3 Research and Development and the Small Firm

Brychan Thomas, Christopher Miller and Gary Packham

"The practice of R&D involves making mistakes, realizations, corrections, and more mistakes…."

TOM HUFF (1943–)

This chapter at a glance

- Introduction
- Spillovers from R&D
- Technology Absorption and R&D
- Measuring R&D activity
- R&D activities in small businesses
- Conclusions

Introduction

This chapter considers Research and Development (R&D) in terms of spillovers and technology absorption. According to Revesz and Boldeman (2006) the economic reason for governments to support R&D is based upon the externalities (spillovers) caused by R&D which has received much interest in innovation literature. Further to this two roles for R&D suggested by Griffith et al (2004) are to stimulate innovation and to create an understanding of discoveries by others which to the originating firm are confidential. A major policy question concerning R&D will be the extent to which indigenous technology progress involving small business is created by local R&D or by developments globally (Revesz and Boldeman, 2006). It must be borne in mind that economic growth can be created through assimilated disembodied knowledge (education, learning, R&D, knowledge systems and economic reform) contrary to the embodiment of technology innovations in imports (DCITA, 2005).

Spillovers from R&D

It has already been recognised that the technological development of indigenous enterprises is influenced by various sources of know-how including R&D, industry contacts, learning, ICT and publications. R&D is therefore a major source for technological progress in a modern economy. A principal justification for government support of R&D policy activities will rest upon the positive spillovers which are the positive externalities from R&D (Revesz and Boldeman, 2006).

The Schumpeterian hypothesis (1934; 1942) suggests market concentration and large production units for R&D intensive industries are not necessarily confirmed through empirical evidence. Whereas in R&D intensive industries there will be a tendency to industrial concentration at a global level (small firms will exist as suppliers of components and as "niche" product competitors), in other R&D intensive industries there will be numerous small enterprises of niche products (Revesz and Boldman, 2006). The process of "creative destruction" (Schumpeter, 1934; 1942) means that enterprises in technology dynamic industries, where there is oligopolistic competition, will need to innovate to maintain their position in the market. Caballero and Jaffe (1993) have provided empirical support for this hypothesis and according to Nelson (1990) the views of R&D and company managers also support this point.

Levin et al (1987) in a survey of large corporations in the United States examined a number of methods used by enterprises to protect the competitive advantage of new or improved processes and products and these were patents, secrecy, lead time, moving quickly along the learning curve and sales and service. With "first mover advantage" it was found that secrecy was the most widely used method to protect intellectual property (IP) in industry (Arundel, 2001). Since small "outsider" enterprises in markets controlled by oligopolies will often need patents in order to release new products they will often licence production to a larger firm (Mazzoleni and Nelson, 1998). Innovation surveys have found similar results, for example the survey reported by Phillips (1997). Also, in some sectors functions of patents can be replaced by copyright (Revesz, 1999). Once knowledge is created and due to non-exclusion it is hard to stop others using it and to keep private and this is the non-appropriation problem (Revesz and Boldeman, 2006). In relation to this Quah (2003) has considered with regard to the information society the public good aspects. Further to this with knowledge there is the implication of only charging for marginal dissemination costs (Arrow, 1962). As a result additional learning costs will be incurred by the user when making use of this knowledge (Mandeville, 1998). It could be suggested that since the market provides the means for appropriating innovation benefits there will be no need for supplementation through government intervention in the form of IP protection and R&D subsidies since oligopoly market conditions will be apparent in R&D intensive service industries and manufacturing (Mandeville et al, 1982). In particular, on a qualitative basis there will be the case both pro and ante for R&D government support and quantitative analysis will be required in order to determine R&D subsidies at an optimum level (Revesz and Boldeman, 2006).

Whereas scientific knowledge (mostly public sector R&D) which contributes to greater understanding instead of new applications in the public domain is more available know-how and technical information ("proprietary" knowledge) tends not to be publicised and surveys of R&D and business managers have supported this view that patent disclosures and technical publications do not play a significant role in the provision of technology information to innovative enterprises (Revesz and Boldeman, 2006). Indeed, a survey in the United States by Schuchman (1981) found that engineers involved with new technologies relied on in-house expertise and talking to colleagues for information that was relevant and they tended not to use technical publications. Further to this, Taylor and Silbertson (1973) considered how much R&D managers in the UK would pay if access to abstracts and patent records was denied.

A number of surveys have been undertaken to consider the time delay and cost in the imitation of inventions (Revesz and Boldeman, 2006). For example, more than one hundred and twenty respondents to a survey (mostly United States R&D executives) were asked by Levin et al (1987) for an estimation of time and costs needed to copy innovations by a competitor and it was found that in less than 5 years most inventions could be imitated. Similarly, Mansfield (1981; 1985) revealed that reverse engineering, personal contacts and the movement of staff between companies were the principal sources of the leakages of information.

Technology Absorption and R&D

According to Griffith et al (2004), two roles for R&D are those of (i) stimulating innovation and (ii) enabling understanding and the imitation of discoveries which remain confidential by other originating firms. R&D therefore plays an important role for the development of an "absorptive capacity" and is equally critical for technology transfer and innovation (Revesz and Boldeman, 2006). Econometric evidence concerning the importance of the "two faces of R&D" are also presented by Griffith et al (2004) through the examination of productivity growth in industries for 12 OECD economies. R&D appears to stimulate innovation indirectly by technology transfer or directly by those involved with leading edge technology frontiers (Revesz and Boldeman, 2006). Further, it is suggested that R&D plays a crucial role in multi factor productivity levels for industries in OECD countries (Griffith et al, 2004). Cohen and Levinthal (1989) have provided a similar view about the importance of R&D in nurturing both learning and innovation. In particular the importance of R&D in enhancing technology absorption is considered important for small businesses.

With regard to patents it is perceived that there are advantages in reducing patent monopolies by limiting protection or reducing duration (Scotchmer, 2004; Mazzoleni and Nelson; 1998 and Revesz, 1999). There can also be a reluctance to seek strong protection for patents (Scotchmer, 2004; Mandeville et al, 1982; Mazzoleni and Nelson, 1998). Before spillover benefits are known it is difficult to estimate these for R&D projects (Allen Consulting, 2005). Michael Polanyi (1943) suggested the replacement of patent monopolies with the government control of invention licensing rights by an expert industry panel awarding the inventor.

Public support schemes for R&D activities, although very often exhibiting problems, can be run with an acceptable level of difficulties and these can include subsidies for business R&D, research by public bodies (especially universities) and IP protection (Revesz and Boldeman, 2006). The level of government support for innovation can be difficult to gauge especially since there is limited information on R&D activity and there may be a number of policy options (Scotchmer, 2004).

Measuring R&D activity

Although there appears to be no data on the commercial return from R&D activities, case studies of firm managers show that they will invest in R&D due to competitor's technology advances and the fear of being out of business (Revesz and Boldeman, 2006). In a study by Revesz and Lattimore (2001) no statistical positive significance between R&D intensity and firm profitability was found and a survey by Jaruzelski et al (2005) also found no direct relationship between R&D spending and corporate success. It is generally agreed that at international and national levels R&D spillovers are considerable and are many times greater than private returns (Lederman and Maloney, 2003; Sena, 2004). Studies on the economic impact of R&D have focused on the rate of return for business R&D at national levels (Maddock, 2002; Shanks and Zheng, 2006).

A major problem when trying to measure R&D activity is that it is a concept based upon definitions and represents activities in the area of scientific and technological acquisition by organisations and enterprises (Revesz and Boldeman, 2006). Statistical agencies in industrialised countries use the Frascati Manual definitions for R&D activity (OECD, 2002). The definition of R&D by the OECD is:

"Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications." (OECD, 2002)

A further definitional measurement problem is that it is difficult to determine the change in R&D activity arising from policy change.

Simple cost reduction measurement was followed by early research into the impact of R&D on productivity (Revesz and Boldeman, 2006). A pioneering study was undertaken by Grilliches (1957) involving a cost benefit analysis of the development of hybrid corn varieties in United States government research stations. Case studies undertaken on cost reductions from R&D in certain areas have provided interesting results (Revesz and Boldeman, 2006). Bresnahan (1986) considered consumer surplus through cost reducations in financial services arising from mainframe computers between 1958 and 1972 in the United States. Trajtenberg (1990), in a case study of computerised tomography scanners, found the rate of return to R&D in the United States to be 270% a year. The rate of return to business R&D was examined by Mansfield et al (1977) using several case studies in the United States. Unfortunately a major drawback of case studies is that they only consider innovations that are successful (Revesz and Boldeman, 2006). Alternatively, case studies can be useful when information about R&D costs and outcomes, which are commercially sensitive, is available from private businesses.

Estimation of knowledge spillovers was considered to be the main challenge for economic analysis of R&D by Grilliches (1992). A number of measures have been propounded for technology knowledge flows and these include the proximity in industrial or research field classification, statistics on foreign direct investment (FDI), statistics on licence fees and royalties, data on foreign trade, input and output linkages across sectors, citations on patents and patent registrations (Eaton and Kortum, 1996, 1999; Mohnen, 1996; Grilliches, 1992). According to Jaffe and Trajtenberg (1998) and Jaffe et al (1993) patent citations appear to be the best approach to determine knowledge flows between industries, regions and countries. Internal R&D can be measured by country (macro), sector (meso) or firm (micro) and external R&D similarly (external R&D indicators can be determined by R&D stocks or external sources and weighted by knowledge flow indicators – patent statistics, for example) (Revesz and Boldeman, 2006). Grilliches (1992) argued that the rate of depreciation of knowledge is quicker at the micro level than at the macro level. Statistical evidence on the obsolescence of R&D capital at the micro level in a technology competitive and dynamic environment supports the depreciation of knowledge supported by Schumpeter's (1934; 1942) creative destruction (Caballero and Jaffe, 1993).

Many R&D studies have only considered manufacturing since it represents the largest spend on R&D than any other sector (Revesz and Boldeman, 2006). The cost savings for 12 manufacturing sectors in the United States were estimated by Nadiri and Theofanis (1994) – the social manufacturing rate of return on public R&D was found to be between six and nine per cent by adding the marginal cost savings estimates. The rate companies registered significant product innovations and patents across technology fields in the United States was analysed by Acs et al (1994) who found that own R&D activity was important for large businesses who ran their own laboratories whereas smaller businesses benefited from publicly funded research knowledge (effectiveness of public research appeared to be enhanced by universities near to private sector research laboratories). Similar results were found by Audretsch and Vivarelli (1996) when investigating patenting activity for 15 Italian regions (own R&D was important for large businesses and regional university scientific research activity). The productivity growth rate in eighteen United States manufacturing sectors between 1953 and 1983 was related to the rate of publication of scientific papers for 9 scientific fields by Adams (1990) (productivity growth was found to be dependent on accumulated field specific scientific research and on industry employment in appropriate fields for scientists). The relationship between the size of R&D activity and the science base for 14 United States R&D sectors between 1961 and 1986 was examined by Adams (1993). He found that the size of the scientific base had a significant positive impact on R&D activity levels. R&D in universities has the important aim to provide post graduate students with research skills and related to this public R&D impulses considerable knowledge spillovers to business through "tacit" knowledge, training of researchers, collaborative ventures, resolving technological dilemmas and scientific and new discoveries (Revesz and Boldeman, 2006).

Whereas Lederman and Maloney (2003) found a relationship that was strongly negative for GDP per capita and national R&D intensity Gittleman and Wolff (1998) found that R&D intensity was positively related to the growth of gross domestic product (GDP) in advanced industrialised countries which infers that R&D is advantageous to countries with industries near to the frontiers of leading edge technologies. A significant policy question for R&D activity is to what extent domestic technology progress is influenced by global developments or domestic R&D (if this is by overseas technology progress there is the argument that there may be little need to foster domestic R&D).

Further to the Coe and Helpman (1995) model for cross border knowledge spillovers Eaton and Kortum (1996; 1999) considered the flow of ideas from abroad as well as those internally generated. Ideas from a country will depend on R&D sector productivity and size, the technological level, cross country patent applications and the use of these ideas by the country and other countries (Revesz and Boldeman, 2006). Pottelsberghe and Lichtenberg (2001) developed the Coe and Helpman (1995) model by including R&D stocks related to outward and inward investment in addition to the R&D content of imports. It is apparent that it is not possible to simply import overseas technologies since their application by local enterprises will require investment in learning involving R&D. Hirsch-Kreinsen et al (2005) observe that for medium low and low tech manufacturing firms the main source of innovation will not come from R&D but from other activities involving assimilation and learning such as contact with people in businesses in the same industry, suppliers and customers. It appears that most innovations in more than ninety per cent of an economy, excluding high and medium tech manufacturing, will not be through indigenous R&D (Revesz and Boldeman, 2006).

R&D activities in small businesses

Introduction

It has been found that R&D does not provide a true picture of innovation in SMEs since smaller enterprises will not have a specialist R&D department (Crespi et al, 2003). Further to this it appears that most innovations originate in certain sectors (Robson et al, 1988) as likewise most R&D (Scherer, 1982). In relation to these aspects this review considers R&D activities in small businesses according to demand, organisation, innovation, imitation and diffusion, complementary assets, networking and government influence on small business R&D.

Demand

With regard to demand it is apparent that the motivation to undertake R&D has involved variables representing market demand conditions which present demand as a major influence on such decisions (Crespi et al, 2003). Unfortunately, as noted by Mowery and Rosenberg (1979) this does not convey much since managers or entrepreneurs will consider the demand outcome before undertaking the development process which is likely to be expensive.

Organisation

According to the Schumpeterian perspective innovation and R&D activities in modern times have required large firms or concentrated industries (Crespi et al, 2003). Consequently, there will be sectors where the spend on R&D will be determined by the minimum operation scale but there will be other sectors where concentration will be in small and medium sized enterprises (SMEs) (Acs and Audretsch (1990) and Audretsch (1995) explain this according to different technological régimes across the different sectors and firm size). Acs and Audretsch (1990) further describe the differences in innovative activity between small and large firms according to the R&D intensities gap. Cohen (1995) notes that the scale economies in R&D may be a possible explanation for the impact of large sized firms. Contrary to this there may be diseconomies with larger firms and as a result government focus in many economies has changed to considering SMEs (Crespi et al, 2003). Further, data on small businesses has tended to underestimate their R&D effort (Tidd et al, 2001). According to von Tunzelmann (1995) all productive units involve the four functions of administration and finance, products, production processes and technology (with augmentation by R&D). In the literature on scale economies in R&D there is justification for merging large high technology firms (Fisher and Temin, 1973; Kohn and Scott, 1982) and in a literature survey by Martin et al (2003) it is shown that for scale economies in university research at team level scale economies are usually obtained by teams of between five and nine people in a subject. Economies in R&D will involve merging diverse technological fields for production and cost advantages (Crespi et al, 2003). Contrary to examples of fusion that are successful there will also be cases where fusion has not been successful in a company (Kodama, 1991). The cycle time is the speed for R&D to be turned into new products and in order to be first to market there will be pressure for small businesses to shorten the time (Crespi et al, 2003). Taking aside increase in complexity a faster cycle time has its own costs (Scherer and Ross, 1990).

Innovation, imitation and diffusion

Ownership of innovation and intellectual property rights (IPRs) will be fundamental to determine the attractiveness to carry out R&D. Recent studies, however, have suggested that R&D is often undertaken in ways that appear more like imitation than innovation (Crespi et al, 2003). Indeed, the work of Cohen and Levinthal (1989, 1990) highlight absorptive capacity which they describe as the capacity to absorb technologies which are generated elsewhere. They contend that R&D increases absorption even if the R&D is not innovative but rather duplicative.

Complementary assets

Within enterprises there is a danger that there will be too narrow focus on innovation and R&D since as well as the ability to create new products and processes absorptive capacity will depend on the other resources and functions within and outside the organisation (Crespi et al, 2003). Teece (1986) has called these other resources complementary assets. In relation to this Dodgson and Rothwell (1994) have purported that SMEs will be likely to encounter difficulties translating external opportunities due to limited internal capabilities. According to many studies a significant determinant of R&D in SMEs appears to be financing of innovation and the role of cash flow (Crespi et al, 2003). In the literature on appropriate methods for the evaluation of the financing of R&D Myers (1984) has suggested options valuations instead of payback procedures or conventional discounted cash flow (DCF). A problem is that if a company leaves an R&D project it may be far more expensive to return at a later date (Mitchell and Hamilton, 1988). Marketing functions also need to be taken into account since there may be a considerable gulf between marketing and R&D (Crespi et al, 2003). Most studies have found a positive connection between R&D intensity and diversification and recent research shows that when the share of external contracted out R&D rises this leads to higher returns (Bönte, 2003).

Networking

Industries have always depended on sources external to the company for technologies for R&D and some of those that have had in-house R&D in recent times have externalised part of the function (Crespi et al, 2003). The performance of R&D in the UK by higher education institutions (HEIs) has increased from a figure below similar countries in 1980 to the same as similar nations (von Tunzelmann, 2004). It is thought that this has arisen due to the triple helix of activities between government, industry and universities (Etzkowitz and Leydesdorff, 2002). It appears that the interrelationship between HEIs and industry is a significant driver regarding the intensity of R&D (Crespi et al, 2003).

Government influence on business R&D

There are a number of ways government activities can influence business R&D and these include basic research funding, industrial R&D finance (by the tax system indirectly or directly) and through IPR. Gains in technological achievements through more R&D and patents can be caused by rising Gross Domestic Product (GDP) and other macroeconomic forces (von Tunzelmann and Efendioglu, 2001). Indeed, surveys of business R&D have revealed that a strong incentive is a macro economy in a buoyant situation (von Tunzelmann, 2003). Furthermore, governments see their contribution to technology from pump priming basic research funding with an emphasis on basic research arising from market failure (funding will contribute to business R&D through the subsidisation of private sector laboratories and spillovers complementing private R&D) (Crespi et al, 2003). There has also been concern since the 1980s over private sector R&D being crowded out by government R&D (Kealey, 1996; David et al, 2000). Other studies in the UK have suggested that increases in government R&D in defence activities resulted in skilled researchers being drawn away from commercialisable and private R&D (Walker, 1980). A study by von Tunzelmann and Efendioglu (2001) of the cross country effects of interest rates on R&D since the 1960s provided a positive long term correlation.

Governments can influence the level of R&D expenditures by small firms in two principal ways and these are by offering fiscal incentives or by directly subsidising such expenditures (an OECD survey in 2002 showed that in order to encourage business R&D countries have used fiscal incentives and these have involved tax deferrals, allowances and credits) (Crespi et al, 2003). Bloom et al (2001) in a study of the effect of fiscal incentives on R&D spending used an econometric model of R&D investment for nine countries from 1979 to 1997 to investigate the relationship between the level of R&D expenditure and tax changes (a ten per cent decrease in the cost of R&D via tax incentives caused a one per cent increase in the short term level of R&D and ten per cent in the longer term). Similar results have been found for US and Canadian studies (Hall and van Reenan, 2000). Furthermore, there is little evidence as to whether non-R&D performing companies can be influenced by tax incentives (Crespi et al, 2003). Governmental considerations over the contribution to R&D are still influenced by supply push and market failure models and the case for market failure is affected by high private and social returns for R&D (Steinmueller, 1994).

Conclusions

It has been recognised that the technological development of small firms is influenced by various sources of know-how including R&D, industry contacts, learning, ICT and publications. R&D is therefore a major source for technological progress in the modern economy. A principal justification for support of R&D policy activities will rest upon the positive spillovers which are the positive externalities from R&D (Revesz and Boldeman, 2006). The studies undertaken in the literature have revealed the major concepts involved in the study of R&D in industrial sectors. In particular the importance of R&D in enhancing technology absorption is considered important for small firms. The approach to the assessment of R&D activity in this chapter has therefore been to focus down from the national (macro) level of policy making to consider the sectoral regional level (meso) and the individual small business level (micro).

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