Similarly, Peneder (2008) tests the impact of venture capital financing on corporate performance by applying propensity score matching on Austrian micro-data. Controlling for differences in industry, location, legal status, size, age, credit rating, export and innovation behaviour, the findings assert that (i) recipients lacked access to satisfactory alternative sources of capital; (ii) venture capital is invested in firms with high performance potential (selection effect); and additionally (iii) confirm a genuine causal impact on firm growth, yet not on innovation output.

6. Summary and conclusions

This short paper has reviewed and arranged major ideas describing how policy can counter the finance-related causes of under-investment in innovation, further producing a tentative mind map for students of innovation studies and policy makers who operate at the crossroads of technology and corporate finance. The policy mind map not only illustrates the numerous instruments available, but also concatenates them with different causes of market failure, their respective rationales for public intervention and the according aims and targets of innovation policies. This attempted systematisation and deliberate choice of a bird's eye view has been motivated by the large array of policy tools, where *system failure*, caused by a lack of coordination among the manifold agents and organisations involved, is a widespread and growing concern. In that respect, the mind map aims to raise the mutual awareness of the particular tasks and responsibilities as well as the critical constraints and complementarities under which different agents operate, hopefully supporting a better coordination among them.

Following the logical structure summarised in Figure 1, the paper began with the identification of two separate causes of underinvestment in innovation: first, the lack of incentives to invest due to the limited appropriability of returns on innovation, and secondly, the lack of means due to imperfections in the capital market. From there we derived the two standard economic rationales for policy intervention, one based on the existence of positive externalities (spillovers), the other on the problem of asymmetric information (together with transaction costs). As a consequence, we also realised that policy must simultaneously pursue two separate aims: first, to change the relative cost of innovation; and second, to bridge the gap in access to external sources of finance. This distinction also revealed important differences in setting the appropriate policy targets. While positive externalities provide a basic rationale for public support, which is awarded primarily on the merits of a particular project (or technology) and not of the firm, the lack of access to financing also calls for policies that specifically target a certain type of enterprise. We then discussed the critical constraints of policy intervention, such as differences in administrative costs, the influence of vested interest and the likely policy impact through leverage or displacement effects ('additionality'). Finally, we presented a simple menu of

available instruments, listed in the categories of fiscal incentives, direct funding, and measures to s(t)imulate capital markets.

The specific design of innovation policies ultimately depends on the particular aim, context, and constraints, which may differ significantly between countries and levels of governance (Peneder, 2001). The proposed mind map can therefore only be a tool to survey and organise the general arguments. Let's keep this in mind when finally turning to a summary of the major conclusions in terms of particular policy instruments.

With respect to policies that address the lack of access to external sources of finance, we have argued that the central concern is to *enable and foster the 'deal flow'* from the early invention of novel ideas to saleable products on the market. At this point, we want to stress four general recommendations:

— *Bridging mechanisms*: Beginning at the earliest stages, *business angels* are particularly important to the initial 'deal flow' of small investments. Commercial motives alone are unlikely to cover the full transaction costs of running 'angel networks' for the corresponding matching and mentoring activities. Hence, there is good reason for the public to share the costs of activities that serve to match nascent entrepreneurs, e.g. from academic research, with financial investors. As informal investors, business angel networks typically operate at the local level, while interlinkages with institutional investors of private equity and venture capital could be fostered through national or even European initiatives.

— *Equity schemes*: If public resources displace funds from private investors, they not only waste the public resources but also inhibit the development of a mature and self-supporting venture capital market. Equity schemes financed by the public should therefore focus on the most persistent gaps in early stage investments, particularly in the seed phase, when private investors are extremely reluctant to enter. To avoid the frequent move of public initiatives towards the same segments of the market as private investors, a clear policy assignment and regular evaluations of compliance are necessary.

— *Guarantee schemes*: Directly addressing the underlying risk of an investment as a principal cause of the 'financing gap', the potential leverage of public guarantee instruments is

considerable. However, they may also cause perfunctory attitudes towards the causes of failure. Even in the case of a subsidy, beneficiaries should be obliged to carry part of the risk and thus remain exposed to some of its consequences. Also, public guarantees should require a risk premium that must be paid by the investor to help prevent the subsidisation of a project that is not truly in need of it.

— *Financial regulation*: With respect to the regulatory environment, international standards for the regulation and taxation of private equity funds would help to foster tax transparency and ease cross border flows. National corporate and tax laws should adopt the best practices from the most developed markets (such as the US and the UK), which would, for instance, stop the double taxation of returns at the level of funds and investors. Quantitative restrictions on institutional investors such as pension funds and insurance companies should reflect the 'prudent' investor's rule, whereby individual high-risk assets are acceptable within a sufficiently diverse portfolio.

Once innovation is no longer hampered by the lack of access to financial resources, other instruments come in place, *compensating for positive spillovers* and thereby raising the incentives to invest:

— *Fiscal incentives*: As a first priority, fiscal incentives should extend their reach into innovative businesses with a longer-term perspective on profits. One tool is the direct payment of an innovation premium to companies that make no profit. An alternative is the Dutch model of providing a rebate on the wage tax and social security contributions of R&D related personnel. Refined policy designs (such as the use of incremental R&D expenditures) may reduce windfall gains and increase the leverage of public funds through narrow rules of eligibility. However, one must critically assess their benefits in light of the additional costs of compliance and administration, as well as unintended consequences (such as the distorted timing of investments).

— *Direct funding*: At the various levels of governance, emphasis should be placed upon the consolidation and streamlining of direct funding schemes, in order to increase the transparency and mutual co-ordination of major public players. While most tax incentives tend to be

procyclical (i.e. most generous when companies earn high profits), direct subsidies could be used as a countercyclical instrument, with which governments raise funds during periods of macroeconomic distress and thus ease the required restructuring processes (Ylä-Anttila and Palmberg, 2005). At the very least, the funds should be based on long-term commitments, which reduce their vulnerability to ad hoc restrictions imposed by short-term fluctuations in the public budgets.

— *Inclusion of 'informal' sources and non-technological innovation*: Most financial support schemes target R&D and investments in technological innovation. The inclusion of informal sources (e.g., learning by doing or using) and non-technological innovations (such as new business practices, organisational models, etc.), would be equally desirable, as long as there exists a clear case of non-appropriability and positive spillovers. In practice, difficulties would arise with respect to the precise definition of such innovations and with the establishment of effective rules for governance and the selection of potential beneficiaries. A strategy worthy of recommendation is to test broader definitions of innovation first for direct subsidy schemes, since this would allow a more targeted selection and better monitoring. The lessons learned might then be useful for broadening the scope of fiscal incentives, although additional provisions would be required to maintain the targeted precision of public expenditures.

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