The Internationalization of R&D

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Abstract

This paper surveys what we know about the internationalization of business R&D spending. I examine three specific questions about the global changes in R&D activity: First, what is the evidence that R&D is becoming more internationalized (more footloose)? Second, what are the factors that influence the choice of location for R&D? The third question asks how this is changing over time. The paper concludes with a discussion of the implications of this research and the trends in business R&D location for Canada.

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1. Introduction

In the past decade, policymakers and others in a number of developed countries have expressed concern that firms in their countries appear to be increasingly locating their R&D facilities outside the home country. For example, in Foray and van Ark (2007), we read

> "There are concerns expressed at different levels in Europe about the increasing numbers of European companies which are basing their R&D operations outside Europe, at the same time as the number of overseas companies carrying out their R&D in Europe is falling."[1]

The introduction of a recent study from the United States National Academies had this to say:

> "….the committee is deeply concerned that the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength."[2]

There is no doubt about the facts: in just ten years between 1995 and 2004, the share of R&D spent outside the home country by Western European multinationals increased from 26 per cent to 44 per cent, by Japanese multinationals from 5 per cent to 11 percent, and in North American multinationals from 23 per cent to 32 per cent (OECD, 2005). Since then has come the growth of investments by these same multinationals in developing economies, especially Brazil, India, and China. We lack very precise data on the extent of this trend, but recent anecdotal evidence is quite persuasive. The Economist reports that companies in the Fortune 500 have 98 R&D facilities in China and 63 in India (Economist 2010). A recent report by Goldman Sachs identifies new and planned R&D facilities in China, India, and Brazil by such companies as Pfizer, Ford, Microsoft, IBM, Boeing, Intel, and Cisco (Goldman Sachs Group 2010).

Are the concerns voiced above justified? There are good reasons to think they may be. The existence of cross-national spillovers does suggest that countries can benefit from R&D done elsewhere and therefore should freeride on that R&D to some extent (Keller 2010). However, the need for development of some absorptive capacity, and the localization of some spillovers would suggest that it is useful to have at least some R&D done within a country (Feldman and Kogler 2010). Also to the extent that successful R&D creates short term rents, both for firms and for their employees, it is viewed as desirable to keep it at home. That is, firms introducing innovative products and services are likely to earn supranormal profits at least for short periods and such profits are usually shared with employees (Blanchflower *et al.* 1996).

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[1] Foray and van Ark (2007), p. 1.

[2] National Research Council (2006), p. 2.

There are also demand issues related to R&D location – consumers that are close to the location of the R&D may be better served by that R&D. The most obvious example of this is linguistic – English-speaking internet users, especially those in the United States, have found that new products are more often introduced first in their market and only later translated and diffused to other markets after first achieving a level of success in the home market. However, the experience with pharmaceuticals suggests that R&D is also attracted to environments where prices are expected to be higher due to less regulation, allowing the high fixed cost in this sector to be covered by the home market. This suggests that in some cases consumers may not necessarily benefit more than foreign consumers from R&D located in their market.

The downside of countries competing to attract R&D investment is that it can lead to wasteful tax competition, where countries and locations compete to attract this kind of investment, dissipating taxpayer funds without ahieving much movement. The spread of the R&D tax credit around the world is viewed by some as an example of this phenomenon. Currently, the UK is introducing a "patent box" whereby income attributed to patents is taxed at 10 per cent rather than the usual corporate rate of 28 per cent, partly in competition with the Netherlands and Belgium, who have such a scheme. Most innovation economists view this kind of highly targeted policy as likely to cost more than the benefits that might accrue to the UK (Griffith and Miller, 2010). In general, however, tax credits seem to have led to an increase in R&D everywhere they have been used (Hall and Van Reenen, 2000).

The remainder of this paper looks at the evidence on three specific questions about the internationalization of R&D activities: First, is there evidence that R&D is becoming more internationalized (more footloose)? The short answer to this question is yes, in spite of the fact that the data on internationalization is often not ideal and can be somewhat spotty. Second, what are the factors that influence the choice of location for R&D? There are a large number of studies on this question from which it is possible to draw a few fairly strong conclusions, in spite of the fact that the studies are often not completely comparable.

The third question asks how this is changing over time. Obviously it is fairly straightforward to look at the trends in location, but somewhat more difficult to determine whether the influence of the underlying factors has been changing. The paper concludes with a discussion of the implications for Canada.

2. Facts about the internationalization of R&D

Figure 1 shows the Gini distribution of GDP and business R&D during two different recent time periods, 1999 and 2005, for approximately 40 large OECD and non-OECD countries. Two basic facts about the distribution of GDP and R&D performance are apparent in this figure. First, R&D performance is slightly more concentrated than GDP (Gini coefficients of 0.78 in 1999 and 0.75 in 2005 as opposed to 0.69 in both years for GDP).[3] Second, R&D has been becoming less concentrated over time, even during this brief six year period, in contrast to the GDP concentration, which has remain essentially unchanged. This change, although it appears small, reflects the internationalization of R&D that has taken place during the same period.

[3] The Gini coefficient is defined as one minus the area under the curve divided by the area under the 45 degree line. Therefore a Gini of zero implies a completely equal distribution and a Gini of one means that on country has all the income.

Consistent time series with a long history for the internationalization of R&D is very difficult to construct, due to the lack of data sources. The OECD, Eurostat, NSF, and UNESCO supply aggregate trends in various reports, for a varying list of countries and regions. With the exception of UNESCO, these agencies tend to concentrate on the developed part of the world, plus the very largest emerging economies. Almost all of the data available is quite spotty with many missing values, so precise trends are difficult to discern.[4] Ideally one would like a set of matrices of sending and receiving countries with the amount of cross-border R&D in each cell, one for each year, along with the equivalent domestic R&D series for each country. This would allow the creation of series in a number of ways. Such data exists in bits and pieces, but there is relatively little available after around 2005.

For the US, although the SEC mandates geographical segment reporting for publicly traded firms that operate in multiple countries, the firms are left free to define the segments themselves, and rarely report their R&D broken down in any meaningful way. A look at the geographic segments file of Standard and Poor's Compustat data reveals that the only two firms that report informative and reasonably lengthy time series of the geographical distribution of their R&D spending are German: Bayer AG and Schering AG, and the latter exited the file in 2005. The best source for the United States is the data collected by the Bureau of Economic Analysis in conjunction with the Census Bureau (U. S. BEA, 2005; Yorgason, 2007), but their study of 1997-1999 and 2004 data appears to be a pilot that has not yet led to a standard annual statistical report.

The most comprehensive set of worldwide figures for inward R&D are the statistics collected by UNESCO on the source of funding for R&D within approximately 200 countries worldwide (UNESCO 2010). These data give the shares of domestic R&D funded from abroad for a much larger number of countries than any of the other sources, in principle for every year between 1996 and 2007. Of course, not all countries are able to supply data: 82 report some R&D funded from abroad during at least one of the years, 1 reports that it received no funding from abroad during the entire period, and 104 have no data at all during this period (or possibly no R&D at all, in most of the cases). Table 2 presents total R&D, R&D funded from abroad, and R&D funded by the business sector in the year 2005 for all countries that report more than one billion dollars of R&D, accounting from more than 99 per cent of worldwide R&D.[5,6] Most countries have an externally funded R&D share in the 5 to 15 per cent range, with a few higher (Ukraine, Greece, United Kingdom), and the aggregate share is 5.8 per cent in 2005.

[4] One reason for the spottiness is that many countries only survey their R&D-performers every other or every third year. This is fairly easy to correct for, since R&D evolves rather slowly, and I discuss later how I have interpolated where necessary.

[5] All of the R&D data in this paper have been converted to real US dollars using the GDP deflator base 2005 and Purchasing Power Parity given by the Penn World Tables (Heston, Summers, and Aten 2009).

[6] Note that the U. S. data in this chart do not come directly from UNESCO, since the U. S. combines the R&D funded from abroad with R&D funded by the business sector. It is probable that the U. S. RD-1 survey on which these numbers are based does not track the ultimate owner of the R&D-performer in the U.S. This may be a problem for other countries too (Japan?), although the U. S. is the most egregious case.

Figure 2 shows the share of R&D funded from abroad for all countries, averaged over the 2004-2006 period to maximize data availability, versus the logarithm of the level of R&D in 2005. There is a very slight negative relationship between the two, as one might have expected, plus a few outliers (Uganda and Panama), where most of the R&D spending comes from abroad. Among the larger R&D intensive countries, Canada is on the high side – a lower foreign share than the UK, but about the same as the United States and Ireland.

The OECD presents figures for *both* inward and outward R&D (OECD, 2005, Hatzichronoglou, 2007) that are derived from their AFA Database. However, as Hatzichronoglou (2007) and Wyckoff and Hatzichronoglou (2003) are careful to point out, the data needed to create a true picture of cross-border investment in general are very difficult to come by. OECD data relies mainly on reports by their member countries, which are fairly accurate about firm behavior within the national boundary, but rarely cover information on affiliates of domestic firms that are located in other countries, partly for legal reasons. Thus much of the recent growth in cross-border R&D outside the OECD cannot be captured by data collected by OECD countries, and even within these countries there are questions about the complete reliability of ultimate ownership information.

Some figures from the OECD are shown in Tables 3 and 4. Table 3a reproduces Table 1.3 in OECD (2008) which appears to be based on a combination of reported inward and outward R&D in manufacturing. The only countries that report outward R&D broken down by destination are Italy, Japan, and the United States. Therefore this table was partly based on the inward R&D figures, which are available only for the manufacturing sector; the data shown are for 2003. Multinational enterprises account for more than two-thirds of worldwide business R&D (UNCTAD 2005) and they are the main players in the internationalization of R&D. Western European firms are the most likely to locate R&D outside the country, followed closely by North American firms, and then by Japan. A great deal of this R&D goes to the US. As a location for foreign R&D, Canada ranks 7th in the world (after the US, UK, China, France, Japan, India).

Table 3b is also drawn from the OECD AFA Database, but it shows the complete breakdown of total business sector (rather than manufacturing only) outward R&D for the three countries that report meaningful data. For Japan and the United States, the data for both 2003 and 2007 is available, which allows us to get some idea of changes in multinational R&D strategy. Both countries appear to have shifted their R&D somewhat away from developed countries towards developing countries, more for Japan than for the United States. The amount of R&D shifted is probably less than the growth in R&D between 2003 and 2007, however. The table also shows that the share of U.S. business R&D going to Canada has declined significantly between 2003 and 2007, although in real expenditure terms the amounts hardly changed, from 2.58 to 2.57 billion US 2005 dollars.

The final column of Table 3b gives us an impression of the relative importance of various regions for U. S. business sector R&D. It shows the inward flow of R&D from the U. S. as a share of total GDP. The OECD sector (including all of Europe) receives R&D investment at four times the rate of the non-OECD sector given the size of their economies. In order of relative importance, the main recipient countries are Ireland, Israel, Sweden, Belgium, the United Kingdom, Singapore, Germany, and Canada. As a share of GDP, external business sector R&D has fallen slightly in Canada between 2003 and 2007, from 0.25 per cent to 0.22 per cent, which is a decline of about one tenth. Note also that both India and China still receive very little R&D investment from the United States relative to the size of their economies.

Table 4 looks at the data a different way, using the inward R&D measures for manufacturing from the AFA Database in 2005. From these it is possible to produce a fairly complete cross-tabulation of flows, albeit one limited to the manufacturing sector. The bottom panel of the table gives the worldwide share of cross-border R&D accounted for by each cell. Thus one can see that Canadian firms conduct 0.8 per cent of the total cross-border R&D, whereas firms from other countries conduct 5.3 per cent within Canada. All but 9.4 per cent of cross-border R&D is between the triad plus Canada. Figure 3, based on the worldwide shares of cross-border R&D presented in Table 4, gives an idea of the "trade balance" for R&D. It shows that Europe and the US, to a lesser extent, are net exporters of R&D spending, while Canada, Japan, and the rest of Asia (including China) are net importers. Africa, the Middle East, and Latin America barely participate.

Figure 4 shows how things are changing. It contains the results of a survey of the largest R&D-performers worldwide conducted by UNCTAD in 2004. The figure shows to the responses to a question about future R&D locations asked of these firms. A full 60 per cent of the responses mentioned China, although only 35 per cent of the firms already had a lab in that country. Nevertheless, the United States was still highly favored, followed by India (where 20 per cent of the firms currently have a lab). Few of the other countries were mentioned by more than 10 per cent of the respondents. So the trend towards China as an R&D location (and to a lesser extent, India) is very clear.

Figure 5, also drawn from the OECD/AFA database but based on Statistics Canada data, takes a closer look at the evolution of foreign controlled R&D as a share of total business enterprise R&D in Canada. For comparison, the US and the UK are shown. During the 2001-2007 period, the share of foreign-controlled R&D in the UK declined from about 43 per cent to 38 per cent, while that in Canada rose from 30 per cent to 35 per cent. The US share remained roughly constant at 15 per cent. So there is little evidence in these data that R&D is moving away from Canada. Table 5 shows a sectoral breakdown for these figures. Chemicals, transport equipment, and computing machinery have a foreign-controlled R&D share greater than 60 per cent, probably mostly from US firms.

2.1 Using patent data

There is an alternative to R&D data that is able to give a picture of cross border activity over a longer period, and that is patent data. In most patent jurisdictions of the world, patent applications contain the geographic location of the inventor, as well as the name of the firm that owns the invention (if there is one). Thus it is possible to know both the location of the inventive activity, and the location of the owner of its output. Pioneering work by Cantwell and co-authors (Cantwell, 1989; Cantwell and Janne, 1997) has used U.S. patenting data in this way.

I show an example of the results from Cantwell and Janne in Figure 6; unfortunately the data in this figure go through 1995 only. These data show levels and trends that are similar to what we know from the R&D and other data, but in somewhat more detail. First, the countries with a substantial patenting presence by foreign-owned firms are the small outward-oriented economies of the Netherlands, Belgium, and Switzerland, where the foreign share is above 50 per cent, followed closely by two with a strong US presence among their R&D performers, Canada and the UK. Second, most of the countries show a significant increase in foreign presence during the latest period (1991-95), and a few show a steady increase between 1970 and 1995 (the US, Germany, the UK, and Sweden).

Guellec and van Pottelsberghe (2001) use EPO and USPTO data from 1993-95 to look at the shares of patents owned by foreigners but invented domestically (SHIA) and the share invented abroad but owned domestically (SHAI), both as a share of domestic patenting. Their figures show that foreigners own 24 per cent of EPO (resp. 21 per cent of US) patents applied for from Canada, and 15 percent of EPO (resp. 18 per cent of US) of Canadian owned patents were invented abroad. These numbers seem to be roughly comparable to the R&D figures cited earlier. Using cross-country analysis, they find that Canada is more internationalized in patenting than would be predicted by country size and R&D intensity, as are the US and the UK.

Recently Harhoff and Thoma (2010) have produced a comprehensive study of R&D location based on patenting activity that updates and expands considerably the Cantwell and Janne study. The first difference from the earlier study is that they consolidate around 100,000 European entities into 1500 corporate groups, and also include 1500 US corporations. In addition, they use EPO and PCT patent applications from the Patstat database, which arguably focuses on more valuable and important applications from around the world. Finally, their data is for 1986 to 2008 and is fairly reliable up to 2005, so they can look at trends over 4 5-year periods from 1986 to 2005. By comparing the location of the inventor(s) on the patent applications and the location of the ultimate owner (firm), they are able to measure the extent to which invention is taking place outside the home country of the firm.

The novel feature of their work is that by regressing the R&D expenditure of the firm on the number of inventors in each location together with country, year, sector, and country-year dummies (thus controlling for overall changes in relative prices, the variable composition of R&D spending across sector and country, etc.) they are able to form an impression of the relative price of R&D labor in each country. It appears that inventors in the USA and Canada are the most expensive, although there are a number of caveats to the result. However, they do not disaggregate these numbers down to the country level, so the result is doubtless driven by the USA.

The raw data in Harhoff and Thoma (2010) shows that Canadian firms have been shifting some R&D abroad between the 1986-1990 period and the post-2000 period, mostly to Germany, the US, and to developing countries including China and India. For applicant firms from the US and the European countries with large amounts of R&D, the Canadian inventor share has not changed dramatically between 1986 and 2006, although Canadian invention by firms headquartered in France, Germany, Great Britain, and Sweden has grown as a share of those firms invention (Table 6). These figures do not suggest that Canada has lost out significantly in the race to attract global R&D.

Another way to look at this issue using patent data is to ask what share of patents obtained by inventors located in Canada is owned by foreign corporations. The OECD (2010) provides such data via their Patstat project. Figure 7 shows the trends in the share of Canadian PCT (Patent Cooperation Treaty) applications owned by foreigners from the US, the EU, Japan, and the rest of the world between 1999 and 2007. The shares are almost constant during this period, with a slight increase in US-owned patents. Figure 8, which is based on patent grants at the USPTO, confirms the modest trend toward US ownership of Canadian-origin patents. By itself, this suggests increased US investment in innovation in Canada relative to domestic investment. However, the data on US patent grants is seriously biased downward after about 2003 due to the application-grant lag, so the probably explanation for this finding is that US applicants have a shorter application-grant lag on average than applicants from other countries due to their proximity to the Patent Office and familiarity with its operations.

Looking in more detail at the patent data can also be enlightening. For example, di Minin and Palmberg (2007) examine the home and foreign patenting of four multinational wireless telephony firms (Ericsson, Motorola, Nokia, and Qualcomm) and find that the essential patents held by these firms are more likely than other patents to have originated in the firm's headquarters country. Essential patents are those defined by the European Telecommunications Standards Institute as essential to a telecommunication standard and these firms held 553 out of 834 such patents. The authors argue that the localization of essential patents occurs both because there is inertia in the organization of a firm's R&D and also because more strategic R&D is likely to be conducted at home.

3. Determinants of R&D location

The R&D location decision is the outcome of a complex decision-making process that depends on a number of factors. The first thing to note is that setting up an R&D lab in a new location is rarely accompanied by the closing of a lab elsewhere. That is, the decision to locate R&D in a foreign country is usually taken together with a decision to expand the R&D program or to redirect it in some way. It is generally far too costly in terms of the loss of firm-specific human capital to shut down a lab in one location and move the people and equipment to a different far away location. A survey of U.S. firms by Thursby and Thursby (2006) found that over 75% of the firms reported that the R&D facility they were considering locating in a new area was for expansion. Applying the term "footloose" to R&D, as some have done, is therefore a bit of hyperbole. The fact that most of the changes in foreign R&D investment comes from the expansion of R&D programs means that changes in the worldwide distribution of R&D spending will inevitably be somewhat sluggish. The numbers in Table 3b support this conclusion.

When a firm considers whether to locate some or all of its R&D outside its home country, it weighs the costs and benefits of staying at home versus those from moving. These take many forms, both financial and non-financial, and I review them in this section of the paper.

Reasons for locating R&D in foreign countries vary considerably depending on the relative levels of (technological and economic) development of the investing and host countries. In choosing among developing countries, factors such as the size of the local market, local labor regulation and costs, the availability of at least some of the relevant scientific and technical expertise, and other local regulations such as IP enforcement and the security of property rights might be expected to matter. Past research has found that firms move R&D to less developed countries primarily based on the need to complement their sales and production activities taking place in those countries. Such R&D is used to tailor process innovation to local conditions, and to customize products for local demand. See, for example, Håkanson and Nobel (1993a), who use survey data and factor analysis to conclude that 37% of the 1987 foreign R&D employment of the top 20 Swedish multinationals is located for reasons of local production support and market proximity. Only 8% of the employment was motivated by a desire to access foreign R&D, and fully 34% was located in foreign countries for reasons labeled by the authors as "political". However, a closer look at the components of this factor reveals that that it includes cost advantages such as lower R&D labor cost and R&D subsidies in addition to pure political factors.

Odagiri and Yasuda (1996) look at overseas R&D conducted by Japanese firms during the 1980s and find similar results. Support for local marketing is an important motivation, especially in Asia, whereas access to advanced technological knowledge and R&D resources appears to be a more important motivation for R&D investment in the US and Europe. Keeping in mind that these results are for the 1980s, they are consistent with the traditional view that MNE R&D investment in developing economies is associated with technology exploitation while in developed economies it is more driven by exploration (technology augmenting) motives. Ito and Wakasugi (2007) revisit this topic using data on Japanese MNEs during the late 1990s, and find that such firms are more likely to establish standalone overseas R&D labs if they are more R&D-intensive in general and that they to locate such labs in countries with abundant R&D-related human capital (that is, developed countries). They also found that the strength of IPR in the host country was an important positive influence in location choice.

When locating R&D in developed economies at the same or even higher level of development, many of the factors listed for developing countries will also matter, of course. However, in addition to these factors, because it is inevitably more costly to operate R&D labs in more than one country, the location must provide features that are not easily attainable in the home location. Among these are the quality and specializations of local universities and research institutions (the available knowledge base), and the availability of scientists and engineers. Pearce (1999) and Pearce and Papanastassiou (1999) document a 1992/94 survey of the R&D laboratories of foreign MNEs in the UK. These laboratories mentioned development of a new product slightly less often than adaptation to local market conditions as their primary activity, but when such development was mentioned, it took primacy. That is, a large minority of such laboratories (34%) were focused on new rather than adaptive R&D.

Location choice can also be based on access to lead markets where diffusion of innovations is more easily achieved, and where the customer base is therefore more likely to contribute to the enhancement of a particular product. Such considerations are especially important in network-based technologies, such as web innovations and end-user telecommunications equipment and may help to explain the large number of foreign R&D labs in the United States.

On the financial side, firms are sensitive to the tax treatment of their R&D spending. Is there an R&D tax credit available, and will they be able to take advantage of the credit even if they have no current taxable income? That these things can matter was shown by Bloom *et al.* (2002) using a panel of 9 OECD countries during the 1979-1997 period. They find a short run tax price elasticity of R&D with respect to its cost of 0.1 and a long run elasticity of unity, suggesting that every dollar the firm saves in R&D cost will be spent on more R&D in the country eventually, but not immediately.[7] A second feature of tax treatment that may matter is the tax treatment of technology royalties that are repatriated to the home country. Hines (1993, 1994) found that firms shifted R&D to a host country when the home country had higher tax rates on these royalties. That is, doing R&D in the host country was to some extent a substitute for R&D in the home country. However, it is worth mentioning that Thursby and

[7] See Hall and van Reenen (2000) for a survey of these kinds of estimates.

Thursby (2006) found that taxes overall were very low on the list of things considered when locating a new R&D facility abroad.

A second financial consideration might be the national treatment with respect to tax credits and subsidies – are these available for foreign firms or only for domestic firms? Most countries seem to apply national treatment in the case of R&D tax credits, allowing them for domestic affiliates of foreign firms (KPMG, 1995). Exceptions are Canada, which refunds the credits to firms that do not pay taxes only if they are privately held domestic firms, and Australia, where the R&D tax credit is not available to branches of foreign firms in the country (Bell 1995). There are also special temporary tax reduction provisions for foreign R&D or knowledge workers available in countries such as Denmark, Belgium, and the Netherlands. Recently Belgium and the Netherlands have introduced special low tax treatment of income that can be attributed to patents, and the UK is projected to follow suit in 2013.[8] However, with the exception of Bloom *et al.* (2002), among the many studies of R&D location choice there almost none that include information on the tax treatment of R&D so we do not know for certain to what extent firms respond to these incentives.

There exist some surveys of multinational firms that ask them to rank the importance of various factors in locating their R&D abroad (Hakanson and Nobel, 1993; Florida, 1997; Kuemmerle 1999; Pearce and Papanastassiou 1999; Edler *et al.*, 2002). Unfortunately, the questions asked and categories used are rarely the same from survey to survey so precise comparison is difficult, but one can get a good overall picture of firm thinking from the results. One of the most informative is the previously mentioned survey done in the Spring and Fall of 2005 by Thursby and Thursby (2006) for the U. S. National Academies. They surveyed high-level R&D executives in over 200 multinational corporations, most of whom were headquartered in the U.S. or Western Europe.[9] The respondents ranked the drivers of location choice for R&D in the following order:

1. close to highly qualified R&D personnel
2. close to customers
3. research collaborations with other firms
4. close to universities
5. availability of sponsored university or other research organization research
6. internet-based searches for solutions to technical problems
7. close to competitors

There was little significant difference between the U.S. and Western European firms in these rankings, except that Western European firms rated closeness to universities somewhat more highly, which may reflect a slight difference in industrial composition (firms in Western Europe are more likely to be chemical or pharmaceutical firms).

The second part of their survey focused on the location of one of the firm's most important proposed or recently established R&D facility, distinguishing between those located in

[8] It is not clear to what extent R&D will move across borders in response to reduced corporate tax rates on income attributable to patents. In fact, firms have considerable flexibility in where the accumulate income and in tracing it back to patent ownership, so that this tax instrument seems unlikely to lead to the movement of large amounts of R&D.

[9] 44% headquartered in the U.S.; 49% in Western Europe; 7% elsewhere in the world.

developed countries, and those located in emerging economies. Table 7 and Figure 9 summarize their results. For location in the home country and other developed countries, access to scientists and engineers, both as employees and at universities, along with IP protection and ownership were clearly important factors. Although these factors also affected the choice of emerging economy location, in that case R&D costs and the size and expected growth of the market were more important. It is noteworthy that tax breaks, subsidies, and the absence of legal requirements were the least important factors in choosing a location, regardless of the development level.

Since the early 1990s, as more and better data has become available, a large number of papers that study the R&D location decision empirically have appeared. Summaries of these papers are given in Table 6, which shows the period covered, the level and type of the analysis, the countries involved, and the factors that were identified as the most important determinants. It is clear from the table that these studies are frequently very non-comparable due to differences in the unit of observation and the variables considered. However, many of them reach similar conclusions, so it is possible to draw some broad conclusions from this body of work.

The first dimension across which the studies vary is the nature of the data that they use: a few are based on specially conducted surveys (Hakanson and Nobel, 1993; Florida, 1997; Edler *et al.*, 2002; Thursby and Thursby, 2006), whereas others draw from R&D data collected by the OECD, the Japanese statistical agency, or the US Bureau of Economic Analysis. In some cases the authors have access to firm-level data, whereas in other they rely on industry or country level data (Kumar, 1996, 2001; Jones and Teegen, 2003; Hegde and Hicks, 2008; Erken and Kleijn, 2010). Because patent data are publicly available at the firm and location level (unlike R&D), a number of studies make use of these data to analyze the location decision for innovative activity (Patel and Vega, 1999; Guellec and van Pottelsberghe, 2001; Le Bas and Sierra, 2002; Cantwell and Piscitello, 2002; Criscuolo *et al.*, 2005).

The second main source of variation is that some studies focus on the choice of host country given a foreign location for R&D (Kumar 1996, 2001; Cantwell and Piscitello, 2002; Belderbos *et al.*, 2008: Hegde and Hicks, 2008; Shimizutani and Todo, 2008; Schmiele 2009; Dachs and Pyka, 2010; Erken and Kleijn, 2010) whereas others look only at the decision to perform R&D outside the home country (Edler *et al*., 2002; von Zedtwitz and Gassmann, 2002; Belderbos *et al*., 2009). The home countries considered range from individual (US, Japan, Sweden) to the Triad, the OECD, or more. Thus the source of variability in studying the location decision can be variation across destination country, variation across source country, or both. However, the only study that really looks at a number of source and destination countries at the same time is the patent citation study by Criscuolo *et al.* (2005).

What do these studies find? Patel and Vega (1999) propose a useful taxonomy based on revealed technical advantage as shown by patents to classify the strategies followed by firms that locate their R&D in another country. There are four strategies, depending on whether the firm has revealed technical advantage (RTA) in the home and/or host country: 1) technology seeking (the host is strong in the area and the firm is weak); 2) home base technology exploiting (the host is weak in the area and the firm is strong); 3) home base technology augmenting (the host and the firm are both strong in the area; and 4) market seeking (non-technology motivated, both are weak in the area). Both these authors and LeBas and Sierra (2002) find that strategies 2 and 3 are by far the most common, which essentially means that firms with an RTA in a particular technology at home will tend to locate R&D in other countries, regardless of whether those countries have any particular advantage in the technology. Home technology exploiting can be viewed as a demand driven strategy, in the sense that the firm is doing R&D in a location which has need for its technology, whereas home technology augmenting is driven more by the need to acquire knowledge from producers of related technology, that is, more supply driven.

The empirical results in the various papers strongly support this view: the variables that most strongly affect location choice are invariably the size of the market, the R&D intensity of the host country, the availability of technical and educated workers, and the presence of lead customers. The sales of the relevant foreign affiliate are also a strong predictor of R&D, where they can be included (when the variability is across firms or host countries). Thus demand considerations (the available market and the need to support local sales) and access to R&D and R&D personnel are the overriding considerations, as suggested by Thursby and Thursby (2006). It is noteworthy that the cost of R&D (usually measured as wages of R&D personnel) rarely enters the regressions significantly, and sometimes enters with the wrong sign. In addition, as mentioned earlier, few of the papers consider the tax costs of R&D as an influence on the location decision.

A couple of the papers are able to look at research and development separately. Von Zedtwitz and Gassman (2002) have aggregate foreign R&D for 81 multinationals in OECD countries broken down by R and D. They find that research depends on the presence of universities and innovation centers, access to R&D personnel, and the availability of subsidies, whereas development is more associated with supporting sales, the presence of lead customers, and costs. Thus there is a clear separation here between technological opportunity, which drives the research location choice, and demand, which drives development. On the other hand, Shimizutani and Todo (2008) look at 12,000 subsidiaries of Japanese MNEs, and find that foreign sales and market size drive both research and development, whereas foreign R&D intensity attracts research and home country R&D intensity makes development in a foreign location more likely. So in this case, although foreign R&D is an attractor for research, demand factors affect both types of R&D.

4. International R&D spillovers

R&D performed in countries outside a firm's headquarters country is assumed to generate and benefit from knowledge spillovers. First, the knowledge generated by this R&D is likely to spill over to some of the local firms. This is especially the case when the firm investing comes from a frontier country and the local firms are technological laggards but not by too much. That is, some local absorptive capacity is necessary. Second, the very reason why the firm chooses to locate its R&D where it does may be to benefit from specialized local knowledge in the form of a particular science base, university research that is strong in a certain area, or even local competitors from whom it can learn. This section of the paper assesses the empirical evidence on the presence of international R&D spillovers, that is, spillovers from R&D done in one country on productivity in another country, under the presumption that one of the channels for these spillovers is the presence of foreign R&D in the host country.

Conceptually it is useful to distinguish two kinds of spillovers: rent spillovers and knowledge spillovers (Griliches, 1992). The first type occurs when a firm or consumer purchases R&D-incorporated goods or services at prices that do not reflect their user value, because of imperfect price discrimination due to asymmetric information and transaction costs, imperfect appropriability and imitation, or mismeasurement of the true value of the transaction due to the lack of hedonic prices. The more competitive are markets, the less ability firms have to appropriate the benefits of their R&D and the more pecuniary spillovers will take place. By contrast, the more prices are corrected for quality improvements, the less we should observe spurious R&D spillovers.

The second type of spillover occurs when an R&D project produces knowledge that can be useful to another firm in doing its own research. Knowledge is a rival and only partially excludable good. Because of weak or incomplete patent protection, inability to keep innovations secret, reverse engineering and imitation, some of the knowledge and benefits from R&D are not kept within the firm. The more knowledge is codified and the higher is the absorptive capacity of other firms, the more knowledge spillover will take place. It is important here to distinguish between spillovers and some kinds of technology transfer. Technology transfer usually refers to trade in technology, which occurs when an agent sells a piece of technology with a price attached to the transaction. A non-pecuniary spillover, on the contrary, refers to an unintended transfer of knowledge, in which no payment is involved.

One of the important questions about R&D spillovers is the extent to which they are localized to an urban area, region, or even country. Presumably the desire to benefit from such localization is a driver of the globalization of R&D. Recent surveys by Feldman and Kogler (2010) and Autant-Bernard, Mairesse, and Massard (2007) review the evidence on this question.[10] Feldman and Kogler summarize the known stylized facts about the geography of innovation in the following way: innovation is spatially concentrated and geography provides a platform for the organization of economic activity. Knowledge spillovers are nuanced, subtle, pervasive, and not easily amenable to measurement, and tend to be geographically localized. The local presence of universities is necessary but not sufficient for innovation. Finally, innovative locations tend to develop over time via an evolutionary process.

4.1 Measuring spillovers[11]

Econometric estimates of the importance of spillovers are obtained by adding a measure of external R&D to a standard production or cost function framework that also includes internal R&D as an input. The R&D spillover variable is measured as a weighted sum of the R&D stocks from sources outside of the firm:

$$S_{it} = \sum_{j \neq i} a_{ji} R_{jt} \qquad (1)$$

where the a_{jt} weights are proportional to some flows or proximity measures between firm, industry, or country *i*, the receiver of R&D spillover, and firm, industry, or country *j*, the source of R&D spillover. In the case of international spillovers, the unit of observation is sometimes a country and sometimes an industry within a country. Only rarely is it a firm within the country.

[10] For surveys on R&D spillovers in general, see Griliches (1992), Hall *et al.* (2010), and Mohnen (1996); on international R&D spillovers in particular, see Branstetter (1998), Cincera and van Pottelsberghe de la Potterie (2001), and Mohnen (1998).

[11] This and the following section are based on Hall *et al.* (2010).

Various flow related weights have been used in the literature: intermediate input transactions (Terleckyj, 1980), investments in capital goods (Sveikauskas, 1981), hiring of R&D personnel, attendance at workshops, seminars or trade fairs, collaborations, adoption of new technologies, flows of patents (Scherer, 1984) or innovations (Sterlacchini, 1989) from industry of origin to industry of use, and patent citations. The intuition is that the more *j* trades with *i*, invests in *i*, collaborates with *i* or gets cited by *i*, the more it is likely to diffuse its knowledge to *i*. Spillovers can also be measured independently of any economic transaction simply on the basis of proximities in various types of space. These proximities can be uncentered correlation coefficients between positions in patent classes (Jaffe, 1986), fields of research (Adams and Jaffe, 1996), qualifications of personnel (Adams, 1990) or lines of business.

Measures of proximity that are independent of any economic transactions are expected to capture pure knowledge spillovers. Rent spillovers, in contrast, are likely to occur whenever monetary transactions take place, i.e. with trade, direct investment, technology payments, hiring of workers, research collaborations, and mergers and acquisitions. In practice the two types of spillover are hard to dissociate, because, on the one hand, knowledge flows are often concomitant with user-producer transactions and the capture of rents, and on the other hand, knowledge gains can be used to reap economic rents.

The measured R&D spillover term is introduced into an extended Cobb-Douglas production function along with the stock of own R&D:

$$Q_{it} = f(X_{it}, R_{it}, S_{it}, T_{it}, \varepsilon_{it}) \qquad (2)$$

where Q_{it} is output, X_{it} are the conventional inputs, R_{it} denotes the own stock of Research and Development (R&D), a proxy for the stock of knowledge, T_{it} is an index of technological change and ε_{it} is a random error term. The return from outside R&D is then estimated as the marginal effect of S_{it}, which represents an elasticity or a marginal productivity depending on the chosen functional form of the production function.

4.2 Empirical evidence

International R&D spillovers are transmitted through the same channels as those documented in the literature on technology transfer: international trade in final goods, intermediate inputs, capital goods, b) foreign direct investment (FDI), especially if it comes with manpower training to operate the new machines and to assimilate new production and management techniques, c) migration of scientists, engineers, educated people in general, or their attendance at workshops, seminars, trade fairs and the like, d) publications in technical journals and scientific papers, referencing other publications, invention revelations through patenting, patent citations, e) international research collaborations or international mergers and acquisitions, f) foreign technology payments, i.e. royalties on copyrights and trademarks, licensing fees, the purchase of patents, the payments for consulting services and the financing of R&D conducted abroad.

A highly cited study of the impact of international R&D spillovers on TFP was conducted by Coe and Helpman (1995). In this study, conducted for 22 developed countries, they used the share of imports from the sending country as weights to aggregate the R&D, confining the possible set of sending countries to the G-7 economies (Canada, France, Germany, Italy, Japan, the UK, and the US). They were able to estimate the own rate of return to R&D as 123% for the G-7, and 85% for the other 15 countries, and the spillover return from the G-7 as 32%, implying that roughly a quarter of the benefits from R&D in G-7 countries accrues to their trading partners.

(Coe *et al.* 1997, 2009). Keller (1997) cast doubt on the trade-related interpretation of Coe and Helpman's R&D spillover by showing that significant foreign R&D spillovers can be obtained when the weights in the construction of the spillover are random rather than based on import shares. This result suggests that the important identifying variation was in the total amount of external R&D rather than being mediated by trade. Lichtenberg and van Pottelsberghe (1998) critique Coe and Helpman's weighting of the foreign R&D stocks by means of the proportion of total imports originating from the foreign R&D sources for being too sensitive to the aggregation of the data and propose instead to normalize the imports from the recipient country by the GDP of the sending country. van Pottelsberghe and Lichtenberg (2001) provide evidence for outward FDI as another channel of international R&D spillovers. Kao, Chiang and Chen (1999) find cointegration between the TFP and R&D variables, using cointegration tests that are appropriate for panel data. When they reestimate the Coe and Helpman specification with a dynamic ordinary least squares (DOLS) estimator (which is not biased in small samples, unlike the ordinary estimator) they no longer obtain a significant effect for the trade-related foreign R&D spillover, although the domestic R&D impact is essentially unchanged.

The relative importance of domestic and foreign R&D contributions to total factor productivity growth depends on the channels of transmission used to estimate foreign R&D spillovers, but all channels combined it is likely that small R&D spenders have relatively more to gain from foreign R&D than big R&D spenders by the sheer size of the absorbable knowledge. It depends of course on the absorption capacity of the receiver and her openness to transmission channels, and therefore the output elasticity to foreign R&D may be higher or lower than the output elasticity of domestic R&D (as shown by van Pottelsberghe and Lichtenberg, 2001).

Table 5 of Hall *et al.* (2010) surveys the econometric literature that estimates the social returns to R&D, and the last panel of that table presents results based on country data, shown here as Table 8. The estimates for the additional rate of return from (unpriced) spillovers to the rest of the world for R&D done in the G-7 economies are typically around 30 per cent, although there is some doubt about the robustness of the results given that they are obtained using aggregate time series data. The weighting matrix used is usually imports from the R&D-performing country to the recipient country. When Mohnen (1992b) simply uses aggregate foreign R&D stocks (unweighted), he obtains a return of 4 to 18 per cent. The main conclusion from the body of work is that R&D done elsewhere does generate spillover benefits for a country, which makes the management of a single country's R&D policy a bit more complex.

5. Conclusions and discussion

Is Canada losing out in the global R&D race? The evidence for this is not particularly strong. Like all developed economies, including the United States, the Canadian share of the world economy has shrunk slightly during the past ten years as the share of the BRICs and other emerging countries has grown. So like the rest of the OECD economies with the possible exception of the US and Japan, Canada's R&D appears rather stagnant. However it does not seem to be true that it is a less favored location for R&D than the rest of the OECD. It is simply the case that new R&D labs are generally being located in countries that are perceived to have high potential growth rates (and therefore increasing market size) and an increasingly well-educated science and engineering labor force. But this is the same situation faced by all OECD economies, not just Canada.

What are the implications for a country like Canada? Is it helpful to compare it to Sweden? Norway? Australia? That is, to developed economies rich in natural resources with relatively low population densities? As a primarily English-speaking country, Canada is different from the Scandinavian countries in one important dimension, which is reflected in the country's relatively high participation in international R&D activity, given its size. Like Ireland, Australia, and the UK, it has been an attractive destination for R&D in the past, although it appears from the OECD data that such investment has grown only moderately during the 2000s. Data from US R&D investment abroad also suggests that investment in Canada has declined slightly between 2003 and 2007 relative the size of its economy, or relative to developing countries. Thus we can say for certain that inward R&D to Canada does not appear to be growing much at all, although the various data problems are such that we cannot conclude that it has declined.

Bernstein and Yan (1997) and Mohnen and Lepine (1991), among others, have documented the beneficial spillover effects of R&D conducted in other countries (Japan and the US, in particular) on Canadian productivity. It is likely that these spillovers would be even stronger if such R&D were conducted in Canada by foreign firms, for reasons of proximity.

It is natural to ask what the source of the apparent stagnation in overseas R&D investment in Canada is. The evidence on location choice emphasizes both supply side and demand side factors as important determinants of R&D location for developed countries. On the supply side are the role of highly qualified R&D personnel and university faculty along with good IP protection. There is no reason to think that these factors have deteriorated enough to cause a decline in absolute Canadian attractiveness; however, it is possible that the supply of R&D personnel in the emerging economies has been increasing, leading to a relative decline in the demand for Canadian researchers. On the demand side, we have the destination market size and its expected growth. This seems a much more likely source of the slight shift in R&D investment away from developed towards developing countries, and can explain the relative stagnation of inward R&D in Canada.

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Figure 1. Concentration of R&D and GDP

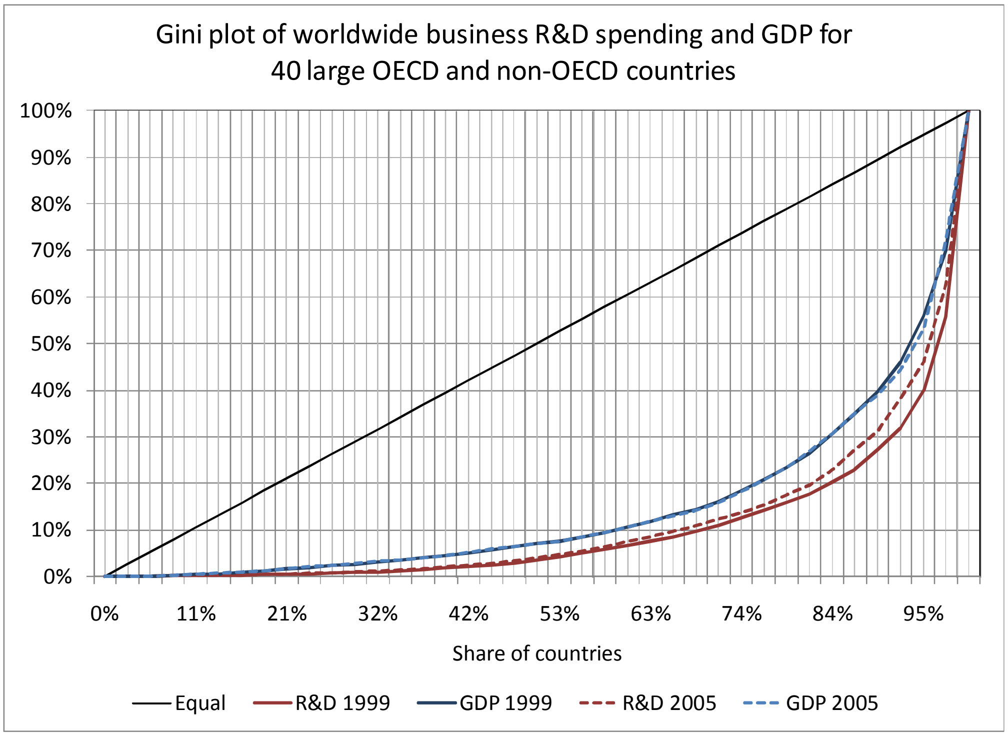


Figure 2

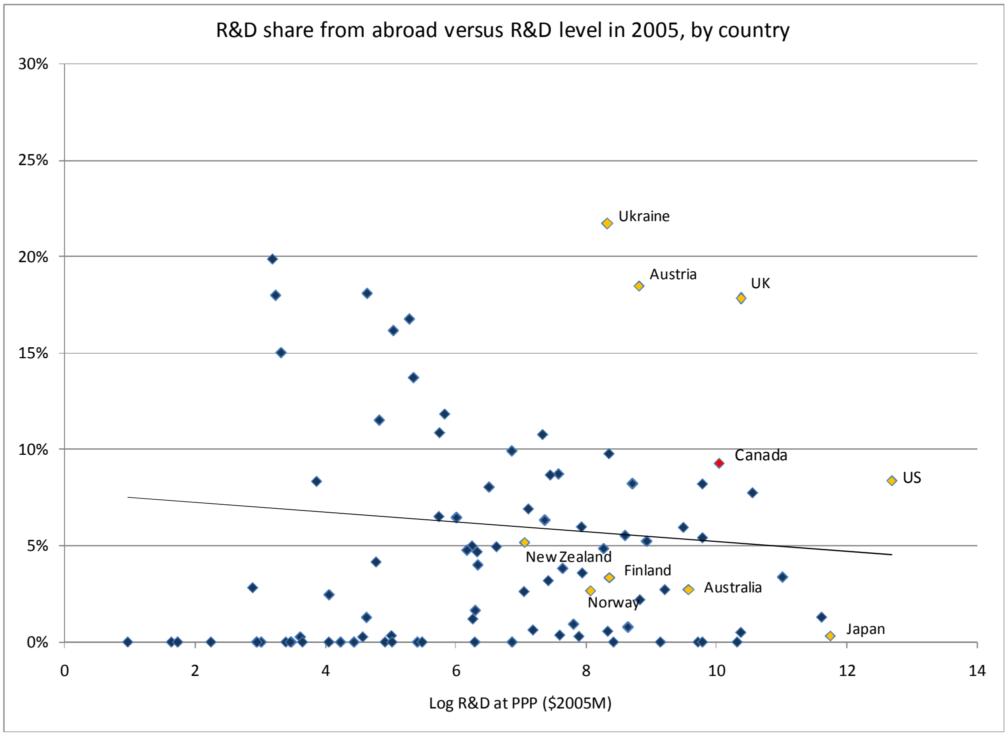
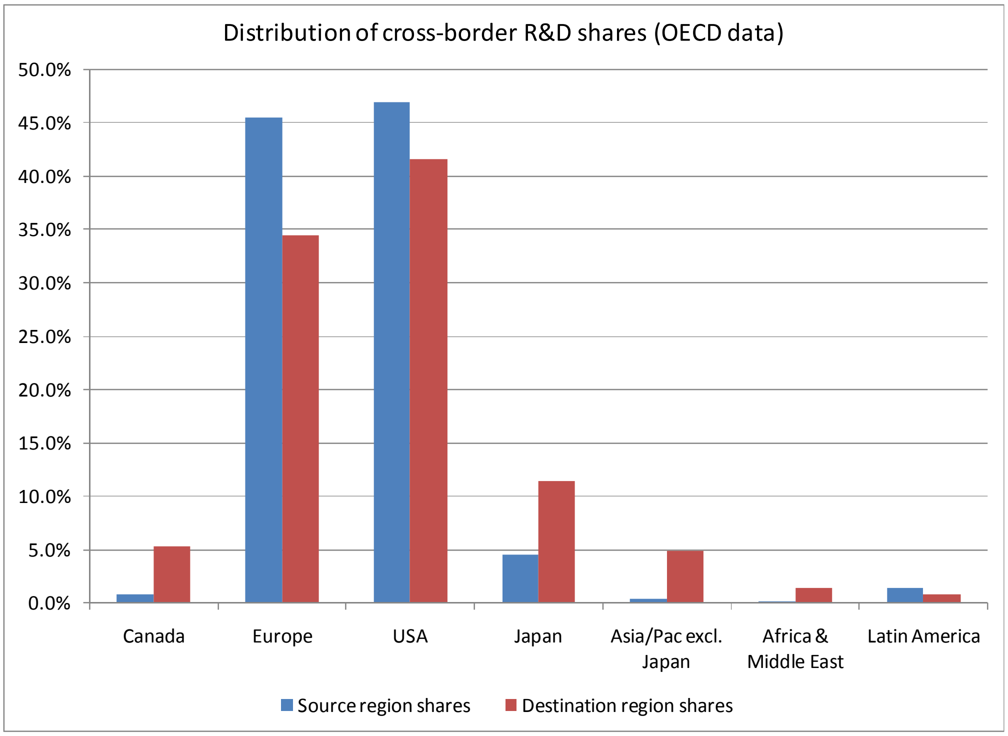
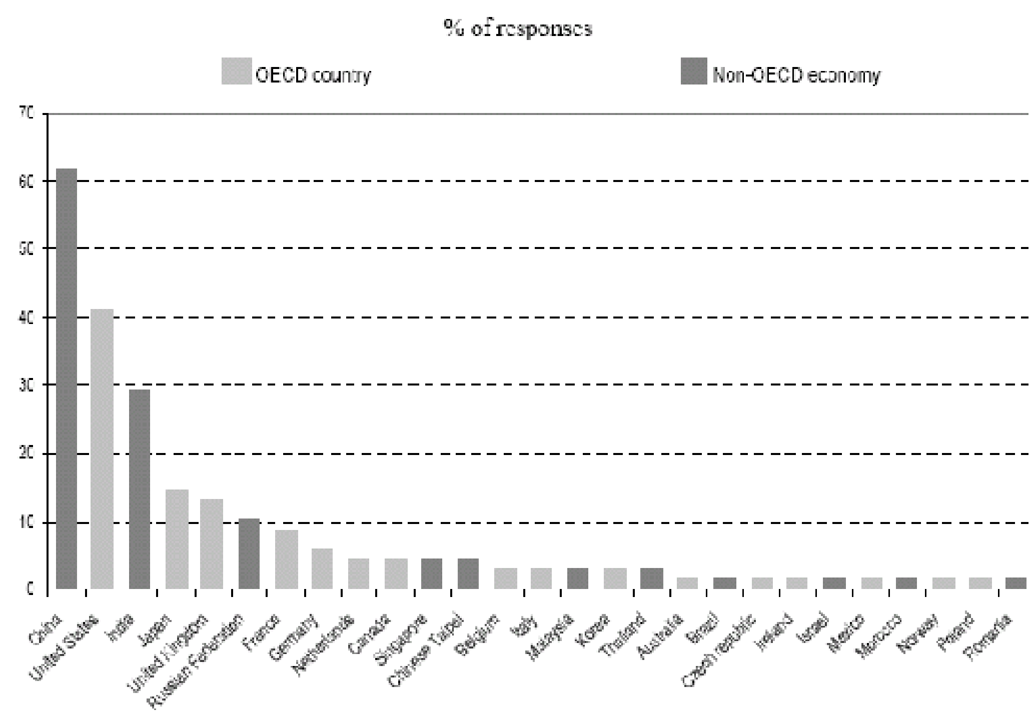


Figure 3. Cross-border R&D shares in 2005



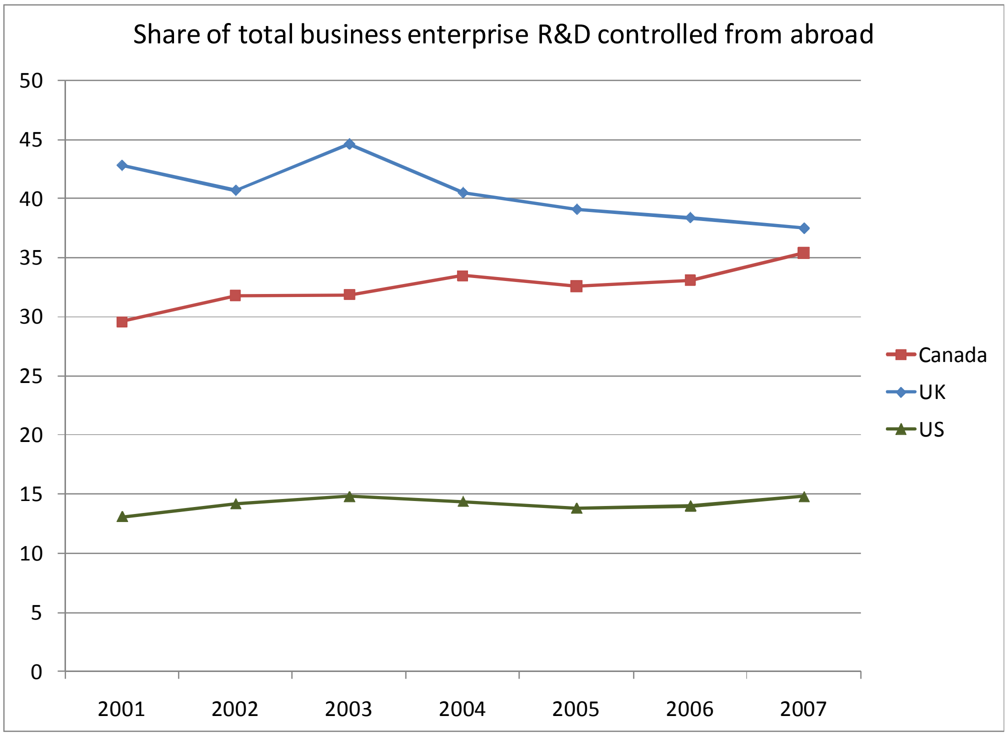
Source: OECD/AFA Database

Figure 4. Most attractive foreign R&D locations



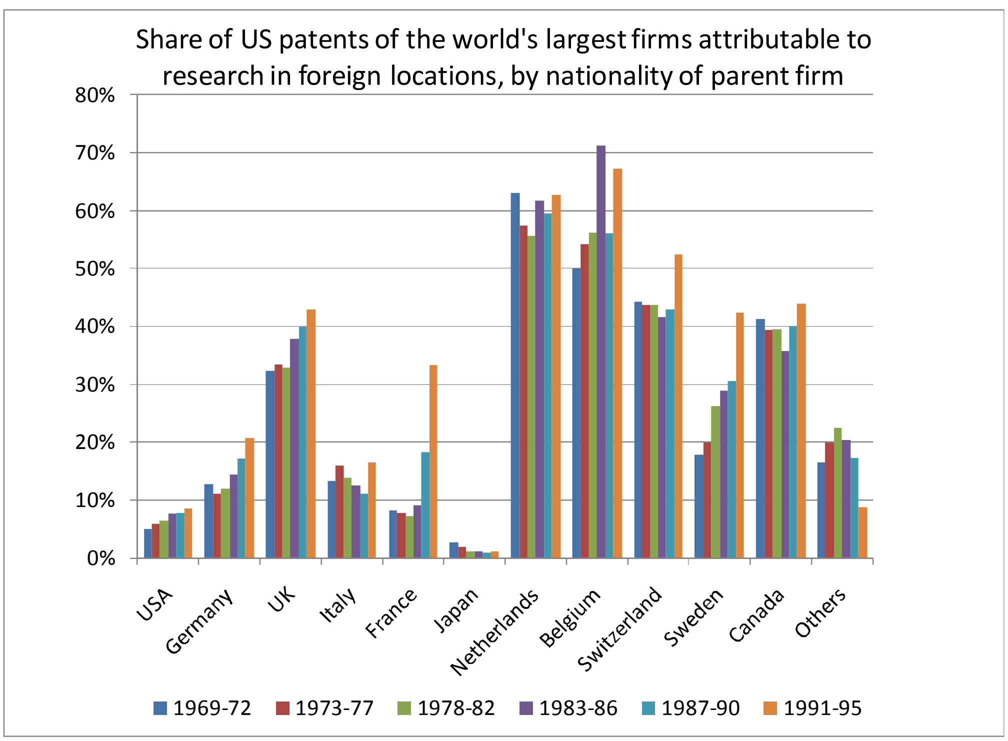
Source: UNCTAD (2005) in OECD (2006a).

Figure 5. Foreign R&D shares



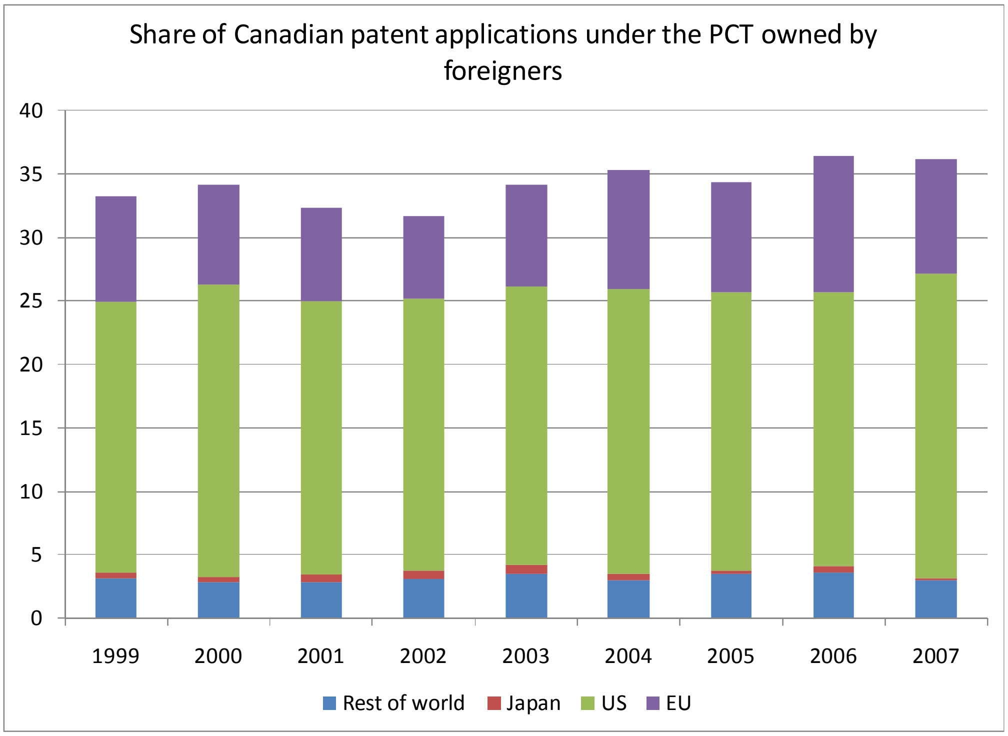
Source: OECD/AFA Databse

Figure 6. International patenting



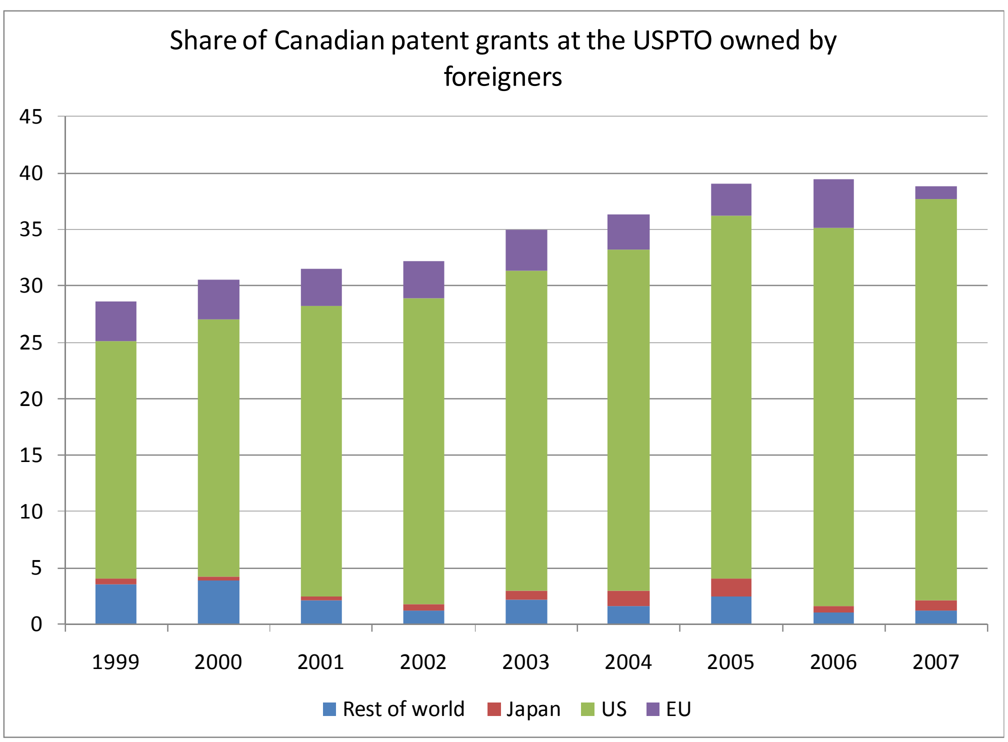
Source: Cantwell and Janne (1997)

Figure 7. Foreign patenting in Canada (PCT applications)



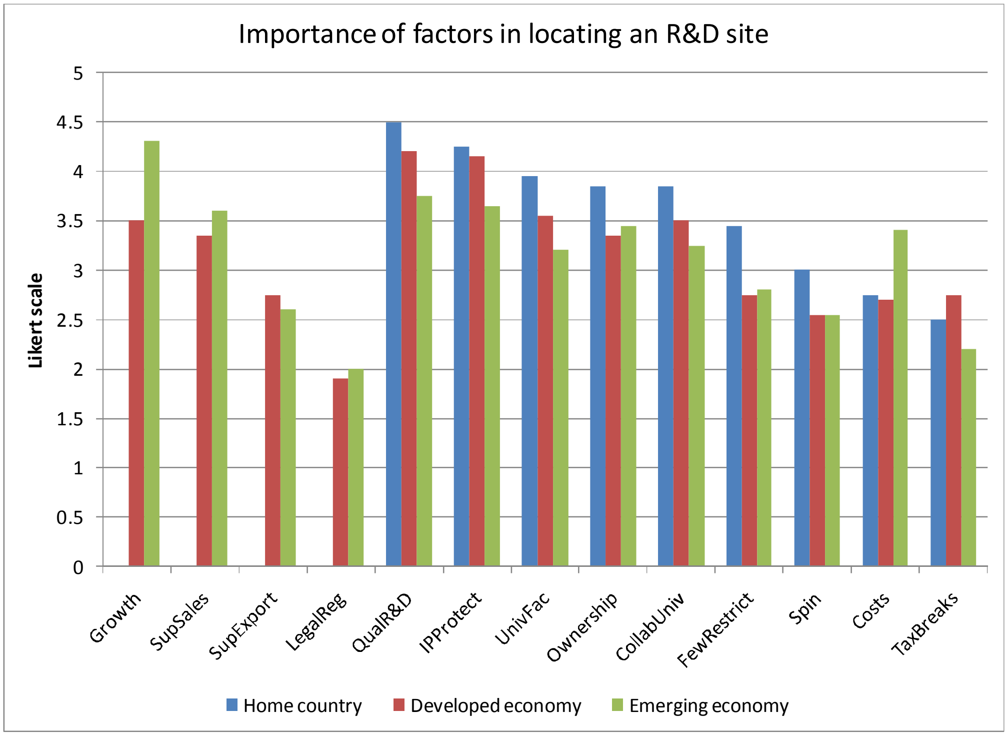
Source: http://stats.oecd.org/Index.aspx?DatasetCode=PATS_COOP

Figure 8. Foreign patenting in Canada (US grants)



Source: http://stats.oecd.org/Index.aspx?DatasetCode=PATS_COOP

Figure 9. Choosing an R&D location



Source: Thursby and Thursby (2006)

Table 1: Share of R&D Budget Spent Outside the Home Country – 209 MNEs

	1995	*1998*	*2001*	*2004 (est.)*
Western Europe	25.7	30.3	33.4	43.7
Japan	4.7	7.0	10.5	14.6
North America	23.2	28.4	31.7	35.1

Percents, based on a survey of 209 MNEs. The geographic zones refer to the origin of the MNEs.
Source: Reger (2002)

Table 2: Total and externally funded R&D for countries with more than $1B in R&D

Country	*Total R&D* Billions of 2005 dollars (PPP)	*Externally-funded R&D* Billions of 2005 dollars (PPP)	*Share externally funded* per cent	*Business sector R&D* Billions of 2005 dollars (PPP)
United States*	323.8530	27.1065	8.37%	207.8410
Japan	126.2105	0.4381	0.35%	96.0738
China*	109.9588	1.0184	1.27%	73.7177
Germany	60.4835	2.2664	3.75%	40.8716
France	38.1810	2.8745	7.53%	19.8291
United Kingdom	32.1844	6.2024	19.27%	13.5367
India	30.1648			4.7125
Canada	22.9354	2.1809	9.51%	11.2110
Italy	17.7025	1.4092	7.96%	7.0214
Russia	17.6578	1.3411	7.59%	5.2980
Brazil	16.4858			7.9786
Spain	13.1997	0.7582	5.74%	6.1101
Australia	13.1448	0.3586	2.73%	7.4529
Sweden	9.9449	0.8075	8.12%	6.3506
Netherlands	9.3032	1.0209	10.97%	4.6205
Switzerland	7.5151	0.3930	5.23%	5.2405
Israel	6.7889	0.2221	3.27%	5.1208
Austria	6.6725	1.1825	17.72%	3.0478
Belgium	6.0499	0.7505	12.40%	3.6106
Mexico	5.6507	0.0421	0.75%	2.6268
Finland	5.4149	0.3401	6.28%	3.6203
Iran	4.5165			0.5505
Denmark	4.2732	0.4303	10.07%	2.5437
South Africa	4.2158	0.5714	13.55%	1.8494
Ukraine	4.1454	1.0106	24.38%	1.3371
Turkey	4.1341	0.0325	0.79%	1.7903
Singapore	3.8908	0.1699	4.37%	2.2859
Norway	3.1958	0.2567	8.03%	1.4831
Czech Republic	2.8091	0.1111	3.96%	1.5194
Poland	2.7687	0.1590	5.74%	0.9234
Argentina	2.4558	0.0207	0.84%	0.7618
Malaysia	2.4347	0.0065	0.27%	1.8915
Hong Kong	2.0787	0.0512	2.46%	1.1015
Pakistan	1.9866	0.0069	0.35%	
Ireland	1.9530	0.1685	8.63%	1.1220
Chile	1.7211	0.1492	8.67%	0.7892
Portugal	1.6661	0.0783	4.70%	0.6042
Greece	1.5780	0.2996	18.99%	0.4902
Hungary	1.5287	0.1631	10.67%	0.6030
Thailand	1.3184	0.0242	1.84%	0.6415
Belarus	1.2265	0.0767	6.25%	0.2603
New Zealand	1.1565	0.0602	5.20%	0.4748
Total in top 42 countries	**934.5554**	**54.5595**	**5.84%**	**558.9148**
Other countries	2.6659	0.2630	9.86%	0.2949
Share in other countries	0.29%	0.48%		0.05%

Source: UNESCO Institute of Statistics (2010). Science and Technology statistics. Available at http://stats.uis.unesco.org

Author's computations using the Penn World Tables version 6.3, R&D data interpolated where necessary.

* from UNESCO Table 14; numbers from Inst of Statistics were incomplete.

Table 3a: Share of R&D expenditures of foreign affiliates abroad by country of destination, 2003

	Source country				
Destination	*United States*	*Japan*	*Germany*	*France*	*United Kingdom*
US		**47%**	**69%**	**35%**	**63%**
France	9%	5%	10%		2%
UK	18%	9%	5%	16%	
Japan	8%		4%	20%	2%
Italy	4%	2%	3%	2%	2%
Belgium	2%	3%	2%	4%	2%
Netherlands	3%	8%	1%	2%	2%
Germany	19%	5%		18%	11%
Sweden	4%	0%	0%	0%	15%
Other	**33%**	19%	2%	1%	1%

Source: OECD, AFA Database, January 2008

Table 3b: Share of total business R&D

	Source country					*Share of GDP**
Destination	*Italy in 2003*	*Japan in 2003*	*Japan in 2007*	*US in 2003*	*US in 2007*	*US in 2007*
United States	9.9%	49.1%	50.4%			
Canada	5.7%			10.7%	7.8%	0.22%
Australia & NZ	0.0%			1.9%	3.2%	0.12%
Belgium	0.6%			2.0%	3.4%	0.32%
France	28.3%	2.7%	1.9%	7.8%	4.8%	0.08%
Germany	19.7%	6.2%	5.7%	17.1%	17.0%	0.22%
Ireland	1.0%			2.6%	4.3%	0.83%
Netherlands	1.2%			2.3%	2.1%	0.12%
Sweden	0.5%			6.1%	4.4%	0.49%
United Kingdom	5.2%	10.4%	7.7%	19.2%	18.6%	0.31%
Other Europe	26.0%	17.1%	11.8%	8.3%	11.3%	0.04%
Israel	0.0%			3.0%	2.7%	0.53%
Japan	0.0%			7.2%	5.7%	0.05%
China, incl. HK	0.1%			3.5%	3.5%	0.01%
Singapore	0.2%			2.3%	1.7%	0.27%
India	0.2%			0.4%	1.3%	0.01%
Other Asia	0.5%	10.9%	16.1%	4.1%	4.6%	0.03%
Latin America	2.2%			1.5%	3.3%	0.05%
ROW, incl. Africa	0.1%	3.6%	6.4%		0.2%	0.00%
Total, OECD+	98.1%	85.5%	77.5%	88.2%	85.5%	0.08%
Total, non-OECD	3.3%	14.5%	22.5%	11.7%	14.5%	0.02%

Source: OECD, AFA Database, January 2008, outward R&D data

+ OECD countries plus the remainder of Europe

** This is the external R&D share of destination country GDP*

Table 4: Source and Destination Region for Multinational R&D from OECD AFA Database

	R&D performed in destination region (2005 M dollars, at PPP)							
Source region	*Canada*	*Europe*	*USA*	*Japan*	*Asia/Pac excl. Japan*	*Africa & Middle East*	*Latin America*	***Total***
Canada	--	274	183	8	--	--	--	**465**
Europe	552	--	21457	4268	--	--	--	**26277**
USA	2433	18638	--	2308	2456	841	433	**27109**
Japan	93	915	1225	--	377	--	--	**2610**
Asia/Pac excl. Japan	0	38	203	8	--	--	--	**249**
Africa & Middle East	0	12	121	0	--	--	--	**133**
Latin America	0	0	826	25	--	--	--	**851**
Total	**3078**	**19877**	**24015**	**6617**	**2833**	**841**	**433**	**57694**

	Share of cross-border R&D							
Canada		0.5%	0.3%	0.0%				**0.8%**
Europe	1.0%		37.2%	7.4%				**45.5%**
USA	4.2%	32.3%		4.0%	4.3%	1.5%	0.8%	**47.0%**
Japan	0.2%	1.6%	2.1%		0.7%			**4.5%**
Asia/Pac excl. Japan		0.1%	0.4%					**0.4%**
Africa & Middle East			0.2%					**0.2%**
Latin America			1.4%					**1.4%**
	5.3%	**34.4%**	**41.6%**	**11.4%**	**4.9%**	**1.5%**	**0.8%**	

Numbers are total mfg R&D in 2005, from OECD AFA Databse
Where data is partly missing, averages over 2004-2006 have been used if possible
Cells denoted "--" have no data available in the source; in some cases they are likely to be zero.
Source: OECD, AFA Database, January 2008, outward R&D data

Table 5: Foreign-controlled R&D in Canada by 2-digit industry

	Foreign-controlled share		*Foreign-controlled ($M Canadian)*	
ISIC3	*2001*	*2007*	*2001*	*2007*
Mining and quarrying	29.9	53.2	64	292
Food, beverages and tobacco	28.7	29.3	27	49
Textiles, wearing apparel, leather, footwear	71.5		68	
Wood and paper products, publishing, printing	9.2	20.0	30	82
All chemical products	71.0	57.8	833	942
Drugs and medicines	80.9		665	
Rubber and plastic products	25.8	21.2	20	24
Non-metallic mineral products	14.0		3	
Basic and fabricated metal products	8.6	51.5	33	272
Non-electrical machinery and equipment	55.9	26.7	463	184
Machinery and equipment n.e.c.	26.7	20.1	93	118
Office, accounting and computing machinery	77.1	63.5	370	66
Electrical machinery and apparatus n.e.c.	58.3		178	
Radio, TV and communication equipment	9.0	9.1	363	132
Medical, precision, opt. instruments	32.6		88	
Motor vehicles	60.8	63.8	216	308
Other transport equipment	57.2	56.6	559	572
Aircraft and spacecraft			545	
Furniture, recycling and manufacturing n.e.c.	18.0		14	
Manufacturing total	**32.2**	**37.5**	**2874**	**3095**
Electricity, gas and water supply, construction	2.0		4	
Trade, repair, hotels and restaurants	46.7		304	530
Finance, insurance, real estate, business act.	25.4	32.6	771	1491
Other activities	10.5		87	
Total Business Enterprise	**29.6**	**35.4**	**4104**	**5622**

Source: Statistics Canada, data extracted on 12 Oct 2010 from OECD.Stat

Table 6: Canadian inventor share of foreign-owned invention around the world

	1986-1990	1991-1995	1996-2000	2001-2006
Switzerland	0.5	0.4	0.7	0.7
Germany	0.3	0.6	0.8	0.9
France	1.1	1.3	1.6	2.0
Great Britain	0.6	0.9	1.4	1.5
Italy	0.6	0.6	0.9	0.7
Netherlands	0.3	0.3	0.4	0.3
other EU	0.5	0.3	0.8	0.8
Sweden	0.5	1.0	1.7	1.5
US	0.9	1.0	1.3	1.3

Source: Harhoff and Thoma (2010)
Top US and European R&D performers only

Table 7: Factors considered important when locating an R&D facility

Factors	*Name*	*Home country*	*Developed economy*	*Emerging economy*
Country has high growth potential.	Growth	NA	3.5	4.3
The R&D facility was established to support sales to foreign customers.	SupSales	NA	3.35	3.6
The R&D facility was established to support production for export.	SupExport	NA	2.75	2.6
The establishment of an R&D facility was a regulatory or legal prerequisite for access to local mkt.	LegalReg	NA	1.9	2
There are highly qualified R&D personnel.	QualR&D	4.5	4.2	3.75
There is good IP protection.	IPProtect	4.25	4.15	3.65
There are university faculty with special scientific or engineering expertise.	UnivFac	3.95	3.55	3.2
It is easy to negotiate ownership of IP from research relationship.	Ownership	3.85	3.35	3.45
It is easy to collaborate with universities.	CollabUniv	3.85	3.5	3.25
There are few regulatory and/or research restrictions in this country.	FewRestrict	3.45	2.75	2.8
The cultural and regulatory environment is conducive to spinning off or spinning in new businesses.	Spin	3	2.55	2.55
Exclusive of tax breaks and direct govt assistance, the costs of R&D are low.	Costs	2.75	2.7	3.4
We were offered tax breaks and/or direct govt. assistance.	TaxBreaks	2.5	2.75	2.2

Source: Thursby and Thursby (2006), pp. 21-28.

Table 8: The determinants of R&D location - literature survey

Authors	*Date of paper*	*Overview*	*Type*	*Dates covered*	*Home country*	*Unit of observation*	*Sample*	*Factors (in order of importance)*
Hakanson and Nobel	1993	23% of Swedish R&D abroad - what are the reasons?	data	1987	Sweden	subsidiary in a foreign country	20 Swedish MNEs (170 foreign subs)	(1) support to local production (5%) (2) market proximity (32%); (3) foreign R&D access (8%); (4) political factors (34%)
Kumar	1996	location determinants for US MNE R&D using aggregate data	emetrics	1977, 1982, 1989	US	foreign country - agg US R&D	US MNEs at agg level (28 countries)	mktsize, R&D intensity, phones (neg), IP (RR index,OECD only), tariff bar (weak, dev only), res pat (dev only)
Florida	1997	globalization of innovation and FDI in R&D - motivations	survey/ data	1994	many	foreign lab in US	207 standalone foreign R&D labs in US	order of importance: biotech, electronics, chem/mat, auto access to tech talent; then links with US S&T; customization & R&D less impt
Patel and Vega	1999	determinants of foreign location of US patenting	patent data analysis	1969-1996	Triad	product group within MNE	220 Triad MNEs	strategies: 1 tech-seeking; 2 home base exploiting; 3 home base augmenting 4 mkt seeking. 2&3 by far the most impt
Kumar	2001	determinants of overseas R&D location & spending level by US and Japanese MNEs	emetrics	1982, 1989, 1994	US; Japan	home country-industry-host country	agg US & Jpn MNEs at 7- ind level investing in 74 countries	US: mktsize, S&E or R&D intensity, EU, not pat, open, local sales US->dev: mktsize, S&E or R&D intensity, not pat, open, local sales JP: mktsize, R&D cost, not pat, open, local sales, R&D intensity JP->dev: mktsize, R&D cost, R&D intensity, patents, not open, local sales
Edler et al.	2002	surveyed R&D strategy in general incl internationalization	survey	1998	Triad	agg external R&D by home country	2009 Triad MNEs	adapt to local req, R&D personnel, lead mkts customers,
von Zedtwitz & Gassmann	2002	Development globally dispersed, research concentrated in 5 regions why?	survey/ data	1998	OECD	agg external R&D by MNE	81 MNEs (US, EU, JP, KR)	Research: univ, R&D personnel, centers of innov, subsidies, support local dev Development: support sales, lead customers, cost
Le Bas and Sierra	2002	Determinants of foreign location of EPO patenting	patent data analysis	1988-1990 1994-1996	OECD	ext pats by tech groups for each MNE	350 MNEs	strategies: 1 tech-seeking; 2 home base exploiting; 3 home base augmenting 4 mkt seeking. 2&3 by far the most impt
Cantwell and Piscitello	2002	relative attractiveness of Italy, Germany and UK for foreign-owned tech development using US patent data	emetrics/p atents	1969-1995	many	agg foreign US pats by host country by tech field	784 largest worldwide patenting firms at regional level in UK Italy Germany	local mktsize in Germany, external sources of K (R&D intensity & education), breadth of tech specialisation in region; ind specific and cluster-based spillovers in Italy and UK but not in Germany (crowding out)

Jones & Teegen	2003	investigate motivations for US MNEs to locate R&D in foreign locations	emetrics	1994	US	host country	agg country-level R&D by US MNEs	affiliate sales, education; R&D cost and S&Es do not enter (small sample)
Criscuolo et al.	2005	EPO citations by US and EU MNEs to home & host country patents	emetrics/patent citations	1977-1999	US/EU	host country by home country by industry	118 US & EU MNEs	EU firms - cite rates same except for pharma - more exploiting than augmenting US firms - cite US more than EU, more exploit than augment
Thursby & Thursby	2006	survey of reasons for choosing an R&D location	survey	2005	US/EU	MNE	US & EU MNEs	OECD econ: R&D personnel, IP protect, univ, growth, support sales, IP ownership Dev econ: growth, R&D personnel, support sales, IP protect, IP ownership, costs, univ
Hegde & Hicks	2008	explain location of US mne R&D and US patents using host country info	emetrics	1991-2002	US	host country by tech class	US MNEs at ind level	R&D: foreign sales, foreign S&E pubs, Europe, chemicals patents: foreign sales, foreign patents, foreign S&E pubs, electrical, other, chemicals, Europe
Shimizutani & Todo	2008	determinants of location for basic/app research and development by subs of Japanese firms	emetrics	1996-2001	Japan	subsidiary in a foreign country	12,466 JP subsidiaries of MNEs	Research: foreign sales, age of sub, mktsize, foreign R&D intensity, R&D cost Development: parent R&D intensity, foreign sales, age of sub, mktsize
Belderbos et al.	2009	What determines Japanese firm inv in US & Japan? Separate R from D	emetrics	1996	Japan	MNE by for/dom R&D	146 Japanese MNEs	relative R&D home/away depends on ind-specific growth in patents for R (tech oppty); ind-specific demand & prod growth for D
Schmiele	2009	What determines overseas innovative activity by German firms	emetrics/CIS	2004-2006	Germany	host country by firm	1439 German firms	exporting, R&D-doer, innov coop with intl, lack of info at home, high cost at home, size, IP user for mfg or new process abroad
Dachs & Pyka	2010	Determinants of cross-border patenting	emetrics/patents	2000-2005	EU	home country by host country	EU patenting firms	GDP & R&D in home & host countries, distance (neg), common language, both EU15, IPR relative to dev level
Erken & Kleijn	2010	What determines where MNEs locate R&D in the developing world? Looks at inward R&D in 13 countries	emetrics	1990-2002 1981-2001	OECD	host country	R&D: panel of 13 countries Patents: 21 OECD countries	inward R&D: foreign VA/GDP, private R&D intensity, IPR (-), R&D cost (+), S&Es & public R&D do not enter except for high tech sectors pats per labor: GDP growth, private R&D intensity, education, pub R&D & wages weak

dev = developing countries; OECD = developed countries; R = basic/applied research; D = development; MNE = multinational; S&E = scientists and engineers; for = foreign

Source: Hall, Mairesse, and Mohnen (2010)