CHAPTER 20

PUBLIC INVESTMENT IN R&D IN IRELAND

MAURICE DAGG[1]

ABSTRACT

The Government Strategy for Science Technology and Innovation 2006-2013, plans for a substantial increase in investment in Research and Development (R&D). This chapter examines recent evidence on the impact of such investment on productivity, human capital development and economic growth, and outlines the key characteristics of research expenditure in Ireland. Based on the evidence reviewed in this chapter, there is a strong case for suggesting that the Strategy will contribute to Ireland's long-term competitiveness, economic growth and improvements in the quality of life.

1 The views expressed are solely those of the authors and do not necessarily reflect the views of Forfás.

20.1 Introduction

Modern economies recognise the importance of a strong public science base to support improvements in welfare. The outputs we get from the science base, which include new knowledge, skilled people, new methodologies and new networks, have contributed to improvements in the things that matter to us, such as our wealth, education, health, environment, culture and public policy. This chapter examines recent evidence on the impact of such investment on productivity, human capital development and economic growth. The Irish experience of, and returns from, public investment in higher education and business research are also examined.

20.2 Returns to Public Investment in R&D

It is difficult to capture all the benefits science contributes to societal welfare, but a wide range of economic studies over a long period have recorded a range of direct benefits to the economy as a whole and to firms individually. Several studies have found academic research to be increasingly important for industrial innovation, accounting for 15 per cent of new products, 11 per cent of new processes and up to five percent of industry sales (Mansfield, 1991; Mansfield, 1998; Beise and Stahl, 1999). These figures capture only technological innovations based on academic research that has been carried out in the preceding 15 years. Patent data has also been used to identify the importance of public research for innovation (Narin et al., 1997). Evidence from Australia, for instance, found that 90 per cent of research papers cited in Australian-invented US patents were publicly funded. Studies of individual industries, in particular the pharmaceuticals industry, highlight the importance of public investment in science, with one study recording a 30 per cent return (Cockburn and Henderson, 2000; Toole, 2000).

Gurdgiev (2006) uses data from the EU Commission report 'Innovation Strengths and Weaknesses' (2005) to plot public sector innovation drivers against economic growth for EU countries. He concludes that "private spending on research outperforms public spending by a factor of at least 4:1, while public R&D spending has virtually nothing to do with economic growth". This is at variance with a recent OECD study, which includes Ireland and 15 other OECD countries, and which quantifies the long-term effects (over the period 1980-98) of various types of R&D on multifactor productivity growth. The study found that for any one country, the largest productivity effects are derived from R&D conducted by other countries, followed by the country's public R&D, and then it's Business Expenditure on R&D (BERD).[1] A one per cent increase in foreign R&D generates 0.46 per cent in productivity growth, a one per cent increase in public R&D generates 0.17 per cent in productivity growth and a one per cent increase in BERD generates 0.13 per cent in productivity growth. These effects are larger in countries which are intensive in BERD. The long-term impact of R&D may be higher when it is performed by the public sector rather than by the business sector, probably because the former concentrates more on basic research, which is known to generate a higher social return.[2]

The OECD also found that the effect of public R&D on productivity increases with the share of public science conducted in universities. Furthermore, the OECD found that the higher the share of business in the funding sources of university research, the lower is its impact on productivity, indicating the key role of universities in carrying out basic research, as opposed to more applied business funded research. Other studies confirm the positive contribution of academic research to economic growth (Bergman, 1990; Martin, 1998).

However, it is important to note that public and private research complement each other (Czarnitski et al., 2004). The productivity effect of public research will depend on firms' ability to absorb and exploit new technologies and, therefore, a substantial level of BERD is essential.[3]

While it could be argued that smaller countries may not benefit to the same extent as larger countries from funding R&D as much of the spillovers flow abroad, it is important to remember that R&D allows a country to (1) make new discoveries, or innovate, and (2) absorb knowledge generated abroad. This second component will be particularly important for countries behind the technological frontier. In order to assimilate R&D information that 'spills over' from other countries, an economy needs to be doing R&D itself (Griffith, Redding and Van Reenen, 1999). Absorptive capacity can be as important as innovation in contributing to the social rate of return from R&D.[4]

In much of the economic analysis, including that of Gurdgiev cited above, the view of basic research as a source merely of useful codified information is too simple and misleading. It neglects the many spillover benefits; in particular it omits the fact that by ensuring a supply of skilled graduates and trained researchers, public research underpins the capabilities of the private sector. Scott et al. (2000), outlined six channels of economic benefit from basic research: 1) increasing the stock of useful knowledge; 2) training skilled graduates; 3) creating new scientific instrumentation and methodologies; 4) forming networks and stimulating social interaction; 5) increasing the capacity for scientific and technological problem solving; and 6) creating new firms. The authors concluded; *"There is great heterogeneity in the relationship between basic research and innovation. Consequently, no simple model of the nature of the economic benefits is possible"*. The overall conclusions emerging from the surveys and case studies are that: (1) the economic benefits from basic research are both real and substantial; (2) they come in a variety of forms; and (3) the key issue is not so much whether the benefits are there but how best to organise the national research and innovation system to make the most effective use of them.

As to whether the state should fund more basic or applied research there are good arguments on both sides. For example, research by Rodriguez-Pose (1999) suggests that in an economy dominated by Small and Medium-Sized Firms (SMEs) with an intermediate technological and industrial base, the returns may be greater from more applied research which is more easily absorbed by local firms. Other commentators argue that the rationale for public funding of basic research needs to take account of the changing nature of research. The nature of knowledge production is shifting, with greater emphasis on collaboration and transdisciplinarity and with research being conducted 'in the context of application' (Gibbons et al., 1994). The distinction between what is public and what is private in knowledge production and therefore in science has become blurred, if not irrelevant.

20.3 Investment in the Public Research System in Ireland

Higher Education Expenditure on R&D (HERD) increased substantially in real terms in recent years, and Ireland has moved up the OECD league table (26 countries) from 19th place in 2002 to 16th in 2004 as a consequence. Over the same period the number of researchers in Higher Education Institutes (HEI) in Ireland increased from 2,695 in 2002 to 4,152 in 2004 (Forfás, 2004; ESRI, 2004).

In terms of the 2000-2006 NDP, the main direct supports for HERD in Ireland were:

- Science Foundation Ireland (SFI) which began work in 2001 with a focus on establishing world-class research capability in niche areas of ICT and biotechnology. Scientists from abroad may apply for SFI funding provided they conduct the resultant research in Ireland. SFI therefore serves as a powerful magnet to attract individuals and groups to add to our national research effort. As of 2006, SFI had established:
    - 204 research groups led by Principal Investigators, of whom 46 are new to Ireland. The groups employ 1,628 research staff - over a fifth of the entire research staff in Irish HEIs.
    - Six Centres for Science Engineering and Technology (CSETs) in core thematic areas. The CSETs bring together researchers from around the world in highly sophisticated, multi-faceted teams at Ireland's universities. These centres are now working with companies such as Bosch, GlaxoSmithKlien, Hewlett-Packard, IMB, Intel and Medtronic.
- The Programme for Research in Third Level Institutions (PRTLI), operated by the Higher Education Authority (HEA), was established in 1998, to develop high quality research infrastructure in third level institutions. Headline results reported by International Assessment Committee in 2004 included new capital, new research buildings along with 34 new academic appointments (14 professorial) as well as over 1,500 new postdoctoral or postgraduate research appointments. Other outputs include a range of new courses as well as extension of collaboration between Irish institutions and internationally.
- Two new research councils were also established in 2000/01: The Irish Research Council for Science, Engineering and Technology (IRCSET) and the Irish Research Council for Humanities and Social Sciences (IRCHSS). The research councils have annual budgets of around €24 million and €10 million respectively, and have funded hundreds of post-doctoral and postgraduate researchers over the last few years as well as providing substantial project based research funding.

Although it is early days to be making judgements about any of these initiatives, recent evaluations have been very positive about scheme outputs, and suggested the need for continuing funding in order to achieve sustained gains. An International Review Panel convened in 2005, for example, examined the work of SFI and concluded: "research excellence is being funded" and "impressive progress towards developing a world class research capability in biotechnology and ICT had been achieved in a short time…the existence of SFI funding is having a positive catalytic effect on the performance of research in its two fields". The review team recommended that "SFI investments are continued and made an established part of the innovation system" (Forfás, 2005). As regards PRTLI, an International Review Committee concluded that "investment in PRTLI is fully justified and should be continued…the important goals of PRTLI will only be achieved if funding on a significant scale is sustained over an extended period … for at least another ten years" (HEA, 2004).

A key output of these initiatives has been the increase in postgraduate and postdoctoral research training in Irish HEIs. There is a growing recognition that high-level skills provide a key impetus for broad economic growth (Florida and Tingali, 2004). By ensuring a supply of skilled graduates public research underpins the capabilities of the private sector. Research-trained staff play a key role in increasing the absorptive capacity of firms and provide a strong inter-personal link between firms and universities. This type of personal linkage has repeatedly been shown to be an important element of knowledge transfer activity (Zucker et al., 1998).

Furthermore, the quality of R&D personnel is the most important factor determining the choice of location of R&D activities by multinational companies (OECD, 2006).

20.4 Investment in Business Enterprise Research

Despite a nominal growth in BERD of 19.4 per cent over the two year period 2001-2003, levels of BERD in Ireland remain below the EU average. Most SMEs in Ireland do not conduct R&D and large MNCs do most of their R&D abroad. For this reason the Government has invested significantly in BERD through the enterprise development agencies, Enterprise Ireland (EI) and Industrial Development Authority (IDA) Ireland.

BERD results in new goods and services, higher quality of output and new production processes. These are factors of productivity growth at the firm level and at the macroeconomic level. The effect of BERD on productivity has been investigated in many empirical studies, performed at all levels of aggregation – business units, firm, industry and country levels – and for many countries (especially the United States). All these studies reach the conclusion that R&D matters. The estimated output elasticity with respect to BERD varied from ten per cent to 30 per cent (Guellec and Van Pottelsberghe de la Potterie, 2001). For example, Coe and Helpman (1993) find that a one per cent increase in the stock of UK domestic R&D capital will lead to an increase in output of around 0.23 per cent. This large variation is mainly due to the fact that the studies differ in terms of the econometric model, data sources, number of economic units, measurement methods for R&D and economic performance, and periods under study.

There has been very few studies based on Irish data, however Gorg and Strobl (2005) investigated whether there is any link between R&D and plant level productivity for Irish firms. They find that own R&D activity of domestic exporters is positively linked to their total factor productivity. This is consistent with the international literature which finds a strong positive relationship between the stock of R&D and productivity at the firm level (Griliches, 1998). The authors did not find as strong a link in foreign firms but this is clouded by the fact that multinational companies carry out most of their R&D outside Ireland and there are difficulties in equating innovation inputs with enterprise performance metrics (sales, employment, etc) in the case of foreign owned companies in Ireland.

The social rate of return has been found in various studies to average about 50 per cent, which is considerably higher than the private return (Nadiri, 1993). The social rate of return is generally obtained by estimating the impact on growth in one firm of R&D done in other firms. These other firms could be within the same industry, the same country or in related industries (for example an upstream industry that supplies parts) or related countries (for example a trading partner). Care must be taken in interpreting estimates of the social rate of return to R&D. Estimates that are carried out at the firm level capture the social rate of return only to that firm. Those at the industry-level capture the social rate of return to that industry, but not spillovers to other industries. Similarly estimates conducted at the national level capture within country spillovers, but not those between countries. In addition, an important part of innovative output is the introduction of new goods and there are considerable difficulties that arise in measuring the value and benefit of these new goods. Estimates for the social rate of return at the industry level from R&D conducted by firms within the same industry range from 17 per cent to 30 per cent (Jones and Williams, 1998). Estimates of the social rate of return attributable to R&D conducted in one country but used in another are significantly higher. Adding these two together implies a social rate of return of around 100 per cent. These estimates are largely based on data for the manufacturing sector (Griffith, 2002).

The social return on R&D is likely to be underestimated in many studies, because spillovers are often estimated only for a limited number of firms and industries. Another way in which these models will underestimate the social rate of return to R&D is that they assume that imitation is costless. However, knowledge is 'tacit' in nature: it takes time and effort to explain and imitate new ideas. Imitation itself can be costly.[5] BERD enhances firms' ability to absorb external science and technology developments. BERD can particularly help firms to digest the knowledge generated in universities.[6] This is because business research develops technologies that in many cases have first been explored by public research.

20.5 Crowding out Versus Additionality

Much of the literature on R&D is concerned with the question of whether public funding stimulates private R&D expenditure or whether it simply acts as a substitute for private financing. There are three mechanisms by which public funding can crowd out private investment. First, it is likely that the labour supply of scientists is quite inelastic, so that when the government provides a subsidy to R&D this may be spent on increased wages rather than new R&D, at least in the short run (Goolsbee, 1998). There may still be positive benefits from these subsidies from encouraging people to become scientists, or by increasing their effort at work by paying them higher salaries. Second, public funding could also simply replace private funding if business substituted public funding for their own funds. Third, public funding could distort resource allocation favouring areas with lower opportunities.

Despite the fact that most developed countries employ some form or other of government R&D subsidy, the empirical evidence regarding their success is generally scarce and mixed. For instance, a substantial literature review on the subject carried out in 1999 found that "the econometric results obtained from careful studies at both the micro and macro levels tend to be running in favour of findings of complementarity between public and private R&D investments. However, that reading is simply an un-weighted summary based upon some 30 diverse studies; it is not a conclusion derived from a formal statistical 'meta-analysis,' and in no sense is it offered here as a judgement that would pretend to settle the issue definitively" (David, Hall and Toole, 2000).

Public support for BERD can encourage private sector investments by addressing market failures associated with incomplete information, inappropriability of the benefits of privately funded research or lack of suitable finance for innovation. An OECD study (Guellec and Van Pottelsberghe, 2004) attempted to quantify the aggregate net effect of government funding on BERD in 17 OECD countries over the previous two decades. The study found:

- Direct government funding of R&D performed by firms (either grants or procurement) has a positive effect on BERD (one dollar given to firms results in 1.70 dollars of research on average);
- The stimulating effect of government funding increases up to a certain threshold (about 13 per cent of BERD) and then decreases beyond;
- Tax incentives have a positive effect on BERD;

- The impact of direct government funding on BERD can be more long-lived than that of tax incentives, reflecting the fact that government programmes target research projects with a longer time horizon than those on the agenda of business;
- These two policy instruments are more effective when they are stable over time;
- Targeted government programmes help firms to digest knowledge generated by universities; and
- Defence research performed in public laboratories and universities crowds out private R&D.

In Ireland, Evaltec's review of the IDA's R&D Capability Grants Scheme 2003 found:

- Public money committed to the Scheme by way of grant approvals over the period 2001-2003, namely €38.2 million, leveraged an R&D spend totalling €147.7 million, over two years. This is a very substantial amount, as the total expenditure on R&D performed by multinational companies in Ireland in 2001 was €598 million;
- The companies themselves funded some three-quarters of the project implementation costs, thereby providing substantial tax revenues;
- The Scheme has had a substantial positive influence on corporate planners' decision to locate in Ireland; and
- The companies increased their R&D staffing levels, resulting in more jobs and higher added value employment.

Evaluations of the Research and Technological Development and Innovation (RTDI) Scheme and the R&D Capability Scheme, both operated by EI, found similar benefits for the Irish economy (Evaltec, 2004). Under both Schemes, most companies described their project as business critical or core business. Some evidence of deadweight was found in 85 per cent of RTDI projects and in 72 per cent of the Capability Scheme projects. However, only 23 per cent RTDI projects and 17 per cent Capability Scheme projects exhibited full deadweight (i.e. the project would have proceeded in an identical manner even if no grant had been received). In many of these cases of full deadweight the companies commented that the funding had allowed them to work on other R&D projects that they would have otherwise postponed or not undertaken at all. Most of the projects supported under the Schemes involved the employment of additional R&D staff, who were subsequently retained, thereby contributing to enhanced R&D expenditure, capability and sustainability within firms. The R&D Capability Scheme funding has allowed companies to take on an average of four additional researchers. Furthermore, allocation of funding enhanced companies' ability to obtain further investment from private sector sources.

These evaluations made a number of recommendations that have guided the design of R&D grant assistance packages currently offered by the agencies:

- The agencies should actively promote inter-firm co-operation on R&D, particularly between indigenous and foreign owned firms;
- The agencies should provide greater financial incentives for firms to undertake longer-term and more risky research. EU state aid rules allow such research to attract higher grant rates than are currently given by the agencies;
- More emphasis should be placed on process research and development;
- The requirements for companies to receive repeat support should be clarified, namely that they have achieved a significant enhancement of their R&D activities; and

- Other recommendations include simplifying the project approval process and optimising operational procedures generally to enhance efficiency and effectiveness, and thereby eventual impacts.

The R&D Tax Credit, introduced in 2004, marked a further step forward in Government support for company R&D.[7] The tax credit scheme should complement EI and IDA direct funding programmes and applies to the full spectrum of R&D, from basic to applied research through to experimental development, and will play an important part in FDI strategy aimed at attracting more research intensive activity to Ireland. In contrast, direct funding programmes will target applied research in strategically important technologies.

The success of any R&D tax credit scheme will depend on a number of factors. It is estimated that the US tax credit, introduced in 1981, stimulated additional R&D spending in the short-run of about $2 billion (1982 dollar value) per year, while the foregone tax revenue was about $1 billion per year (Hall, 1998). In other countries, for example Spain, tax credits have had less of an impact. This suggests that the effectiveness of any tax credit scheme will depend not only on its design, but also on other factors such as the availability of skills, the degree of local competition and cultural openness to new technologies, products and services.

20.6 A Systems Approach

The relationship between R&D and innovation is not a linear one. The outputs from science and technology activities depend not only on the amount of R&D input, but also on the efficiency of the entire innovation system (OECD, 1999a). In order to optimise the efficiency of this system it is vital that effective linkages are developed between its different components, which would facilitate the transfer of scientific knowledge. The Government has a key role to play in this area (OECD, 1999b).

The most important support for Higher Education-industry collaboration under the NDP 2000-2006 was the RTDI for Collaboration Programme. The principal schemes supported under the programme were:

- Innovation Partnerships, which aimed to build R&D partnerships between industry and the Third Level Institutions;
- The Commercialisation Fund, which financed 'technology push' projects within academia - testing and developing their commercial and technical potential; and
- The Programmes in Advanced Technology, which focused on commercialisation of academic research and some research and innovation support services to industry.

Other initiatives include the Centres for Science, Engineering and Technology (CSETs), established by SFI in 2001 and the IRCSET 'Enterprise Partnership Scheme' which facilitated the movement of researchers between academia and enterprise.

Given the concentration of scientific and technological resources in the major cities, companies in regional locations can find it more difficult to access support for innovation. The Institutes of Technology represent an important resource in this context. Their multi-regional location and openness to working with industry will allow them to develop into effective technology resources, focused on collaboration with local industry on the basis of applied research.

A key action outlined in the Strategy for Science Technology and Innovation, 2006-2013, is that all HEIs would encompass Intellectual Property management and commercialisation as a central part of their mission, equal to teaching and research. This has the potential to increase the value added derived from public funding of higher education research activity and to help to embed mobile firms in Ireland by increasing the strength of their relationship to local knowledge providers (ESRI, 2006).

20.7 Conclusion

There are mixed messages in the economic literature as to the extent of the returns from publicly funded research. However, the weight of evidence suggests that publicly funded research does make a substantial positive contribution to productivity, human capital development and economic growth. The challenge is to organise the national research and innovation system in such a way as to maximise return on investment. The benefits that spill over from public and private research are becoming increasingly important, as knowledge, high-level skills and innovative capacity are key sources of competitive advantage going forward. Independent evaluations of publicly funded research programmes have concluded that progress to date has been impressive and that funding must be continued in order to achieve sustained gains. The Government's Strategy for Science Technology and Innovation, 2006-2013, outlines a comprehensive programme, which will build on recent progress. The initiatives outlined in the Strategy are designed to enhance Ireland's research capability, improve the quantity and quality of BERD and ensure coherence within our National System of Innovation. Based on the evidence reviewed in this chapter, there is a strong case for suggesting that the Strategy will contribute to Ireland's long-term competitiveness, economic growth and improvements in the quality of life.

Notes

1 Guellec and Van Pottelsberghe de la Potterie (2001), R&D and Productivity Growth : Panel Data Analysis of 16 OECD countries, OECD Economic Studies No. 33, 200/11.

2 The OECD Frascatti Manual defines 'basic research' as "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view".

3 See Swan (2002), Guellec and Van Pottlesberghe (2001), Cohen and Levinthal (1989), Schmidt (2005), and Coe and Helpman (1995).

4 Ibid.

5 Mansfield et al. (1986) present evidence of substantial costs of imitation (on average 65 per cent of innovation costs).

6 See Swan (2002), Guellec and Van Pottlesberghe (2001), Cohen and Levinthal (1989), Schmidt (2005), Coe and Helpman (1995).

7 The Scheme currently provides for a 20 per cent tax credit available to companies for qualifying incremental expenditure on R&D.

References

Beise, M. and Stahl, H. (1999), "Public Research and Industrial Innovations in Germany", *Research Policy,* 28(4): 397-422.

Bergman, E.M. (1990), "The Impact of Industry Funded University R&D", *Research Policy,* 19: 340–355.

Cockburn, I. and Henderson, R. (2000), "Publicly Funded Science and the Productivity of the Pharmaceutical Industry," in *Innovation Policy and the Economy,* Vol. 1, A. B. Jaffe, J. Lerner and S. Stern, eds., Cambridge, MA: MIT Press, 2001: 1-34.

Coe, D. and Helpman. E. (1995), "International R&D Spillovers," *National Bureau of Economic Research Working Papers,* 4444.

Cohen, W. and Levinthal, D. (1989), "Innovation and Learning: The Two Faces of R&D", *The Economic Journal,* 99: 569-596.

Czarnitzki, D. (2004), *European Competitiveness Report,* EU Commission, Brussels.

David, P., Hall, B. and Toole, A. (2000), "Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence", *Research Policy,* 29: 497-529.

ESRI (2004), *Survey of Research and Development in the Higher Education Sector,* Economic and Social Research institute, Dublin.

ESRI (2006), *Ex-ante Evaluation of the Investment Priorities for the National Development Plan (2007-2013),* Economic and Social Research Institute, Dublin.

EU Commission (2005), '*Innovation Strengths and Weaknesses',* December 5, 2005.
Evaltec (2004), *Evaluation of Agency Supports for R&D Performed in the Business Sector,* Forfás, Dublin.

Florida, R. (2002), *The Rise of the Creative Class,* Basic Books, New York.

Forfás (2004), *Survey of Research and Development in the Higher Education Sector,* Forfás, Dublin.

Forfás (2005), *Report of an International Evaluation Panel, SFI, The First Years 2001-2005,* Forfás, Dublin.

Gibbons, M. (1994), *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies,* Sage, London.

Goolsbee, A. (1998), "Does Government R&D Policy Mainly Benefit Scientists and Engineers?", *American Economic Review,* American Economic Association, Vol. 88(2), 298-302, May.

Gorg, H. and Strobl, E. (2005), “The Effect of R&D Subsidies on Private R&D”, *GEP Research Papers,* 2005/38.

Griffith R., Redding S. and Van Reenen, J. (1999), “Mapping the Two Faces of R&D; Productivity Growth in a Panel of OECD Industries”, *Centre for Economic Policy Research,* Discussion Paper.

Griffith, R. (2002), “How Important is Business R&D for Economic Growth and Should the Government Subsidise it?”, *Institute for Fiscal Studies Briefing Note,* 12.

Griliches, Z. (1998), “R&D and Productivity”, *National Bureau of Economic Research Working Paper,* 1778.

Guellec, D. and Van Pottelsberghe de la Potterie, B. (2001), “R&D and Productivity Growth”, *OECD Science, Technology and Industry Working Papers,* 2001/3.

Guellec, D. and Van Pottelsberghe, B. (2004), “The Impact of Public R&D Expenditure on Business R&D”, *OECD Science, Technology and Industry Working Papers,* 2000/4.

Gurdgiev, C. (2006), “MNCs: Mothers of Invention”, *Business and Finance Magazine,* July 2006.

Hall, B. (1992), “R&D Tax Policy During the Eighties”, *National Bureau of Economic Research Working Paper,* 4240.

Hall, B. and Mairesse, J. (1995), “How Effective are Fiscal Measures to Support R&D? A Review of the Evidence”, *Research Policy,* 29: 449-469.

HEA (2004), *Report by the International Assessment Committee, PRTLI – Impact Assessment,* Higher Education Authority, Dublin.

Jones, C. and Williams, J. (1998), “Measuring the Social Rate of Return to R&D”, *Quarterly Journal of Economics,* 113(4): 1119-1135.

Mansfield, E. (1991), “Academic Research and Industrial Innovation”, *Research Policy,* 20(1).

Mansfield, E. (1986), “Patents and Innovation: An Empirical Study”, *Management Science* 32: 173-181.

Mansfield, E. (1998), “Academic Research and Industrial Innovation: An Update of Empirical Findings”, *Research Policy* 26: 773-776.

Martin, W. (1998), “The Economic Impact of Canadian University R&D”, *Research Policy,* 27(7): 677-687.

Nadiri, M. (1993), “Innovations and Technological Spillovers”, *National Bureau of Economic Research Working Paper,* 4423.

Narin, M. (1997), “The Linkages between US Technology and Public Science”, *Research Policy,* 26: 317-330.

OECD (1999a), *Managing National Innovation Systems*, OECD, Paris.

OECD (1999b), *Science, Technology and Industry Scoreboard, Benchmarking KBEs*, OECD, Paris.

OECD (2006), *Recent Trends in the Internationalisation of R&D in the Enterprise Sector*, OECD, Paris.

Rodríguez-Pose, A. (1999), Innovation Prone and Innovation Averse Societies: Economic Performance in Europe, Growth and Change, 30, 1, 75-105.

Schmidt, T. (2005), "Absorptive Capacity – One size fits all? A Firm Level Analysis of Absorptive Capacity for Different Kinds of Knowledge", Centre for European Economic Research, *ZEW Discussion Paper,* 05-72.

Scott, A. (2000), "The Economic Returns to Basic Research and the Benefits of University-Industry Relationships", *Research Policy,* 30: 509–532.

Swan, J. (2002), *Innovative Business and the Science and Technology Base: An Analysis Using CIS 3 Data,* Report for UK Department of Trade and Industry.

Toole, A. (2000), "The Impact of Public Research on Industrial Innovation: Evidence From the Pharmaceutical Industry", *SIEPR Discussion Paper.*

Zucker, L. (1998), "Intellectual Human Capital and the Birth of US Biotechnology Enterprises", *American Economic Review,* 88: 209-306.