



The public/private nexus of R&D

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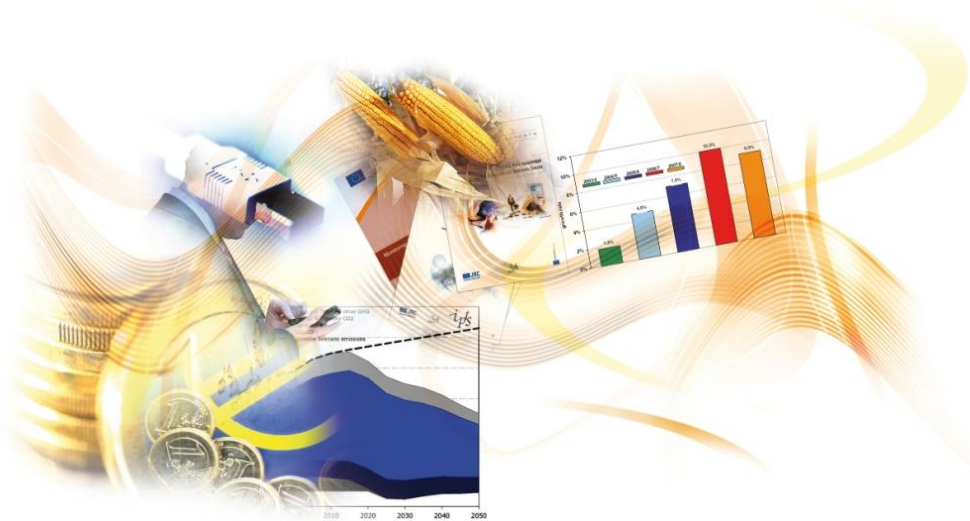
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***IPTS WORKING PAPER on
CORPORATE R&D AND INNOVATION - No. 06/2009***

The public/private nexus of R&D

Deborah Cox and Dimitri Gagliardi



The *IPTS Working Papers on Corporate R&D and Innovation* sheds light on economic and policy questions related to industrial research and innovation. Mainly addressed to policy analysts and the academic community, these are scientific papers (policy relevant, highlighting possible policy implications) and proper scientific publications which will be typically issued at the moment they are submitted to peer-reviewed scientific journals. The working papers are useful to communicate to a broad audience the preliminary research findings of the work we develop, to generate discussion and to attract critical comments for further improvements. The working papers are considered works in progress and are subject to revision.

These *IPTS Working Papers on Corporate R&D and Innovation* can take the form of more *policy oriented notes*, mainly addressed to EU policy-makers. These kinds of papers take a position on a sharply focused policy issue based on the most compelling empirical evidence available. They present policy implications derived from our own research and the views of the most prominent authors in the field, making the appropriate references.

Such Working Papers Series are issued in the context of *Industrial Research Monitoring and Analysis (IRMA)*¹ activities that are jointly carried out by the European Commission's Joint Research Centre (JRC) – Institute for Prospective Technological Studies (IPTS) and the Directorate General Research - Directorate C, European Research Area: Knowledge-based economy.

IRMA activities aim to improve the understanding of industrial R&D and Innovation in the EU and to identify medium and long-term policy implications. More information, including activities and publications, is available at: <http://iri.jrc.es/> and <http://ec.europa.eu/invest-in-research/>

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¹ IRMA activities correspond to the implementation of the approach set out in "Investing in research: an action plan for Europe" (COM, 2003) and in further Communications of the Commission: "More Research and Innovation – Investing for Growth and Employment – A common approach", COM (2005) 488 final, "Implementing the Community Lisbon Programme: A policy framework to strengthen EU manufacturing – Towards a more integrated approach for industrial policy", COM (2005) 474 final.

Abstract

The public-private nexus is a complex interface where policies and infrastructure influence management decisions about R&D investments and innovation opportunities. The interface is continuously evolving and conditions vary from country to country and industry to industry. Technological and market change and industry restructuring introduce new management options to decision makers in established and new entrant companies. Easier access to information and expertise stimulates new ways of working between companies and with other organisations and makes the public-private nexus an international or supranational issue and not just a regional or national concern. Finance and projects can be moved internationally via multinational corporations (MNCs) and global supply-chain networks, and knowledge can be accessed and exploited internationally. Some public-private nexus challenges may, therefore, be outside the scope of policy intervention because they transcend traditional boundaries.

There are some problems related to the public-private nexus which have been studied inconclusively for many years and where the framework for asking questions has now changed. In particular is the question of public investments 'crowding out' private investments. The contexts in which this phenomenon might occur are becoming more complicated and the distinctions between the public sector and private sector are becoming less clear as a result of partnerships and open or collaborative R&D being devised. The conceptual understanding of these contexts and how best to manage them is increasing via an ongoing analysis of innovation systems and processes. There is no single optimum answer or 'one size fits all' solution but rather a need for deeper understanding of the nexus and a practical framework for adapting policy proposals. In addition the effects of policy mix and inherited situations rather than individual or isolated policy initiatives need to be considered. For example, Enzing et al. (2004) contradict the proposition that countries with dedicated biotechnology policy instruments show better commercialisation performance in biotechnology than countries without such instruments. Instead, success is more likely to be determined by the systemic character of public policies that address all elements of the innovation system, including instruments that stimulate the life sciences knowledge base and its commercialisation.

The extent to which the public-private nexus might modify incentives for R&D and innovation investment and the extent to which it facilitates support and entrepreneurial inspiration will depend partly on the relative significance of small and medium-sized enterprises and large companies, as industry leaders within an economy, and according to the knowledge intensity of the industries represented. Individuals' skills, levels of education and a propensity to pursue relevant careers in science, technology and innovation will be important. In addition the availability, quality and reputation of R&D facilities and universities' research capabilities will determine the scope for change. This document discusses certain aspects of the public-private nexus of R&D.

JEL Classification: O33

Keywords: public-private nexus of R&D, R&D incentives

1 Introduction

The public-private nexus is a complex interface where policies and infrastructure influence management decisions about R&D investments and innovation opportunities. The interface is continuously evolving and conditions vary from country to country and industry to industry. Technological and market change and industry restructuring introduce new management options to decision makers in established and new entrant companies. Easier access to information and expertise stimulates new ways of working between companies and with other organisations and makes the public-private nexus an international or supranational issue and not just a regional or national concern. Finance and projects can be moved internationally via multinational corporations (MNCs) and global supply-chain networks, and knowledge can be accessed and exploited internationally. Some public-private nexus challenges may, therefore, be outside the scope of policy intervention because they transcend traditional boundaries.

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2 Methodology

This document emerged from the *Digest of Industrial R&D*², whose objective is to provide a review of the recent literature on industrial R&D in a policy-maker friendly format, aiming for a better understanding of industrial³ R&D investment in Europe⁴. The *Digest* uses systematic information screening, selection and processing activities in order to develop a “bottom-up” picture of the most relevant issues surrounding this subject.

Publicly-available sources, including academic books and papers, documents produced by national governments and international organisations (such as the OECD, the UN and the EU), in-house research at the IPTS and other EC-related working groups, and reports by private organisations were covered in the *Digest* activities.

Four main topics emerged in the first edition of the *Digest*⁵: the impact of business R&D, levels and patterns of business R&D investment, factors that influence those investments, and the internationalisation of business R&D. Following the experience with the first edition, the methodology was improved through incorporating a wider range of sources, in-depth expert discussions for trend identification, and the use of standard templates to structure the information. The most relevant topics have been selected according to the degree of relevance for the following issues:

- (a) **Problématique**: the issue at stake and its economic and policy relevance.
- (b) **State of the art**: the novelty of literature on this topic.
- (c) **Divergence**: the different points of view on the issue, based on existing literature.
- (d) **Blind spots**: areas where there is a lack of policy relevant information.

The process was designed to make the exercise as comprehensive, up-to-date and policy-relevant as possible. Given the “bottom-up” character of the process and the quality of the resulting reports, the most interesting reports are published as self-standing documents.

The present report, *The Public/Private Nexus of R&D*, aims to be a useful reference work for policy-making, research and business alike. Comments, feedback and other input are welcome and can be sent by email to: JRC-IPTS-IRI@ec.europa.eu.

² The *Digest* was an activity within the Industrial Research and Innovation Monitoring (IRIM) project carried out jointly by the Joint Research Centre (JRC) and the Directorate General Research (DG RTD) of the European Commission. The other IRIM activities are the EU Industrial R&D Investment Scoreboard, the EU Survey on R&D Investment Business Trends, and the Economic and Policy Analysis Report.

³ The terms *industrial, corporate, business, and private-sector* R&D are used interchangeably throughout this document.

⁴ IRIM activities are undertaken at the JRC's Institute for Prospective Technological Studies (JRC-IPTS) and are co-funded by DG Research.

⁵ The pilot *Digest* is available at http://iri.jrc.es/research/docs/annual_digest_ird.pdf

3 Is the Market Failure Perspective Enough to Justify Public Intervention?

Traditionally, research and development activities have been classified as basic or 'blue sky' research, applied research and pre-competitive development (OECD, 1994 and updates, Aghion and Howitt, 1998). While the first category has traditionally been a competence of the public sector, the latter has been always seen as the competence of industry. The justification for this dichotomy is in the fact that basic research requires a much longer term before the investment yields returns (if it ever does at all) and the level of uncertainty is extremely high, too high in fact to justify private commitment. Firms tend to under invest in research due to this short term investment perspective. On the other hand applied research is seen as a competence of industry as its scope pertains to the sphere of profitability and competitive advantage rather than long-term scientific progress.

As an outcome of this dichotomy, to raise research funding to a socially optimum level, government needs to invest in basic research, which is understood to be a non-rivalrous and non-excludable public good. This means that consumption of the knowledge created by basic research does not reduce the amount of the knowledge available for consumption by others and no one can be effectively excluded from using that knowledge. In these circumstances, the characteristics of knowledge creation and diffusion provide a sound structure for the next stages of the research and development process. Applied research and pre-competitive development, as competences of industry, are understood as being 'regulated by market forces' and because of the risks, uncertainties and time lags involved, market failures occur.

The public sector compensates for market failures but is less efficient than private sector funding. The traditional explanation for this is that there is insufficient funding of R&D by the private sector because the benefits are often intangible and too far downstream. The reasons that the market invests less in R&D (or innovative activities in general) than is socially desirable (Nelson, 1959; Arrow 1962) include knowledge spillovers, financial market failures, skilled labour shortages and informational imperfections. The ability of competitors and follow-on innovators to benefit from new knowledge is likely to mean that the social rate of return to knowledge production exceeds the private rate of return (Jones and Williams, 1998). However, increasing globalisation in recent years means that knowledge can be more easily accessed and exploited and the boundaries of the regions or economies in which spillovers take place are more difficult to define.

This basic proposition has been used as justification for the development of many types of policy intervention in the innovation process. Public intervention is found to be a complement to private R&D efforts because of *complementarities* and the combination of public and private often involves beneficial synergies. Some industries actively lobby governments for R&D support. In the case of small to medium-sized enterprises, they often carry out research and development activities in large publicly owned, research facilities and without such facilities these projects may often be impossible. Another example is the propensity for large high-tech companies to collaborate with university departments and public research laboratories.

The heading to this introductory section can be challenged as an inappropriate question to ask. Public intervention need not be justified on the basis of a simple dichotomy of public sector 'bad', private sector 'good'. Cumbers and Birch (2006) argue instead for the need to develop a more sophisticated understanding of how the two interrelate in successful and balanced economies. The unit of observation is important and if the lens is focused on individuals, such as scientists, engineers or other knowledge workers as agents of innovation

(Audretsch, 2004) then the important and justifiable challenges become how best to support them and how best to appropriate the returns from their knowledge. This might be thought of as being closer to justifying a state role in education and enterprise rather than R&D for firms.

4 The Wider Rationale for Public Intervention

There are a number of arguments as to why and how private R&D investments are suboptimal. Those arguments fall into four main categories, the first being linked to the financial aspects of R&D investments. A second argument links the decision to invest in R&D to strategic aspects. The third argument is based on the principle that social returns to R&D are higher than private returns as the funders/performers of research and development activities cannot fully benefit from their investment due to the spillover effects. A further argument explains investments in R&D by linking decisions to invest in human capital in the form of researchers and research capabilities in general.

Privately-owned businesses often decide to fund R&D projects using resources from within the company (European Commission, 2007). This trend is discernible by analysing the correlation between the R&D investment and the cash-flow of the company. R&D investments are procyclical (De Marchi and Rocchi, 2005, amongst many others). There are various reasons to explain the high correlation between R&D investments and turnover (cash-flow). The first relies on the observation that employing the company's own resources allows for autonomy of the company to steer its research projects according to its internal decision-making processes. In addition, several recent studies have tested the hypothesis that companies suffer financial constraints on their R&D projects, consequently they only have a limited menu of funding options. Nevertheless, there is substantial evidence supporting the view that the flow of internal resources is the main determinant of industrial R&D investments (Himmelberg and Petersen, 1994; Harhoff, 1998; Hall, 2002; Guellec and van Pottelsberghe, 2004). Both private funds and access to market finance are evidently not enough to cover for the resources necessary for optimal R&D. It is therefore not uncommon for R&D managers to find themselves in a situation where the number of research projects they want to start exceeds the funding available (Hall, 2002; Bougheas, 2004; Hall, 2005).

Other important reasons for suboptimal R&D investment relate to the role of infrastructure and its effects on R&D spending. For example, the closeness to the end market plays a decisive role in directing a large share of global R&D investments, such as in the case of the first migration of R&D facilities from the US to India and China, where investments directly mirror development activities yielding larger gains when performed in or in close proximity to the market, in which the end products will be sold and with direct input from local users and developers.

Business finance for R&D

Financial problems facing private companies who are considering investment in R&D include issues linked to 'opportunity', as the risk and uncertainty involved in research projects might off-set future profits (notwithstanding the positive net present value) or to 'financial constraints due to short term sources of R&D funds versus long term R&D projects. R&D projects are not directly bounded by the financial year while the financial year determines the availability of own funds budgeted for Research and Development projects (Funk, 2006).

Business R&D is funded through both private and public monies. A company's own funds are the principal source for financing its R&D (between 50% and 60% among companies in the EU), followed by tax incentives and public grants. Private funding of R&D is highly dependent on the institutional set up of the market and companies in highly R&D intensive sectors rely more on the stock market and joint ventures than their counterparts in other sectors (European Commission, 2007). A company can pay for its R&D from internal resources, borrowing from banks or with money raised on financial markets. However, R&D is a risky activity and listed companies often prefer not to use their own resources given the unpredictable effect that a large commitment to R&D can have on a company's stock value.

Public funding of R&D has a positive impact on the innovation process. Although its impact on growth and productivity is lower compared to business funded R&D, public funded research and development can 'kick start' the provision of innovation in the presence of market failures. Given the suboptimal volume of private investments on R&D, for the reasons cited above, there are alternative sources of finance that can be identified. These include credit markets, venture capital, stock markets and business angels.

Credit markets can be an alternative source from which to fund private R&D investment however, previous studies find that financing constraints may be more widespread in the high-tech sector and most small high-tech firms obtain little debt financing (Carpenter and Petersen, 2002; Hall, 2002). More generally, low intensity R&D firms are less favoured by credit markets and have a higher probability of their loan applications being rejected by lenders, compared to firms with high R&D intensity (Atzeni and Piga, 2005).

Bougheas (2004) provides empirical evidence which suggests that while small firms in the United States, United Kingdom and Canada rely on internal funds for financing R&D, similar firms in Japan, Germany and France have access to bank loans. The evidence indicates that the high ratio of intangible assets and high risk nature of investments inhibits the ability of small firms to raise debt in external capital markets. It also shows that financing R&D with bank loans might be feasible, especially if banks are willing to monitor the investment activities of their clients.

In capital markets, three potential sources of R&D finance exist: venture capitalists, stock markets and business angels. The **venture capital** industry comprises specialised pools of funds (usually from private investors) that are managed and invested in companies by individuals who are knowledgeable about the particular industry in which they are investing. Venture capitalists increase the value of the firms they finance, especially when they are experienced investors. The rise of the venture capital industry is often seen as a 'free market' solution to the problems of financing innovation. Firms backed by seasoned venture capital financiers are more likely to successfully time the market when they go public, and to employ the most reputable underwriters. At a macro-economic level, venture capital funding tends to be pro-cyclical but it is difficult to disentangle whether the supply of funding causes growth or productivity growth encourages funding (Hall & Oriani, 2006). Whilst the availability of venture capital or private equity is essentially a private or market issue, there are policy implications and opportunities to improve access and availability across regions and to improve dialogues between entrepreneurs and financiers (and between universities and finance).

Salmenkaita and Salo (2002) outline four rationales for examining the role of government agencies in comparison with, or as a complement to, private venture capital: market and systemic failure, structural rigidities, and "anticipatory myopia", which posits that individuals and organisations tend to underinvest in the generation and assimilation of information that would contribute to their ability to act with foresight. Here, the role of government intervention is to promote the identification and pursuit of new long-term opportunities.

There is some evidence with a European focus showing that the venture capital backed firms grow faster than the non-venture capital backed firms. The limit of venture capital to finance R&D is that it is constrained to a few sectors at a time and that the minimum investment size may still be too large for many start-ups (Hall, 2005). It is clear that the market does not offer a viable option at the lower end and that business angels are becoming more and more necessary as the first investor for start-up companies, whereas venture capitalists are moving towards the later stage and towards higher value deals, with a noticeable preference for management buy-outs (MBOs) (Aernoudt, 2005).

Stock markets are an important source of alternative funds particularly for newer and younger firms, and they provide an exit strategy for venture capital investors allowing them to move on to finance new start-ups. Evidence suggests that raising capital on the stock market is much more important for highly R&D intensive firms and for joint ventures (European Commission, 2006)⁶.

Business angels are individuals who invest in one or more high potential start-ups and also contribute their expertise in business management and network of personal contacts. Business angel intervention is long-term and may take a variety of forms. Normally business angels invest smaller amounts, ranging between €25,000-€250,000, compared to the institutionalised venture capital firms (Munck & Saublens, 2006). Business angels often work in syndication, and their primary importance is to try to fill the equity gap (sometimes also called the funding or capital gap). This is the difficulty that entrepreneurs have in finding funding at the stage beyond the seed funding round (more than around € 500,000) and less than the first round of venture capital funding (less than € 2,000,000). The equity gap exists because it is difficult and risky for a business angel or a small group of business angels to invest an amount over € 500,000 (Carriere, 2006). There is an argument that more public policy attention should focus on the business angel phenomenon. Policy initiatives involving public money could be aimed at stimulating the syndication process, the investors' readiness, the location of the potential business angel, the involvement of large firms, the establishment and improved efficiency of the business angel networks and the integration of financing resources. However, if co-investment schemes are needed, the due diligence should be done at business angel level without the involvement of public financiers (Aernoudt, 2005).

The differences between venture capitalists, business angels and private equity investments in R&D, technologies and innovation depend on the maturity of the firms in which investments might be made and the uncertainty of the ideas on which the entrepreneurial opportunity is based.

A further source of R&D funding for firms is the non-profit sector. The smallest share of R&D has historically been performed by the private non-profit sector. In the EU15 the share of research and development has been in the region of 1% since 1981. The minimum share of Private Non-profit expenditure on R&D (PNPRD) was registered in 1991 when PNPRD in the EU-15 was 0.89% of the total R&D performed within the fifteen countries. The recent trend for PNPRD is positive. From 1997 to 2004, PNPRD increased its share of GERD from 0.9% to 1.31%.

A broad sweep of the former 15 European Union (EU) Member States gives an approximate total of over 200,000 organisations that are classed as foundations. A mapping exercise of the foundation sector in selected EU countries undertaken by the European Foundation Centre (EFC) Research Task Force in 2003/2004, estimated that there were some 62,000 foundations operating in the 'old' 15 EU Member States in 2001. Non profit foundations can increase the volume of research funds for fundamental, 'blue-sky' research, or research in

⁶ However, companies in high R&D intensive sectors also show a certain preference for tax incentives, equity and venture capital and bank loans.

orphan areas and early-stage applied research that is not sufficiently developed to attract industry funding in the EU context, to further integration by supporting cross-border research projects. In addition, non-profit foundations appear to be the perfect candidate for interdisciplinary projects in order to enhance researchers' mobility, exchange and collaborations, provide a structure to fund small projects and a strategy to fund research in a long-term and coherent framework complementary to industry and government (European Commission, 2005).

However, the existing level of funds that are actually devoted to research by foundations in Europe remains low, despite the existence of a few large research foundations in Europe and some new national initiatives in this area. The foundation sector as a whole accounts for a very small share of the overall R&D effort in most EU countries. The impact cannot, however, be reduced to absolute figures because foundations not only bring money (quantity) but also competences and unique characteristics (quality) which contribute to the pluralism of R&D funding. Their support tends to be concentrated in certain research areas, in particular biomedicine. Foundations' grant making is mostly to universities, where often foundations fund only the direct costs of research (European Commission, 2005).

Knowledge spillover and intellectual property rights

The public funding of research can also be justified in terms of knowledge spillovers. The spillover argument is based on the fact that the end result of a research project is knowledge, which by definition is non rival. This means it can be used by the knowledge creator and also by third parties and the returns on this 'knowledge' cannot be fully exploited by its creator.

It can also be argued that the social returns to R&D are higher than the private returns making the equilibrium level of investment lower than the optimal level. There is substantial evidence that strong IPR regimes stimulate private R&D investments. However, strong IPR regimes close the gap between social returns to R&D and private returns (in favour of the latter) being a cause of litigation and impeding distributed technical change. The aim of a fair intellectual property rights (IPR) regime is therefore to stimulate R&D investments while maintaining a balance between social and private returns (many analysts consider the USPTO and EPO⁷ to be examples of such regimes). The relationship between the IP system, patenting and innovative activity is complex. There are some benefits from having protection for IP rights, but this should not be exaggerated, especially when taking into account the cumulative nature of the research process and the dynamics of product market competition. Although stronger IPR regimes direct innovation towards patentable activities, they may not give the greatest benefits for society as a whole. IP regimes can also affect industry structure and the extent to which knowledge is diffused both within and across national borders (Jaumotte and Pain, 2005).

Human capital constraints

An important element in R&D is human capital; this includes not only labour but also intellectual capital and experience. Around 50% of R&D expenditure is devoted to the salaries of R&D personnel (Hall, 2002). Human capital input into the innovation process becomes relevant in deciding how and where to invest large sums of money for long periods. A deficiency in, or the costs both in monetary and opportunity terms, of suitably trained scientists and engineers is the main argument brought forward in discussions on human capital constraints on conducting R&D. A further argument that is often mentioned regarding HR

⁷ United States Patent and Trademark Office and European Patent Office

issues is the nature of the knowledge generated by R&D projects. This is for the most part tacit in nature; consequently it is mainly linked to the scientist or the engineer who executed the project. In the event that a researcher leaves a company, the tacit knowledge follows the researcher and the company is unable to exploit it. This argument is closely connected to that of spillovers, as this variable also reduces the extent to which research results can be appropriated by the funding organisation

Collaborative financing for R&D

Collaborative financing of R&D is useful for long term/high-risk R&D and wherever there are high risks or delayed revenues (Funk, 2006; Hall, 2005). For example, small and start-up firms in R&D intensive sectors can benefit from venture capital funding, while large and established firms prefer to use internally generated funds to pay for R&D investments. The venture capital solution to the problem of financing R&D, however, has its limits: it only focuses on a few sectors at a time, in some fields the minimum investment size can be too large for start-ups and requires a liquid market in small and new firm stocks in order to provide an exit strategy for early stage investors (Hall, 2005).

Other sources of finance for R&D can be government supported incubators, seed funding, loan guarantees, and other similar policies for funding and encouraging R&D, including tax treatment. Many such schemes currently exist in various forms in different countries. In addition to pooling expertise, which has a long term financial impact on R&D strategy, schemes to support collaborative R&D can be promoted; these reduce risks and share the costs of developments.

5 Is Public Support for R&D a Stimulus to Private R&D Investments?

The measures employed to raise EU R&D intensity can be categorised as follows:

- 1) Improving the effectiveness of the mix of public support mechanisms for private sector research and development
- 2) Direct measures
- 3) Fiscal measures
- 4) Risk capital measures
- 5) Guarantee measures

Factors influencing the deployment of measures:

- Fiscal measures are cheaper than direct financial incentives and are widely-used in European countries.
- Support to companies or sectors can be differentiated. The emphasis placed on SMEs has significantly increased in recent years, and the service sector is receiving more attention.
- Strengthening the links between science and industry has several benefits. One is to increase the mobility of researchers in private companies. Another is to amplify and leverage the effect of public R&D spending on private R&D investment. Public-private partnerships can do this effectively.
- The Barcelona '3% Action Plan' emphasised to governments the need to rationalise their efforts and policy measures by designing and implementing policy mixes.

R&D activities and especially early-stage R&D are perceived to be high risk investment opportunities with technological as well as market uncertainties. Managing R&D via new business start-ups is one way to reduce and share the exposure to risk but the market does not encourage early stage venture capital investments without good prospective exit routes (including acquisitions and flotations). Interventions can improve perceptions of market volatility and longer term strategies and there are national schemes to try to increase R&D in newly established or growing companies. In addition, the European Commission has developed its own specific initiatives, including a scheme to promote early stage investments: *Risk Capital for Enterprises in the Start-up Phase*. This action has had some success in stimulating the supply of equity finance but has not been as successful in creating a community-wide network for seed capital funds. Some more effective actions would have to directly involve R&D performers, namely the business community.

Does public investment in R&D ‘crowd out’ private investment?

Concerns about public subsidies on R&D crowding-out private investments should be addressed recognising the modern (‘open’ and globalised) R&D and innovation environment in which many businesses now operate. Crowding out can be defined as a situation when government spending in an equilibrium economy pushes out private investment by producing disincentive effects (Griffiths and Wall, 2001). Crowding out arguments were central to neoclassical economists in the UK in the 1970s in explaining the decline of British industry. Industrial decline was attributed to the displacement of private industry by the public sector (Cumbers and Birch, 2006). The crowding out problem originates within fiscal policies. The main point is that if fiscal policy is expansive and heavily based on borrowing then public expenditure crowds out private demand for goods and services because market mechanisms will cause pressures on the interest rates, hence making alternative investments (on the financial market) more attractive, thus crowding out private investments, for example in R&D.

Concerns about the crowding out of private capital by public funds may be overstated, as only circumstantial evidence of crowding out has been found against a conspicuous body of research finding an overall positive effect from public subsidies for R&D on productivity and innovation. Properly constructed public-private R&D partnerships can actually elicit ‘crowding in’ phenomena with public R&D investments providing the needed signals to attract private R&D investment.

Hujer and Radic (2005) conducted an evaluation of the impact of R&D subsidies on a large sample of German establishments. The analysis by Hujer and Radic (2005) did not find evidence of crowding out, as in the west and the eastern regions public subsidies to R&D have had a statistically significant impact on innovation, although the magnitudes were rather different. In western Germany subsidies to R&D have had a limited impact on innovation and this is probably due to the fact that companies would have undertaken similar levels of R&D with or without subsidies. In eastern Germany, however, the impact has been positive and significant.

Several other recent studies (Lach, 2002, Czarnitzki et al 2006, Czarnitzki and Fier 2002, Duguet 2003 and Ebersberger 2004) have found a positive relation between several forms of public subsidies (research grants, tax credits funding of cooperative R&D) and innovation output (either measured in terms of the propensity to patent or by other innovation indicators).

A recent literature review by David *et al.* (2000) points out that on three levels of analysis the effect of public R&D spending is to complement private R&D investment:

- in firm level studies, although the effect of complementarity is the most commonly found in the US and in Finland when the SMEs are overrepresented within the sample,
- in industry level studies, complementarity effects are present in each of the studies,
- at a macro-level, the effect of complementarity is also prevalent in all the studies systematically analysed by the authors.

A wider discussion of crowding-out needs to take into account whether the R&D ‘cake’ in an economy is a fixed size or if it can be expanded. There is increasing recognition of the changing nature of innovation, including the restructuring of industry value chains and hence greater dependence on SMEs and an associated trend towards an entrepreneurial economy (Audretsch, 2006, 2007) and a better understanding of the ‘hidden’ characteristics of innovation in what have been considered less technology-intensive sectors, especially services (Salter *et al.*, 2000; NESTA, 2007). Advanced economies are becoming significantly more service intensive and R&D strategies can (and must) be orientated to address these changes. Ideas from a wider range of sources, not just science and technology-based research, including activities in the arts and creative industries (Cunningham, 2004) can stimulate increased (downstream) R&D investment opportunities based either on science and technology to meet a new need or based on new kinds of R&D (Rosa and Gault, 2003). These trends have not been easy to measure but alongside the valuation of intangible assets they are receiving more attention. The overall complexity of R&D and innovation activity may cause the crowding out question to become a too simplistic model.

6 Policy Mix Arguments

As stated earlier, a range and mix of public measures is desirable to boost private investment in R&D activities. Many countries endeavour to increase business R&D expenditure with the ultimate aim of improving economic performance or social benefits such as quality of life. New R&D funding programmes and tax incentives for business R&D have been introduced in a number of countries, and many existing programmes have been modified (OECD, 2006). The public-private nexus needs to be regarded as a complex reality or interface so that the questions such as crowding out discussed above can be better put into perspective. The concept of additionality assists in this respect.

The various policy instruments need to be assessed to determine how much if any R&D has been performed and how the policy initiative has affected the conduct and direction of business R&D. Measuring the effects and impacts of policy measures to boost private R&D is not at all easy and it is recognised that measuring such *behavioural* changes remains difficult due to a range of conceptual and methodological challenges (OECD, 2006).

RTD policies are designed and implemented to reflect the underlying principles of the still dominant, linear model of innovation. Within this model investments in research result in increases in the stock of knowledge and innovation in products and/or processes. The linear model has promoted implementation of policy measures focusing on the stimulation of R&D investment, and facilitation of the transformation of knowledge into innovation through enhancing and directing the flow of investment in innovation in critical scientific and technological fields.

This model of innovation and the resulting RTD policy framework was seriously challenged from both a theoretical point of view and from empirical evidence by the systems model of innovation put forward by Edquist, Lundval, Nelson, Metcalfe and others during the 1990s. In the systems model, basic and applied research, and development are no longer linearly linked but are best described as having a series of feedback loops and causal connections. The

innovation model is seen as systemic, that is there are systems of innovation at either national, regional local or sectoral level. The systemic view of the innovation process has introduced new challenges in the policy-making process. The first step of the process was concerned with understanding how to intervene and improve the innovation process, considering that research and development activities are closely interconnected with commercialisation, technology adoption and diffusion.

Innovation is increasingly becoming central to policy objectives at the same level as macroeconomic stability and monetary policy. Innovation policy is also broadening its reach (NESTA, 2006). Nevertheless the relevance or justification for RTD policy still stands, since the relationship between R&D investment and economic growth is unquestionable; support for R&D is a viable way to increase the stock of knowledge and foster innovation. How this intangible resource or capability is distributed becomes an issue. RTD policy, education policy, especially in science, technology and engineering, has a complementary role in the innovation framework. Bilbao-Osorio and Rodriguez-Pose (2004) found that R&D and higher education investments in peripheral regions of Europe have a strong influence on innovation and economic growth. They also highlighted the point that socio-economic characteristics of the regions studied affect the capacity of regions to transform R&D investment into innovation.

Canton *et al.* (2005) have analysed a large body of literature regarding the effect of human capital, research and development and market structure on macroeconomic growth. Their findings are in line with the hypotheses that macroeconomic growth is driven by productivity growth. Productivity growth is, in turn, the result of interaction between R&D, human capital and the structure of the market. The authors also analyse cross-interactions between R&D and market structure, and R&D and human capital. In the first case, increasing market competition improves overall levels of efficiency, including R&D effectiveness, resulting in an increase in productivity. In the second case, interactions between R&D and human capital have a double tie, as the increasing stock of human capital will provide input for R&D, at the same time, an increase in the stock of human capital will reallocate consumers' preference towards goods and services with higher technological content.

The logic behind the policy mix approach for Europe can be summarised as follows. The status of Europe's R&D compared to that of Japan, the US, and the newly industrialised countries shows that the gap in terms of human resources, entrepreneurship and R&D investment in general is systemic (European Commission, 2003). This implies that the strategy to put in place in order to achieve the Lisbon/Barcelona targets also needs to be systemic. A systemic approach to innovation and economic and social development has to take into consideration all the elements of the picture simultaneously rather than tackle one aspect at a time and consequently devise policy measures accordingly to the comprehensive/systemic view by integrating various factors in the same framework, including:

- Regulatory and institutional reforms
- Governance
- Competition policy
- Education and culture policy
- Employment policy
- Enterprise policy
- Environment/sustainability policy
- Financial services and risk capital
- Taxation policy
- ICT policy
- IPR policy
- Regional policy
- Trade policy

In other words, the policy mix to foster innovation, encapsulates the 'old view' of RTD policy as a self-standing body of policy measures and contextualises it within a larger framework. This includes, of course, RTD policy measures and R&D governance (funding of public and private R&D and R&D public-private partnerships), but also measures aiming at improving general economic conditions by creating an innovation friendly environment, promoting an overarching strategy of human capital creation/accumulation, putting in place measures to facilitate technology transfer, networking and collaboration amongst enterprises and enterprises and other organisations (universities and research laboratories), improving access to credit, and removing inefficiencies in the capital market.

Measures aiming at creating an 'innovation friendly' or 'entrepreneurial friendly' environment are implemented through the promotion of an innovation culture in the business sector including the higher education sector and research organisations. Measures with this aim also include clear and lean regulation addressing issues related to intellectual property rights, direct or indirect support for spin-offs and new technology-based firms either through promoting a more efficient capital market (pre-seed and first stage capital) or through funding incubators, and training for young (or new) entrepreneurs. At the same time industries and economies are adapting to the need for entrepreneurialism (Audretsch, 2007). This restructuring could in turn stimulate new (more distributed) demand for R&D.

Measures aiming at increasing the stock of human capital might include support for graduates in Science Technology and Engineering (STE) to follow a career path in research, development and innovation, beginning with focused curriculum development and following with training of researchers in businesses and research centres. A further set of measures might be devised to promote national and international mobility of scientists in order to maximise the positive effect of spillovers or, in general, to promote the diffusion of knowledge.

Networking and co-location strategies are designed and implemented in order to facilitate networking and interaction among enterprises, and businesses and scientific/research organisations. These measures aim to foster cooperation between potentially innovative actors (for example SMEs) which otherwise would not fully exploit this potential.

Policy measures regarding knowledge and technology transfer focus on supporting the commercialisation of research results obtained by universities and public research laboratories either by directly supporting the transfer from the public to the private sector through intermediaries or by developing infrastructures that allow the exchange to take place (technology parks and innovation centres).

RTD and innovation policy can also involve support for public research in strategic sectors with significant spillovers in order to increase the effects of basic or 'blue sky' research on technology-based firms enhancing both absorption capacity and development capabilities of the business sector. These measures include public investments in research infrastructures, direct funding of public R&D, support of centres of excellence, grants for research projects carried out within universities or other public research organisations, and incentives to encourage commercialisation of research results either via spin-off (the universities' so-called 'third mission') or in collaboration with industry.

The financial market plays an important role in providing funding for R&D-intensive firms. Direct and indirect measures to facilitate access to finance can be grouped into two categories: (a) intervention to facilitate firms' investments in R&D and innovation through grants, conditional loans or tax incentives, and (b) infrastructure-related measures consisting of improving the efficiency of the capital markets by removing barriers to investment in risky ventures. There is an active debate on the venture capital market and the role that public policy can have in driving it towards higher levels of efficiency or even steer investments

towards key sectors of the economy. Empirical evidence shows that heavy-handed intervention in the capital market, and in the venture capital market in particular, is often the cause of distortions rather than improved efficiency (Cumming and MacIntosh, 2006). Nevertheless, indirect measures (i.e. reduction of capital gains tax rates) or structural measures, for example, creating a stock market aimed at entrepreneurs in high-tech sectors, could have a positive effect in increasing the market share of high-tech and early-stage ventures and the performance of the relevant funds (Da Rin *et al.* 2006).

The systemic approach introduces the role of demand for innovation into the policy context. Georghiou (2007) and Edler and Georghiou (2007) highlight that lead users or even lead markets (created by the action of a number of lead users) may have a substantial role to play in the policy mix in stimulating R&D and innovation. In fact, increasing the rate of diffusion of a particular innovation will reduce the risk of innovation 'failure' and increase the incentive to innovate (Bhidé, 2006). The public sector can assume the role of lead user, adopting 'intelligent public procurement' as a valid instrument for promoting R&D investment in the private sector.

Although this approach to policy-making is mostly appropriate for innovation policy, some challenges might arise in its implementation phase. Indeed, some of its goals might conflict with one another, as might the rationales behind them. For example, difficulties in coordinating policy objectives might arise when the policies are defined centrally while their implementation relies on regional or local government departments. Policy instruments, as well, might be a source of possible challenges for innovation policy mixes. In fact, conflicting policy instruments might be implemented by different agencies and government department following different prioritisation strategies. For example, the use of public procurement is an effective policy instrument for fostering further research and development commitments in up and coming economic activities but also it might foster cosy client relationship with uncompetitive national champions.

The various policy instruments need to be assessed to determine how much, if any, R&D has been performed and how the policy initiative has affected the conduct and direction of business R&D. Measuring the effects and impacts of policy measures to boost private R&D is not at all easy and it has to be acknowledged that measuring such behavioural changes remains difficult due to a range of conceptual and methodological challenges (OECD, 2006).

7 Conclusions

Contemporary argument highlights that Europe needs to improve its systems of tax credits to encourage private sector research, a mechanism in which has been used successfully in the United States. In addition regulatory and tax burdens could be eased to help high-tech start-ups within a more effective regulatory framework. Overall there is considerable duplication of public sector research funding effort in Europe and this could be improved by increased and more effective coordination by national governments.

The market failure perspective has been highly successful in providing a general rationale for policy intervention, but it is inherently unable to provide specific guidance on policy prescriptions (Metcalfe and Georghiou, 1998).

Examining trends in the financing of R&D in simple monetary value terms may not give the whole picture. It has been posited that the emphasis of the Barcelona Council on the spending target for R&D could even be misplaced, as the question is not so much one of increasing the level, but rather of enhancing the efficiency of R&D in Europe. Policy measures aimed at boosting the efficiency and productivity of R&D in Europe should focus on the level of workers' knowledge and the capacity of entrepreneurs to translate scientific excellence into viable technological innovation (Botazzi, 2004). In this framework the system of SMEs in Europe takes centre stage in view of SMEs' role in the growth and development processes envisaged by the Lisbon agenda.

Public-funded business research and development has not usually compared favourably with industry-funded R&D but it is difficult to compare like with like and complementarity is how the public-private nexus should best be regarded. Public-private partnerships can be used to successfully 'kick start' R&D projects and innovation.

A systemic approach needs to be envisaged, analysing how policy measures can be tailored to specific cases and how they interact with each other, in order to boost their effectiveness. Using this approach means promoting an entrepreneurial culture and economic environment which will at the same time enhance the viability of the venture capital market across all stages of investment opportunity. By promoting partnerships and collaborative R&D programmes, companies can compensate for some of the costs by accessing capital markets and eventually spread some of the cost as well as some of the expected revenues from R&D projects amongst funding partners.

The public private nexus has become a complex reality where policies may be designed to encourage more R&D investment but their efficacy is constrained by the achievements and standards obtained by previous efforts. A cumulative or plateau effect may exist in some situations whilst the same policy might provide a much greater stimulus in another region or industry context. The resources, infrastructure, institutions and systems for supporting R&D vary significantly from region to region, although they can often be accessed and utilised internationally. It is important to appreciate the impact of public support to look not only at policies but also at the quality of intellectual assets and institutional capabilities that are available and at the styles and attitudes of business management teams to make use of those assets. Consequently the efficiency of interactions and support interventions in the public/private nexus are subject to a complex set of variables.

In addition to the intended direct effects of policies, which may or may not succeed, the overall effects of policies, direct and indirect and in combination with other policies, should be evaluated so as to appreciate the public-private nexus. Aspects of any evaluation will have to take into account the cumulative effects of policies on systems and resources, the capabilities that these offer as a platform for future policy intervention and additional support mechanisms, and also take into consideration the effects on management styles and behaviour, including the willingness and propensity to benefit from publicly available resources.

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Title: The Public/Private R&D nexus of R&D

Author(s): Deborah Cox and Dimitri Gagliardi (Manchester Institute of Innovation Research)

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Technical Note

Abstract

The public-private nexus is a complex interface where policies and infrastructure influence management decisions about R&D investments and innovation opportunities. The interface is continuously evolving and conditions vary from country to country and industry to industry. Technological and market change and industry restructuring introduce new management options to decision makers in established and new entrant companies. Easier access to information and expertise stimulates new ways of working between companies and with other organisations and makes the public-private nexus an international or supranational issue and not just a regional or national concern. Finance and projects can be moved internationally via multinational corporations (MNCs) and global supply-chain networks, and knowledge can be accessed and exploited internationally. Some public-private nexus challenges may, therefore, be outside the scope of policy intervention because they transcend traditional boundaries.

There are some problems related to the public-private nexus which have been studied inconclusively for many years and where the framework for asking questions has now changed. In particular is the question of public investments 'crowding out' private investments. The contexts in which this phenomenon might occur are becoming more complicated and the distinctions between the public sector and private sector are becoming less clear as a result of partnerships and open or collaborative R&D being devised. The conceptual understanding of these contexts and how best to manage them is increasing via an ongoing analysis of innovation systems and processes. There is no single optimum answer or 'one size fits all' solution but rather a need for deeper understanding of the nexus and a practical framework for adapting policy proposals. In addition the effects of policy mix and inherited situations rather than individual or isolated policy initiatives need to be considered. For example, Enzing et al. (2004) contradict the proposition that countries with dedicated biotechnology policy instruments show better commercialisation performance in biotechnology than countries without such instruments. Instead, success is more likely to be determined by the systemic character of public policies that address all elements of the innovation system, including instruments that stimulate the life sciences knowledge base and its commercialisation.

The extent to which the public-private nexus might modify incentives for R&D and innovation investment and the extent to which it facilitates support and entrepreneurial inspiration will depend partly on the relative significance of small and medium-sized enterprises and large companies, as industry leaders within an economy, and according to the knowledge intensity of the industries represented. Individuals' skills, levels of education and a propensity to pursue relevant careers in science, technology and innovation will be important. In addition the availability, quality and reputation of R&D facilities and universities' research capabilities will determine the scope for change. This document discusses certain aspects of the public-private nexus of R&D.

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