Internationalisation of R&D:
Trends, Impact and Policy Implications

Very preliminary first draft, for comments only

The rising internationalisation of R&D has caused concern among policy makers of both net recipient and net source countries. Governments of *net recipient countries* on the one hand actively compete to attract foreign firms, but at the same time fear that foreign-owned firms may act as 'Trojan horses' since they may drain the national technology and production base while keeping the core of their innovative activities in their home countries. Countries that are *net sources* of foreign R&D investment are worried that the internationalisation of R&D may relocate ("hollow out") the domestic knowledge base to abroad.

Although the internationalisation of R&D is generally felt to have a major impact on economic development and public policy, and some of its aspects are well discussed, the processes are complex. The existence of the phenomenon is generally accepted, but its importance, the trends, and its impact not yet clearly understood. Most countries are grappling with the challenges of globalisation. In order to address the policy implications of internationalization of R&D from an evidence based perspective (section III), this note first looks at the prevailing trends in the internationalisation of R&D (section I), and also reviews the evidence on impact of internationalization of R&D on host and home economies (section II).

A few ex ante caveats. This note largely focuses on MNEs in order to identify trends and analyse drivers behind the internationalisation of R&D. Multinationals are the leading players in the global R&D landscape as they are the largest R&D investors: firms account for almost 70% of total R&D expenditure in the OECD area and most is carried out by large firms. The focus on business should not detract from other important aspects that complement the internationalisation of business R&D such as the internationalisation of science and the international mobility of researchers. Successful innovative firms are typically part of a system of formal and informal links with other firms, public research institutions, universities and other knowledge-creating bodies.

Although the note will focus mostly on MNEs' internationalisation of R&D strategies through R&D-FDI, we will also take into account the wider perspective on international knowledge transfers, since in practice they are often complementary and hence their impact for actors and policy makers difficult to disentangle[1]. Furthermore the internationalisation of R&D through R&D-FDI is embedded and cannot be understood without considering the overall process of globalisation of production.

I. Internationalisation of R&D: characterizing the phenomenon

In view of the importance of Multinational Firms as driving forces in R&D-internationalisation, a key indicator is the internationalisation of R&D activities by these firms [2] We first review the

[1] The OECD has ongoing activities monitoring the internationalisation of R&D, see eg OECD, Science, Technology Industry Outlook 2006. Also EC, DG Research with the European Report on S&T indicators and the Key Figures, EUROSTAT, Statistics in Focus 7/2005 and ECFIN, European Economy Annual Review 2005;

[2] The internationalisation of R&D by establishing R&D affiliates abroad (R&D-FDI) is an important mechanism for international know-how diffusion. But from a policy perspective, it is important to remember that technology is also transferred internationally through other channels than subsidiaries of MNEs. When considering a broader perspective, encompassing the whole spectrum of international know-how diffusion, other mechanisms need to be considered as well, such as licensing, purchase of equipment, international movement of personnel, the reverse engineering of imported goods and other, more informal, channels. There is a growing emphasis on the importance of networking and the formation of alliances in order to access and transfer technology internationally.

indicators based on the latest available data on internationally comparable R&D expenditures and patent data (section 1.1). The section will further discuss in section 1.2. the evidence on location factors and motives for R&D internationalisation. Since data still tend to be incomplete and not fully comparable across time and countries, robust trends are difficult to identify.

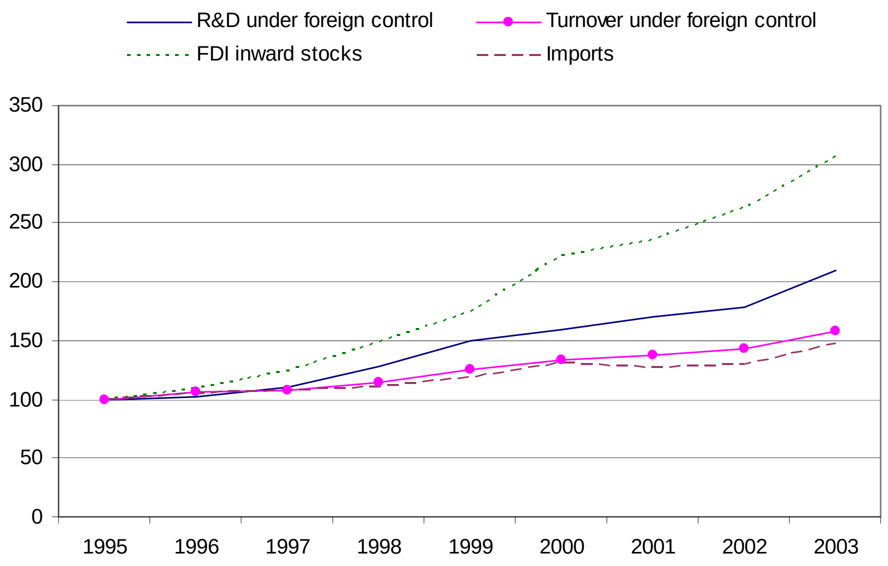
1.1. Trends in Internationalisation of R&D

Internationalisation of R&D on the rise

Since 1995, R&D expenditure by foreign-controlled affiliates has grown faster than their turnover or total imports in the OECD area. These results show that R&D is one of the most dynamic elements in the globalisation process.

Evolution of the main driving forces of globalisation of goods and services in the OECD[1] area

1995 = 100 (current prices)



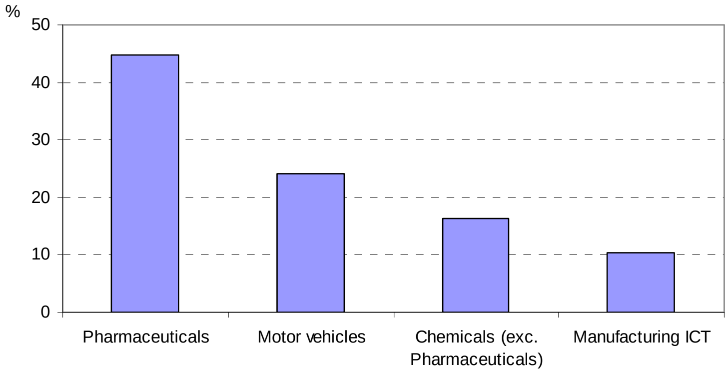
1. Countries included: United States, Japan, United Kingdom, France, Germany, Canada, Netherlands, Sweden, Czech Republic, Finland, Hungary, Ireland and Poland.

Source: OECD, AFA, International investment, International trade databases, June 2006.

High-tech sectors are the most internationalized in R&D

The sector with the most internationalized R&D is pharmaceuticals, while manufacturing ICT is the high-tech sector with the lowest international R&D (data on services not being available). Another important trend is the shift towards the service sectors. During the FDI boom of the late 90s the service sectors saw their share in FDI increase to two thirds of total OECD inflows, mostly accounted for by the knowledge intensive services. In 2002, services accounted for more the 75% of FDI inflows in the OECD area. But also the service share in FDI flows to developing countries' increased (OECD (2004)).

Share of R&D under foreign control by industrial sector, total OECD[1], 2001



1. Include the United States, Japan, the United Kingdom, France, Canada, the Netherlands, Sweden, Spain, Portugal, the Czech Republic, Poland. Countries that are not included cannot isolate pharmaceuticals from the chemical industry.

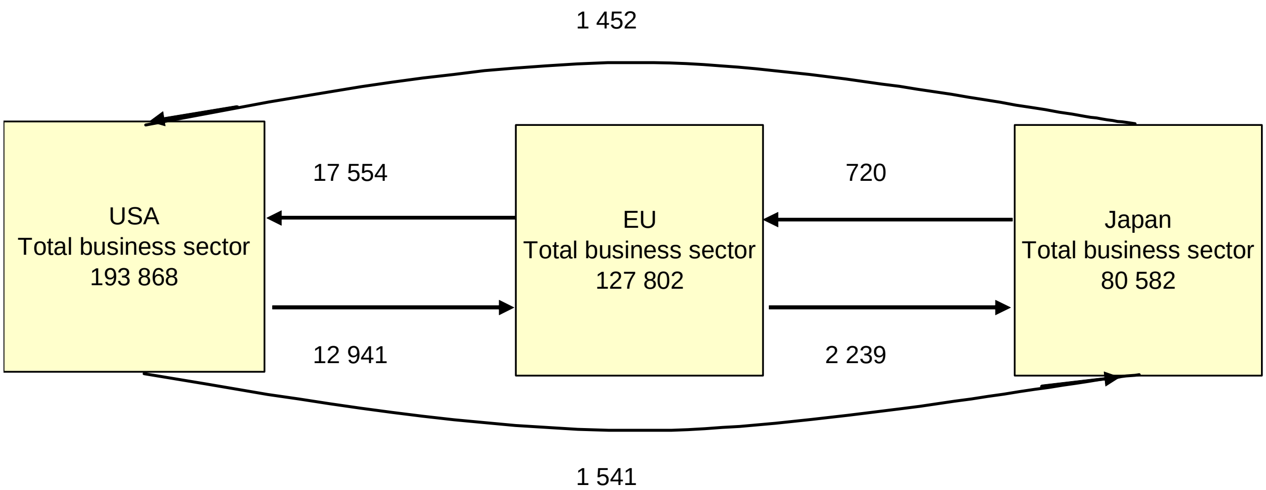
Source: OECD, AFA database, June 2006.

R&D internationalisation still is mainly an intra-Triad phenomenon: EU firms most internationalized in R&D

The EU business sector is the most internationalised wrt R&D spending: more than 13% of its total R&D is spent outside the EU, while for the US this is 7% and for Japan only 4%. Japan is the least open area, also in terms of attracting inward R&D-FDI, which accounts for 4.5% of total R&D in Japan. Most of the EU outward R&D-FDI is destined for the US and vica versa. Investment by American multinationals in the European Union essentially concerns three sectors: automobiles (33%), the pharmaceutical industry (26%) and computers and electronics (14%). European R&D investments in the United States mainly concern the chemical and pharmaceutical industry (50%), computers and electronics (13%) and petroleum distribution (10%).

R&D flows between the EU-15, US and Japan, 2002

Millions of PPP dollars



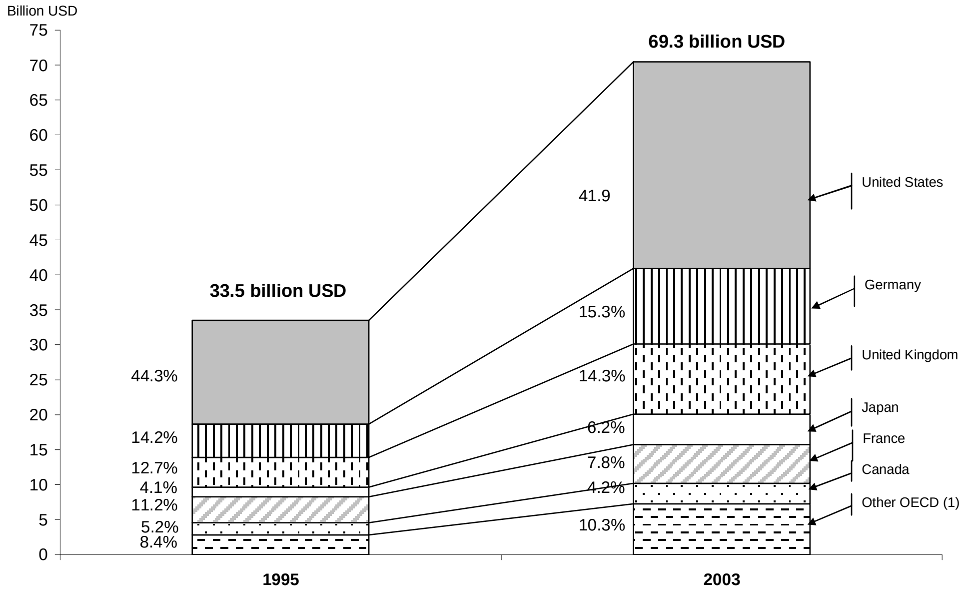
Source: OECD, AFA database and OECD estimates, June 2006.

The US remains the major destination country for foreign R&D

The growth of R&D located abroad holds across all major destination areas. Nevertheless in relative terms, the shares of Germany, Japan and the United Kingdom increased, while those of the United States, France and Canada declined. Despite this decline, the United States continued to attract 41.9% of total R&D expenditure by foreign affiliates in the OECD area, although in terms of turnover, the share of the same affiliates was only 38.5%. This shows that, for foreign affiliates, the United States is a more attractive country for research than for production. The opposite holds for France: in 2003, the turnover of foreign affiliates there was 14.4% of the total turnover of foreign affiliates in the OECD area, but the R&D expenditure of those same affiliates accounted for only 7.8% of the area total.

Trends in the share of R&D expenditure under foreign control in the business sector in selected OECD countries between 1995 and 2003

Current dollars



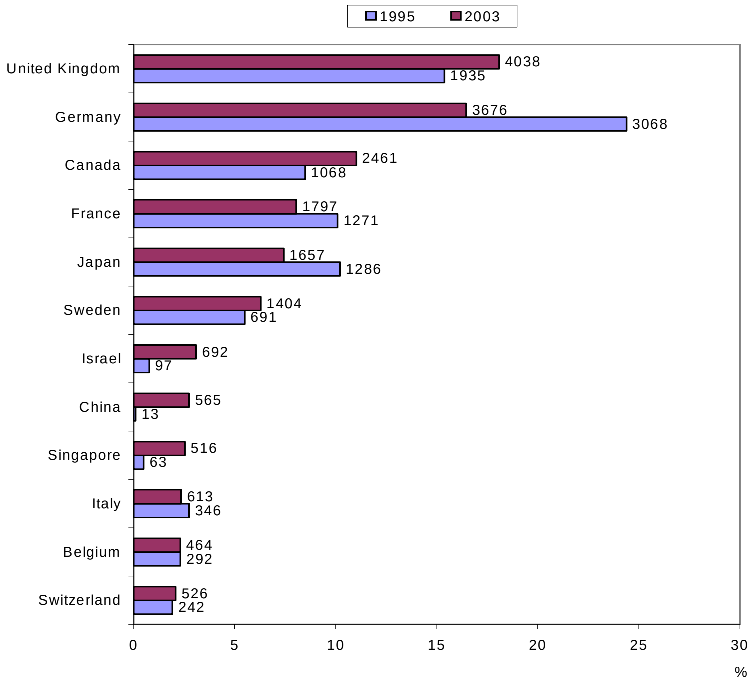
1. Consists of the Czech Republic, Finland, Hungary, Ireland, Poland, the Netherlands and Sweden.

Source: OECD, AFA database, June 2006.

Outside Triad R&D-FDI flows are the rise;

In contrast to the Triadisation documented supra, the trend has increasingly become more truly global. If the EU has long been the major host for US foreign research, the emerging markets and most notably China, are currently attracting also an increasing share of overseas outlays by MNEs.

Geographical distribution of overseas R&D expenditure by US-owned subsidiaries, 1995 and 2003



Source: OECD, AFA database, June 2006.

Survey evidence on intentions for R&D investments confirms the increasing importance of emerging markets:

- A survey of investor intensions more generally (not restricted to R&D) (UNCTAD2004), found that more the 70% of the largest MNEs expect FDI to increase, but unequally distributed among host countries. On the whole, developing and transition countries appear to figure more prominently in investment plans. Within the Central and Eastern European countries, Poland figures prominently, while within Asia, China is expected to receive (even) higher FDI flows than today.
- A survey of the largest R&D investors, undertaken by UNCTAD from November 2004 to March 2005, suggests that the pace of internationalising R&D may be accelerating (UNCTAD, 2005): as many as 69% of responding firms stated that their share of foreign R&D is set to increase (only 2% indicated a decline and the remaining 29% expected the level of internationalisation to remain unchanged). Momentum appears to be particularly strong among companies in Japan and Korea, which have so far been less aggressive in terms of internationalisation of R&D: nine out of ten Japanese firms in the sample and about 80% of the Korean firms planned to increase their foreign R&D, while 61% of the European firms indicated similar intentions. In the UNCTAD survey of the largest R&D spenders worldwide, China (3rd) and India (6th) were among the top ranks as developing countries for current locations for R&D. Other developing countries, including Singapore, Brazil and some eastern European countries, also appeared in the ranking. It is expected that this shift towards emerging countries will continue to some extent, as demonstrated by the findings on future R&D investments in the same UNCTAD survey. China was the R&D location mentioned most often, followed by the United States. India was in third place, and Russia was also among the top ten target locations. Other emerging economies named were Singapore, Chinese Taipei and Thailand.
- E&Y's European Attractiveness Survey 2005 puts within the EU, the UK still in the lead of destination for FDI in general. While the UK continues the hold the leading posting as FDI destination with the EU, its market share has fallen slightly between 2004 and 2003. This decline is attributed to fewer expansion projects and fewer US companies investing in the EU, with US companies a traditional strong investor in the UK. With respect to R&D, the most preferred site ranked on R&D quality and capacity within the EU nevertheless remains Germany: 32% (up from 26% in 2004). While in 2004 the UK had a similar score than Germany (26%), this has dropped to 20% in 2005.

- A global survey conducted by The Economist Intelligence Unit in 2004 showed that top companies' favorite location for planned R&D investment was China followed by the US and India.

This corresponds to an increasing share of countries like China and South Korea in patenting activities. Although this rise holds in all broad technologies areas, China and Hong Kong are particularly strengthening their knowledge base in key technologies such as material sciences.

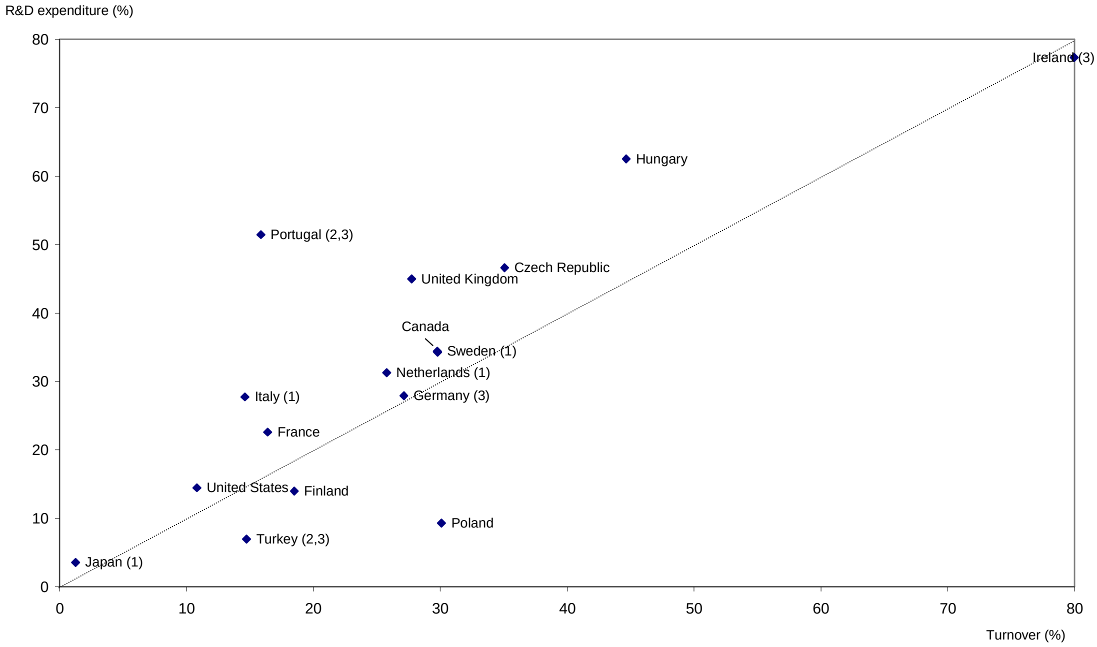
Some R&D statistics for China (2003)
• R&D as % of GDP: 1.31% (0.7 in 1998)
• Real Annual Growth of R&D (1998-2003): 15%
• Government funding of R&D as % of GDP: 0.8%
• S&E in R&D per 10.000 labour force: 11.3 (6.7 in 1998)
• China ranks 6th for scientific publications (ISI)
• China ranks 12th in patents (WIPO)
• Share of High-Tech Products in Exports: 25% (11% in 1998)

Increasing importance of foreign controlled R&D in total country R&D

The share of foreign affiliates in local industrial R&D varies widely across countries, ranging from less than 5% in Japan to over 70% in Hungary and Ireland[3]. These differences primarily reflect the contribution of foreign affiliates to industrial activity. Nevertheless, in many OECD countries, the share of foreign affiliates in R&D is smaller then their share in manufacturing production, like in the US, France and the UK. Hence R&D activities are still less internationalised than production. This suggests that most research still remains at corporate headquarters.

[3] It should also be mentioned that Hungary and Ireland were the only countries where R&D intensities (*i.e.* ratio of R&D expenditure to turnover) were higher than for domestically-controlled firms. This may reflect the relative lack of investment in R&D by domestically-controlled enterprises in those two countries. It can also be observed that both in Hungary and Ireland, technology payments (licences, patents, know-how, technical assistance, studies, R&D, etc.) far exceeded the R&D expenditure of enterprises in general. This was also the case in Poland and Portugal. There is a presumption that firms in general in these countries tend to buy the bulk of the technology they need abroad rather than developing it at home.

Share of R&D expenditure and turnover of affiliates under foreign control in total business sector R&D and turnover, 2003

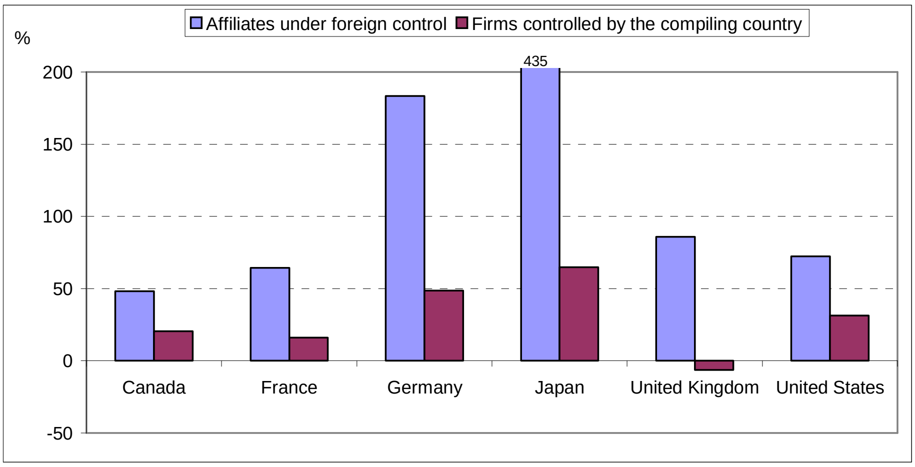


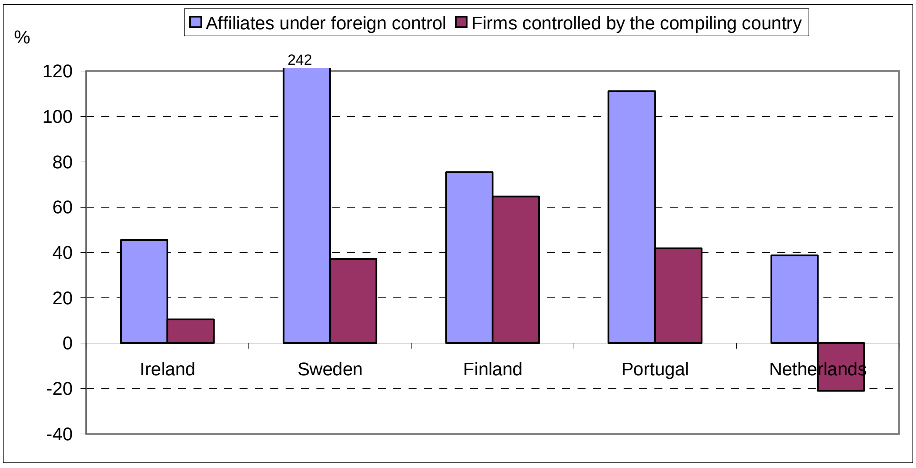
1. 2002. 2. 2001. 3. Manufacturing sector only.
Source: OECD, AFA database, June 2006.

Although the home market remains the major location for R&D, the share of R&D activities located abroad is on the rise, resulting in an importance of foreign controlled R&D for recipient countries. In all countries except Spain, foreign-controlled firms increased their R&D expenditure by between half and three times as much as firms under national control, increasing their importance in total R&D expenditures. In the United Kingdom, only foreign-controlled affiliates showed strong growth, while the R&D expenditure of domestically-controlled firms showed a decline. It is thanks to R&D investment by foreign affiliates that overall growth of business-sector R&D in these two countries was not negative.

Growth of R&D expenditures of affiliates under foreign control and firms controlled by the compiling country between 1995 and 2003 in selected OECD countries

In constant PPP (2000)





Note: Finland: 1997-2003; Netherlands: 1997-2002; Portugal: 1999-2003.

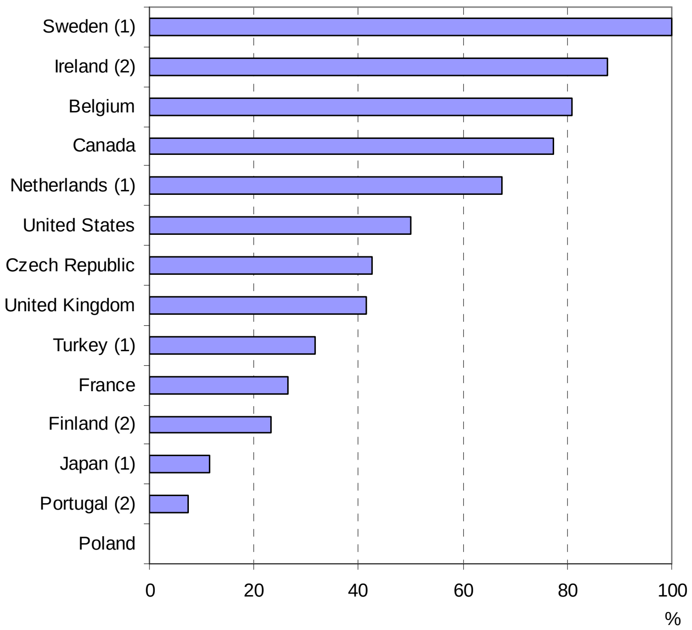
Source: OECD, AFA database, June 2006.

The importance of foreign R&D by sector

In Sweden, virtually all of the R&D in the pharmaceutical sector is performed by foreign affiliates, whereas in Ireland, Belgium and Canada the proportion ranges between 80% and 90%. Even in the United States, 45% of pharmaceutical R&D is performed by foreign-controlled affiliates – a ratio that is higher than in any other industry.

As a rule, foreign pharmaceutical affiliates' share of R&D tends to correspond to their share of the industry's turnover. In some countries, however, there are substantial differences. In the United Kingdom, for example, 85% of the pharmaceutical industry's turnover is under foreign control, but only 42% of its R&D. Similarly, in France over 52% of the industry's turnover is foreign-controlled but only 28% of its R&D.

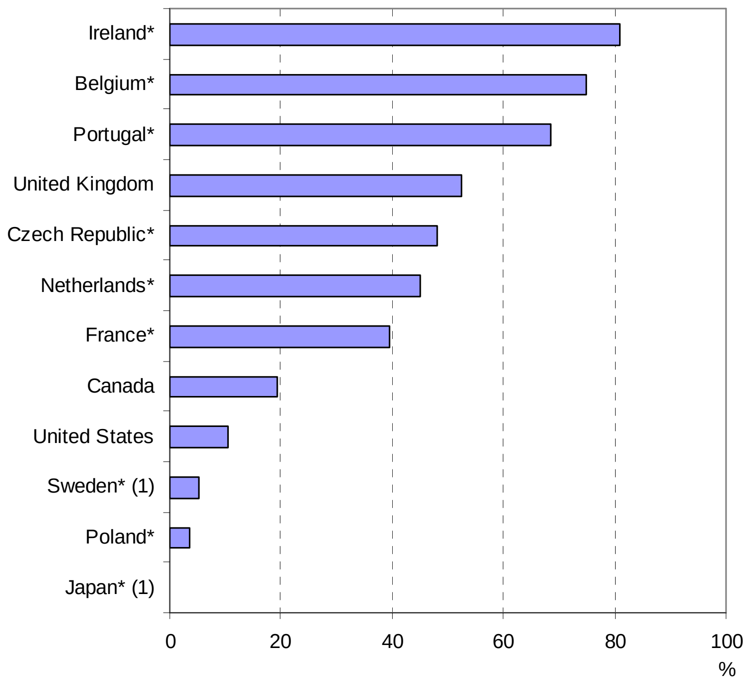
Share of R&D expenditure under foreign control in the pharmaceutical sector, 2003



1. 2002. 2. 2001. *Source:* OECD, AFA database, June 2006.

In small countries, like Ireland and Belgium, the share of ICT-R&D than is under foreign control exceeds 70%. For Ireland this is mostly US controlled, while for Belgium this is EU control. Among the large countries, France and the UK have foreign R&D shares greater than or equal to 40%.

Share of R&D expenditure under foreign control in the ICT sector, 2003



* Manufacturing sector only. 1. 2002. *Source:* OECD, AFA database, June 2006.

Internationalisation of Technology Development using Patent Data

Next to R&D expenditures, the trend of R&D internationalisation can also be analysed using data on patenting by firms. Two main indicators of internationalisation can be constructed with patent data information. The first one is the share for a given country of patents with a domestic inventor and a foreign (owned) applicant in the country's total domestic inventions. It reflects the extent to which foreign firms control domestic inventions (*inward*). The second one is the share for a given country of patents with a foreign inventor and a domestic applicant in the country's total domestic applications. It reflects the extent to which domestic firms control foreign inventions (*outward*). In general patent data indicators indicate the same trends as the R&D expenditures data.

2002	Share of EPO patents owned by foreign residents (*inward*)	Share of EPO patents with inventions abroad (*outward*)
Japan	3.4%	3.7%
US	12.2%	17.2%
EU-25	11.1%	7.4%
EU-15	11.1%	7.7%
UK	36.9%	18.6%
GER	13.8%	12.4%
FRA	23.4%	20.3%
FI	8.9%	25.4%
BEL	43.1%	30.5%

Source: Eurostat: Statistics in Focus 2005 on the basis of OECD

Similar patterns as the ones described for R&D data emerge. During the 1990s, there has also been a considerable increase in the share of domestic ownership of inventions made abroad (outward R&D-FDI). This share increased from 10.8% of all EPO patents in 1990-92 to 15.8% in 2000-2002. At the same time, 15.8% of all patented inventions in EPO were owned or co-owned by a foreign resident in 2000 (inward R&D-FDI). This compares to 10.8% in 1992, a modestly increasing trend. This increasing trend holds for most countries, but there is an important cross-country difference in terms of levels. Foreign ownership of domestic inventions is high in small open countries like Belgium, but also the UK stands out. Japan is much less internationalised in terms of cross-border ownership of inventions with few local inventions owned by foreigners and few owned inventions made abroad[4].

These patent indicators provide an incomplete insight into internationalisation of R&D as they ignore the ownership of patented inventions. Considered as 'domestic' the assignees which are based in the reporting country, they ignore the influence of subsidiaries controlled by foreign MNE's. Especially in view of the pervasiveness of MNEs in the technological landscape, correctly taking into account foreign ownership may lead to a more pervasive pattern of R&D internationalisation than has been documented in the previous section. The EU-3rd S&T indicator report (2003) identifies foreign ownership of patents including foreign owned subsidiaries.

In relative terms, when one looks at the percentage of European patents invented in a country by affiliates of foreign multinationals, Belgium and Spain stand out with the highest presence of technological activity by foreign companies (EC (2003). Especially in these countries, taking into account foreign ownership of patents rather than foreign applicants, considerably increases the

[4] Guellec and van Pottelsberghe (2001, 2004) further analyse econometrically the country differences in foreign ownership of domestic patents. The authors show that the countries that are larger and the countries that are more intensive in R&D are less "internationalized" at least in relative terms. Two countries are more likely to be linked by cross-ownership if they are geographically close to each other, if they have a similar technological specialization and if they share a common language.

internationalisation dimension, as compared to the previous section. Four out of five European patents invented in Belgium are controlled by foreign-owned firms. (Cincera et al (2005)).

Criscuolo and Patel (2003) analyse the patenting activities of the largest American, Japanese, and European MNEs between 1996-2000, repeating the analysis of Patel and Pavitt (1992) for 1969-86. Also these studies use a consolidated firm approach to assign foreign ownership. Although European companies show on average a higher tendency to relocate their R&D activities abroad with respect to their Japanese and American counterparts, the degree to which European companies have internationalised their activities varies considerable across countries. MNEs from small countries, such as Belgium, the Netherlands, Sweden and Switzerland, are the most internationalised in their R&D operations, while MNEs from large European countries (the exception being the UK) are less so. There has been a modest increase in the last 15 years in internationalisation of technological activities. Most of the growth has occurred for MNEs from small European countries. Despite the growing internationalisation of R&D activities, especially by EU MNEs, the results obtained in this study suggest that home-based technological activities of large firms from large countries continue to have a big influence on the activities of their home countries.

Summary of main findings

- The trend towards more internationalisation of R&D is gradually increasing.
- R&D internationalisation is still mainly an intra-Triad phenomenon with the EU but even more the US, as major locations for foreign R&D while US and especially EU firms have the largest shares of foreign R&D.
- MNEs, especially from small European countries, have increased their foreign R&D activities in the last decade.
- More recently the trend toward internationalisation has increasingly become more truly global. The emerging markets are currently attracting also an increasing share of overseas R&D outlays by MNEs.
- The high-tech sectors and especially the pharmaceutical industry tops in terms of having the most internationalized R&D.

1.2. Changing innovative strategies of transnational companies

While traditionally most R&D abroad was associated with market-related motives (integration with foreign production, responsiveness to local demand and regulations), the increase in foreign R&D activities that emerged from the early 90s, could not solely be explained by demand related motives. The new evidence gathered during this period showed that MNEs were establishing foreign R&D facilities, driven increasingly more by supply related motives; in an attempt to tap into knowledge and technology sources in centres of scientific excellence located worldwide. Location decisions for this type of R&D facility are based not only on the technological infrastructure of the host country, but also on the presence of other firms and institutions, which may create externalities that investing firms could absorb. Such externalities may result from spillovers of information from other R&D units, access to trained personnel, established links with universities or government institutions, and the existence of an appropriate infrastructure for specific kinds of research [5]. This section presents the evidence documenting the changing drivers for internationalisation of R&D for multinational firms.

1.2.1. Analysis of destination patterns in foreign R&D expenditures and patents;

[5] One could argue that to access local sources and to transfer know-how, firms need not necessarily be present through affiliates in the local market. International collaboration or presence in local markets through exports, can be an alternative to access globally dispersed know-how (*cf* supra). Nevertheless, if networks are mainly informal and tacit, then embeddedness is important, spillovers will be localized and being present close to the source will be important for accessing know-how. Jaffe, Trajtenberg and Henderson (1993) using patent data show that proximity matters and that being close to an external information source increases the impact of spillovers from that source on own know-how.

A number of studies have analysed the R&D expenditures or patents by foreign affiliates of Japanese MNEs to look for which countries are most likely to attract foreign R&D expenditures. (Kumar (2001), Odagiri and Yasuda (1996) and Belderbos (2001, 2003)). Country characteristics most favourable for location of R&D resources by MNEs are larger local markets and markets with high per capita income, reflecting the demand related motives. But also the abundance of R&D manpower and the technological specialisation of the host country in the industry explain the location choice of R&D, reflecting the technology sourcing motive.

1.2.2. Patent Citation Analysis

More recently the empirical literature has turned to using patent citation information to trace *technology transfers from local sources to foreign subsidiaries*. A higher than expected level of citations in patents by foreign subsidiaries to sources in the host market are suggestive of technology sourcing motives for foreign R&D.

Almeida (1996) analyses the citations contained in a sample of major patents granted by the USPTO to foreign MNEs in the US semiconductor industry and finds that foreign subsidiaries build upon localised sources of knowledge. The patents cited by foreign affiliates are more likely to have originated in the U.S. or in the same U.S. State where they operate. Similarly Branstetter (2000) analyses USPTO patent and citation data on Japanese FDI into the US. He finds that the likelihood of patent citations by the investing Japanese firms to local US sources is higher than expected, suggestive of a technology sourcing motive for Japanese FDI into the US. Frost (1998, 2001) builds upon and extends the work by Almeida and Branstetter investigating both the geographic sources of foreign subsidiaries' innovation activities across a much broader sample of MNEs operating in the US and the determinants of local technology sourcing. Results show that both the characteristics of the subsidiary, such as the amount and type of innovation activity carried out, and the technological specialization of the home and host country are important in determining the geographic sources of innovation. Less innovative affiliates are more likely to build on the knowledge base of the parent company, while more innovative subsidiaries, being more embedded in the local context, tend to draw upon local sources of knowledge.

1.2.3. Survey evidence on location factors and motives for R&D internationalisation

Recent surveys find substantial support for the increasing importance of 'supply-side' factors, with access to human capital and technological expertise becoming a major force. Florida (1997) surveys a sample of 207 R&D facilities in the US in four technology sectors (electronics, automotive, chemicals and materials, and biotechnology) with regard to the relative importance of their technology-oriented activities and market oriented-activities. The findings of this study suggest that both types of activities play an important role in the overall activities of the sampled laboratories. However technology-oriented activities are relatively more significant, especially in R&D units operating in the biotechnology and pharmaceutical sectors, while R&D sites in the chemical and automotive sectors seem to concentrate on tasks related to the support of manufacturing activities and the adaptation of products to local market conditions. The results for electronics are more mixed: both supply and demand considerations are considered important. The innovating performance of the laboratories in the sample confirms that these sites are not mere 'listening posts' but are dedicated to the creation of new scientific and technological knowledge. The survey indicates also that one of most implemented strategies for gaining access to localised knowledge is the recruitment of high-quality scientists.

Kuemmerle (1999) analyses the activities of 238 foreign R&D facilities from 32 American, Japanese and European pharmaceuticals and electronics companies in different host countries over time and investigates the motives, location characteristics, and mode of entry for R&D facilities abroad. He finds that technology sourcing has increasingly become a motivation for setting-up foreign R&D laboratories. When the purpose of R&D is to try and gain access to localised knowledge, firms will establish centers in proximity to universities or national laboratories. When instead they are supporting manufacturing and marketing activities R&D sites they will be located near a lead market or in a cluster of competitors.

A more recent survey by Thursby & Thursby (2006) on 229 US and EU multinationals across different sectors, identified as factors important in maintaining R&D activity in the country of origin: quality of R&D personnel as first, foloowed closely by IP protection and presence and proximity of universities. When developing or relocating R&D to other developed countries, the same factors showed up, complemented by potential for growth and support that R&D can give to sales to foreign customers, confirming the close link between demand and supply drivers. As regards the location of R&D activities in developing or emerging countries, the factor judged to be the most important is potential for growth, followed by the quality of research personnel. The most significant difference involves the assessment of IP projection: despite the recognition of the importance of IP protection in emerging markets, this does not seem to be a sufficient reason not to set up there.

All these studies confirm that both demand and supply related motives are important, but that technology sourcing motives are on the rise. In summary, the literature suggests a shift towards subsidiaries that are R&D active, not just in incremental, adaptive innovations, based on development activities, but also in searching and generating basic generic know-how.

II. Impact of the R&D internationalisation process on host and home economies

Despite core technology development remaining largely rooted in the parent operations of MNEs, there is ever more evidence, provided in the previous sections, that foreign subsidiaries increasingly tap into the knowledge generated in centers of excellence around the world. This new phenomenon has caused concern among policy makers of both net recipient and net source countries.

This section examines in more detail the impact of international R&D by MNEs on the national and regional STI-systems and ultimate economic growth of both host countries and home countries. Although the central focus of this section is on the impact of R&D-FDI through technology diffusion, in practice, this impact is difficult to disentangle from the effects of FDI in general on the host and home economies, that can go beyond technology diffusion.

2.1. The impact of international R&D on the host economy

Foreign subsidiaries, through their share in employment, investment, trade balances and growth contribute *directly* to the host economy. But there is also the *indirect effect* of FDI affecting the host economy, through the impact from FDI, particularly R&D-FDI, on domestic firms. Caves (1974) in one of the early contributions, distinguishes between three benefits of the presence of multinational firms for the firms located in the host country. First, the increase in market competition due to the entry of a foreign subsidiary increases allocative efficiency and decreases the excess profits realized by the domestic firms. Second, domestic firms in monopolistic markets will increase their level of technical efficiency or X-efficiency. This benefit flows from either the competitive effect of the multinational entry or through a demonstration effect. Finally, the entry of the subsidiary of a multinational can speed up the transfer and diffusion of technology in the local market and hence increase the rate of innovation in the host country. While the focus of the discussion here will be on the technology diffusion effect from R&D-FDI, the first two effects have to be born in mind as interacting forces determining the overall impact.

Transfers of technology occur through interactions with local suppliers and customers. These are the backward and forward linkages. However, internationally transferred know-how may also spill over to local firms, including competitors, through many informal channels such as imitation and reverse engineering, movement of personnel, conferences and meetings, patent applications among others. Especially the movement of personnel has been identified as an important source of technological spillovers (Veugelers and Cassiman (2004)). When workers previously employed and trained by MNEs move to a local firm or set up their own business, the knowledge embodied in these workers are transferred from the foreign subsidiaries to the local economy.

2.1.1. Conditions for international spillovers to the host economy

While the affiliate might have access to the base of know-how present at corporate level, this does not automatically imply that this know-how will be transferred to the local market. Technology spillovers from the MNE to the local economy will not always materialize, depending on (i) whether the MNE is able and willing to *prevent know-how leakage to the external local environment?* and (ii) whether the host country firms are able to absorb know-how flows from R&D-FDI and transfer them into firm growth. This depends on the *host country's absorptive capacity and the technology gap between the host country and the MNE*.

Spillovers are partly exogeneous to the firm, reflecting the effectiveness of the IPR regime in appropriating the returns to innovation. A host country's IPR is an important policy variable in determining not only the amount of R&D-FDI undertaken, but also the technology content of the activities undertaken by the MNE (eg Mansfield et al (1982)). But spillovers are also partly influenced by firms. MNEs may engage in strategies to prevent know-how from leaking out. While MNEs may have an incentive to improve the productivity of their local suppliers or customers in case of vertical spillovers, MNEs will try to *minimize* (the effects of) *technology leakage* to local competitors in case of horizontal spillovers. For instance, beyond building in secrecy, complexity or lead time, they can minimize the mobility of personnel through paying higher wages, select an entry mode or activity profile abroad that minimizes (the consequences of) spillovers.

Rather than inhibit informal flows of know-how, firms are nevertheless often found to actively nurture these flows, as the growing emphasis on the importance of networking suggests. The motivation for the sender lies in the reciprocal access to know-how (von Hippel (1988)). Firms transfer know-how to be able to acquire technology in return in a quid-pro-quo type of arrangement. This is particularly more likely to hold when MNEs are locating R&D abroad for technology sourcing motives. Alliances can be a particularly effective mechanism for technology sourcing MNEs to link to external technology sources. Technological alliances allow firms to actively and voluntarily manage transfers of know-how between partners. Therefore, cooperative agreements between local firms and subsidiaries can include an important technology transfer component, at least if the technologies available in exchange are valuable to the partners. This implies an attractive host economy, with a strong technological know-how base.

The trend toward technology sourcing motives for internationalizing R&D would predict more potential danger to the host economy from loss over domestic innovative capacity. But at the same time, it also creates more scope for potential benefits since more technology transfers to the host locations are likely to occur, first because the host locations being selected by a MNE in a technology sourcing strategy, will have a stronger technology capability and thus are more likely to have the capacity to absorb international technology. In addition, they are interesting clusters for exchange of know-how in quid-pro-quo networking arrangements. [6] However, if strong competitors are located in these local clusters, MNEs will be more concerned to protect their core know-how to safeguard their competitive position.

[6] Note that in the preceding section we did not observe a significant increase in international R&D collaboration, but the networking indicated here remain local, between subsidiaries and local firms;

2.1.2. Empirical evidence on the impact of international R&D on the host economy: which recipient countries are benefiting?

We first discuss the firm level studies that examine directly whether FDI is associated with technology transfers to the local economy. Next we discuss the studies that examine the impact on the local productivity from the presence of MNEs in the host economy. These studies assess technology transfers through FDI indirectly, by inferring them from their effect on local productivity.

(i) Do transfers of technology from subsidiaries to local firms occur?

When assessing technology transfers through FDI directly, scholars have used (i) *patent citations to foreign subsidiaries by local firms* as well as (ii) survey results on technology transfers.

Almeida (1996), using *USPTO patent citations by local US firms to foreign subsidiaries located in the US* in the semiconductor industry, finds that patents belonging to foreign firms located in the US are cited by local US firms more than expected, supporting positive technology transfers through FDI. Branstetter (2000) also uses *patent citations to Japanese foreign subsidiaries by local US firms*. From analyzing US Patent Office data on the impact of changes in Japanese firm-level FDI on USPTO patent citation counts, he finds that Japanese FDI in the US is a significant channel of knowledge spillovers, *i.e*. increasing the likelihood of patent citations by the indigenous US firms to the investing Japanese firm. Almeida and Branstetter demonstrated at the same time the importance of the reverse stream of spillovers from the local economy to the technology sourcing foreign subsidiaries, as reported supra. In a recent study based on USPTO patents granted to 4400 MNEs from six countries (US, Japan, Germany, France, UK and Canada) between 1986-1995, Singh (2004) finds that foreign subsidiaries cite host-country patents more often than they are cited by host country inventors, suggesting that foreign subsidiaries gain more in terms of local knowledge than they contribute.

Patent citations are only a partial measure for technology transfers if only because not all innovations are patented. *Survey level evidence* provides more direct, be it subjective, evidence of technology transfers arising through affiliates of foreign firms. Using Belgian company survey data from the EUROSTAT Community Innovation Survey, Veugelers and Cassiman (2004) examine econometrically the likelihood of technology transfers, whether foreign subsidiaries acquire technology internationally and whether they transfer technology to the host economy. A few important results emerge. First, foreign affiliates are more likely to source technology internationally, typically from their parent company. Second, firms sourcing technology internationally are more active in transferring technological know-how to local firms. Third, having controlled for their size and acquisition of technology internationally, foreign subsidiaries have a significantly lower probability of transferring know-how locally, as compared to local firms. This negative direct effect can be related to a higher appropriation of know-how within multinational firms. They especially minimize spillovers by having a low personnel exit rate. Fourth, the significant positive indirect effect for foreign subsidiaries through their higher international technology sourcing is not strong enough to compensate for the negative direct effect. This leaves a total effect for the Belgian sample, which is negative, although not significant. This suggests that MNEs are not obvious channels of transfer of technology to the local economy. It would be interesting to examine other CIS-samples to see whether these negative effects are specific to the Belgian sample, or can be generalized to other EU countries. Finally, cooperative R&D agreements between foreign subsidiaries and local firms are an important channel for the host country to benefit from technology transfers, confirming the typical two-way flows of know-how between foreign subsidiaries and the local economy.

(ii) The effect of MNEs on local firms' productivity

Most industry level studies focus on the issue of whether the presence of MNEs affects domestic firms' productivity. These studies, generally involve regressing the domestic firms' productivity on a variable capturing the MNEs presence in the same sector, *e.g*. the share of employment in foreign-owned firms or the share of output produced by foreign subsidiaries, and a number of other variables controlling for host markets characteristics such as the level of host market competition, technology gap, absorptive capacity. These studies test for the impact on domestic firms' productivity in the same sector and hence for the presence of horizontal spillovers.

Earlier studies based on industry level cross-sectional data find a statistically significant horizontal spillovers effect both in host developed countries (Caves 1974, in Australia and Canada, Globerman 1979, in Canada) and developing countries (Blömstrom and Persson 1983, Blömstrom 1986, Kokko 1994 in Mexico). But cross-sectional studies typically overestimate the spillover effects of MNEs because they are not able to control for firm or sector specific fixed effects. In a recent survey of studies using panel data sets, Görg and Greenaway (2003) find that only six studies for industrialized countries and none for developing countries report positive within-industry spillover effects. However, Keller and Yeaple (2003), estimating international technology spillovers via FDI to US manufacturing firms' productivity growth between 87 and 96, finds a significant productivity gain for US firms. They also discuss why their results are likely to generalize to other countries and periods[7].

One explanation for the difficulty to find evidence of positive spillovers is that spillovers from FDI are more likely to be vertical rather than horizontal in nature, since the latter have to account for the negative competitive effects[8] (Markusen and Venables (1999). But even if competition effects would be mute, as in vertical spillovers, the potential benefits from FDI may not materialize, since a critical factor to exploit spillovers is the technological capability of indigeneous firms (Blomström and Kokko (1998)). Also Cantwell (1989) stresses the need for a high level of local competence to be able to absorb spillovers from multinational presence. Most of the empirical studies on developing countries have failed to find robust evidence of positive knowledge spillovers from multinational investment, accounted for by the lack of absorptive capacity in these host countries (*e.g*. Aitken and Harrison (1999)). Haskel et al. (2002) find a significant positive correlation, using firm level data from the UK, but this correlation is smaller for lagging domestic plants, again underscoring even for developed countries the need for absorptive capacity. Girma (2003) on a UK sample for the period 89-99, finds an inverted U-shaped relationship between absorptive capacity and foreign presence.

Girma (2003) finds evidence suggesting that asset-exploiting FDI is more conducive to positive effects on local firm's productivity growth than asset-augmenting activities, an important finding in light of the trend towards more technology sourcing R&D-FDI documented above.

When multinational firms are technology leaders and affiliates are located in countries with an insufficiently developed intellectual property rights protection regime, maintaining control over core technologies is a key issue, discouraging firms from localizing R&D abroad or inciting MNEs to prevent know-how leakage to the local environment. A study by Branstetter et al (2003) provides evidence that R&D by US firms is very responsive to positive reforms in intellectual property rights protection regimes in host markets, but this applies primarily to technology leaders in the industry that are most active in patent applications. Zhao (2004) for instance, shows how foreign R&D labs in China mostly engage in R&D for technologies where the parent maintains control over key complementary technologies. Other studies have also found that multinational firms adapt the type of activities located abroad in response to intellectual property rights concerns, with knowledge intensive

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7 The main reason for the difference from previous work is the classification of foreign affiliates in the industries in which they operate in the US, rather than according to the main activity of the parent firm.

8 Veugelers and Vanden Houte (1990) provide evidence for Belgium that the presence of foreign MNEs reduce innovative investment for local firms when foreign and domestic products are more homogeneous and the competitive pressure outweighs any positive impact from technology spillovers.

and higher value added activities reserved for countries with stronger IPR regimes (Lee and Mansfield, 1996; Smarzynska, 2004).

In general, it is fair to conclude that the results on positive spillovers on host economies are not strong and robust, partly because of poor controls for absorptive capacity, the technological position of the host economy, the technological activities undertaken by the MNE, as well as the motives for locating R&D abroad, all of which are important conditions for the emergence of positive spillovers. In addition the recent studies that have examined the potential for vertical (inter-industry) spillovers find evidence suggesting that these types of externalities may be more important than intra-industry spillovers.

2.2. The impact of international R&D on the home economy

When MNEs use increasingly more their affiliates in technology sourcing strategies, the home countries of the multinational firms experience benefits and costs of international technology diffusion from their MNEs investing R&D abroad. The impact of outward R&D-FDI on the home country is an aspect of the R&D internationalisation process which has been treated less in the FDI literature (Criscuola (2005)) but continues to receive considerable policy attention. Countries that are net sources of foreign R&D investment are worried that the internationalisation of R&D may substitute for R&D undertaken at home. But at the same time, foreign R&D activities of MNEs may provide access to foreign technologies and they can therefore represent a channel for transferring knowledge back to the home country.

2.2.1. Conditions for international spillovers to the home economy

There are the *direct (private) effects* of outward R&D-FDI, that is, the effect that these R&D investment activities have on the home part of the multinational. But associated to these direct effects of outward FDI, there may be also important *indirect effects*, *i.e*. effects on other home country firms, such as suppliers or customers.

The expansion abroad of locally based MNEs may improve the productivity of the home-country suppliers to these MNEs through economies of scale deriving from horizontal outward FDI. To the extent that these activities are characterized by economies of scale, the increase in foreign sales stimulates a raise in R&D expenditure by the parent company providing in turn a source of potential spillover effects for other home country firms (Globerman 1994, Blömstrom and Kokko 1998).

But more specifically for R&D-FDI motivated by technology sourcing, positive externalities may derive from *inter-firm reverse technology transfer*, *i.e*. from R&D activities performed abroad aiming at tapping into foreign centres of excellence and creating new technological assets that build on localised sources of knowledge. The knowledge accumulated abroad AND transferred within the multinational organization from the subsidiary back to the parent, may leak outside the MNE's boundaries to other home country firms and institutions. Most of these spillover channels work better if the MNEs involved are locally embedded in their home market, and if home country firms have the necessary absorptive capacity.

There are also negative externality effects deriving from relocating production and R&D activities outside the home country. First, one consequence of outward FDI could be the reduction of knowledge intensive activities in the home country if MNEs decide to relocate advanced production stages from home to countries with a higher-skilled labour supply or with a better knowledge infrastructure. Second, a potential adverse effect from the relocation of R&D activities abroad may be the successful imitation of MNEs' technologies and of home country developed innovations by foreign competitors. As a result of these potential leakage effects arising from the presence of home country affiliates in foreign markets, MNEs may suffer a decrease in demand for their products, which in turn may result in a decrease in demand for products made by other home country firms. Furthermore the home country as a whole may lose control over a key technology and with it a strategic position in the international market. According to the Anchor Tenant hypothesis, R&D capacities above a certain size are powerful in generating externalities in the form of thickening markets for innovation that will benefit the whole system. Delocalisation therefore deprives the home country of these externalities (Foray (2006)).

2.2.2. Empirical evidence on the impact of international R&D on the home economy: which source countries are benefiting?

(i) Evidence on effects from R&D FDI on the parent MNE

Reddaway et al (1968) surveyed UK MNEs in the chemical and food, drink and tobacco sectors on whether they benefited from the knowledge produced in their foreign subsidiaries. In particular in the chemical sector these benefits derive from formal research activities carried out in foreign units, while in food, drink and tobacco companies the greatest contribution comes from informal know-how feedback. Across all sectors, subsidiaries located in the US appear to be the source of most of these knowledge flows and companies seem to value extremely highly the informal 'know-how' from these subsidiaries.

Mansfield *et al*. (1982) finds that foreign affiliates' sales and overseas investment contribute to generating higher returns from R&D. In particular they estimate that if firms were not allowed to use new technologies in foreign units, R&D expenditure would fall by between 12 percent and 15 percent. If foreign rent could not be earned at all, R&D spending would fall by an average of 16 to 26 percent.

Mansfield and Romeo (1984) carried out a survey of a random sample of 29 US MNEs in chemicals and pharmaceuticals, petroleum, machinery, electrical equipment, instruments, and glass and rubber industries in order to obtain data on the extent of technology transfer from R&D facilities located abroad (mainly in Europe and Canada). Mansfield and Romeo find that about 47 per cent of foreign R&D expenditure in 1979 resulted in technologies that were transferred back to the US parent company. The technology being transferred is in most cases embodied in new products and, based on a 'rough' estimate, the authors calculate that the overall contribution of this technological feedback during the 1970-1979 period amounted to 4 per cent of total profits of US manufacturing firms in 1980. In addition the results show that the lag between when the transferred technology was first applied overseas and when it was subsequently applied in the US is on average less than one year. This reflects the importance of the US market for these firms.

Combining patent and account data for the largest UK firms, Griffith, Harrison and van Reenen (2004) estimate the effects of domestic and foreign R&D spillovers on firm productivity. As channel to access the stock of industry R&D located in the US through foreign R&D, they use the location of the inventor in the patents of the UK firms. To further identify the technology sourcing motive from R&D labs located in the US, they single out the patents that cite other firms located in the US, as proxy for technology sourcing. In general, they find no evidence on international knowledge spillovers in general, but when taking into account whether the UK firms have US inventors on their patents, they do find a positive and significant effect of the stock of US sectoral R&D on the firms TFP growth, suggesting that having established R&D labs abroad is a channel for accessing US technology spillovers. When further refining their measure to check for the technology sourcing motive, the effects are even larger. Furthermore, since their results also hold even if the UK firms have no foreign production, the technology transfer is related to the R&D activities abroad and not (only) to production activities abroad. From these results, the authors conclude that the UK benefits from R&D labs established in the US, since they act as listening posts for new ideas which are transferred back to the UK and lead to productivity gains.

(ii) Empirical evidence on effects from R&D-FDI on other home country firms

Very few studies examine spillovers from R&D-FDI to other firms located in the home country of the MNE undertaking the investment. The use of patent citations to proxy for knowledge flows associated with outward FDI has been proposed by Globerman, Kokko and Sjöholm (2000) who analyse 220 patents applied for by Swedish MNEs and SMEs. They find, not only for the sample of MNE patents but also for SMEs, that higher outward FDI is associated with more patent citations to the partner countries. If these results confirm the hypothesis of intra-firm reverse technology transfers, they also support the existence of inter-firm transfers, *i.e*. 'that knowledge is systematically diffused from the headquarters of Swedish MNEs to smaller non-multinational firms'.

To conclude, firm level studies show mixed evidence on MNEs generating positive spillovers on the home economy. The type of activity carried out by foreign subsidiaries matters significantly for the incidence of spillovers. Positive findings on intra-firm reverse technology transfers are only found for R&D-FDI driven by technology motives.

III. POLICIES VIS-A-VIS INTERNATIONALISATION OF R&D

The new forms of internationalisation of R&D, based on global sourcing and integration of complex knowledge bases, present challenges to national approaches. When innovation networks span national boundaries, how should national innovation systems relate to the global division of labour in knowledge production?

3.1. Some principles for policies towards internationalisation of R&D

It is clear that policy should not attempt to restrict the internationalisation of R&D phenomenon. It is essential for firms to be able to access international markets, exploit efficiency advantages and access the best S&T assets worldwide in order to stay competitive. Rather, policymakers should aim at putting in place framework conditions that enable firms and countries to benefit fully from internationalisation.

If countries want to attract foreign R&D, it is essential to look at the economic fundamentals. Since R&D investments are still strongly associated with production and sales infrastructure, inward R&D investment is not independent of policies that influence the attractiveness for foreign direct investment in general. Fundamental factors like political stability, public infrastructure, market size and development, tax rates, labour market conditions are highly decisive for R&D location decisions. Policy should therefore in the first place provide and secure a "healthy business environment"

Stimulating the development of *excellence in own Science & Technology capacities* and providing *an innovation friendly environment* is key to any policy towards R&D internationalisation.

- Developing domestic clusters of S&T excellence are an important attractor for innovative companies, R&D institutes and R&D workers from abroad. A strong and vibrant academic and industrial research base, efficient protection of intellectual property rights and a well-trained workforce are major determinants for MNE investment in R&D, but will also promote the growth of domestic enterprises. Hence, these policy measures should be aimed simultaneously at domestic and foreign-owned domiciled enterprises.

- At the same time, in order to benefit from the internationalisation of R&D, economies should build up their absorptive capacity and networking with multinational firms. Among the factors to improve absorptive capacity, two stand out, viz. a high educational level of the local labor force and a well-developed technological capacity of domestic firms.

3.2. *Actual Policies used towards internationalisation of R&D*

Which policies do countries *use in practice* to maximise the benefits of the globalisation of R&D? Screening the relevant literature as well as policies adopted by OECD countries resulted in the identification of policy measures in three important fields of R&D internationalisation (i) policies to attracting R&D units from abroad, (ii) measures to link domestic firms to knowledge from abroad and (iii) policies towards the mobility of human resources.

3.2.1. Instruments to attract industrial R&D capabilities from abroad

While incentives to attract foreign direct investment (FDI) in general are quite common, special incentives for FDI in R&D play only a minor role. This is in line with theoretical and empirical findings that show that R&D investment by multinational enterprises (MNEs) is to a high degree driven by *fundamental economic factors* (market size, labour market conditions, *etc*.), the scientific and technological specialisation and capabilities of the country and the political environment (stability and endowment with an appropriate public infrastructure).

- An important determinant of a country's attractiveness is the *quality and specialisation of the domestic knowledge base*. Hence, all measures to improve the scientific and technological capabilities of an economy will also increase the country's attractiveness for R&D investment by MNEs. At the same time, an indigeneous strong science and technology base will improve the country's ability to efficiently absorb spillovers from FDI-R&D. In the EU R&D and innovation is boosted through a variety of policy instruments, which will enhance the national capacity of attraction (see EC and National Member States R&D and Innovation Action Plans). Direct support mechanisms have lost in importance, while indirect mechanisms (providing framework conditions) gained in importance.

    - In this context, the most import measures relate to human resource development, intellectual property protection, a first-class infrastructure, excellent universities and research organisations and linking partners in the business enterprise sector.

    - Both direct financial support and fiscal incentives are not extensively used by OECD countries as *specific* measures of attracting new R&D activities of foreign MNEs. Of course, this does not imply that the existence and generosity of these measures is of no importance in locational decisions of firms. But in many countries these measures face tight budgetary constraints.

- *Non-discrimination* of foreign firms vis-à-vis domestic enterprises and free access to national funding and public procurement for (domiciled) foreign-owned enterprises is the guiding principle concerning the treatment of foreign affiliates in most countries of the OECD. National technology programmes should work as platforms that facilitate a flexible integration of different kinds of operators. For this purpose, *interconnection* should be as easy and efficient as possible, regardless of its location. As for instance in Finland, where Tekes has opened its technology programmes in order to gather big enough clusters of competence attracting international interest.

3.2.2. Linking the domestic economy to foreign sources of research and innovation

The mere incidence of internationalisation only increases the *opportunities* for knowledge spillovers but appropriation of new knowledge by the host economy is not straightforward and requires a high level of absorptive capacity. Therefore, prior building of technological capabilities within a country's firms is crucial for their ability to interact and absorb knowledge made available by inward and outward R&D-FDI. Promoting international collaboration in science and technology and helping to link domestic enterprises to foreign sources of knowledge, located abroad or at home, is on the policy agenda in many countries. Policies directly aiming at new and deepening linkages between domestic R&D and foreign actors commonly involve various elements, including support for networking, the provision of information and matchmaking activities.

- Most countries are highly aware of the importance for international networking. An obvious approach to the internationalisation of R&D followed by all countries is to participate in existing international R&D networks or international promotion schemes (such as the Framework Programmes within Europe). Moreover, some countries provide additional funding for participating in international organizations and the Framework Programmes to domestic enterprises, especially SMEs, or enter into specific bilateral co-operation agreements to help domestic enterprises to access foreign knowledge.

- Another basic line of policy initiatives to help domestic firms link up with foreign sources of excellence involves assistance in identifying appropriate partners and projects. At a more general level, available instruments include all kinds of information services such as the organization of respective seminars and missions, holding *of* or participation *in* international fairs and exhibitions, the provision of electronic databases...

- Some governments follow a more proactive strategy of matchmaking and have founded own agencies that offer benchmarking services to foreign affiliates to identify and select suitable suppliers. Tekes, the government's R&D agency in Finland, eg has established such offices overseas (in Japan, China and the U.S.).

- An effective way to link foreign to domestic firms at home is to support the building of clusters, *i.e*. networks of companies, universities, educational and other institutions, mixing local and foreign actors. The government may (help to) set up internationally connected science parks and could offer incentives to both, foreign and domestic firms for engaging in co-operation with other firms or research institutes where particular emphasis is laid on technology transfers, training and learning effects of the local staff. Likewise governments may give incentives to universities and public research institutes to cooperate with both domestic and foreign firms.

3.2.3. Policies towards foreign talent

Policies towards attracting and retaining foreign highly-skilled labour are an important field for governments with respect to the internationalisation of R&D. Policy and legislation do not drive the mobility of highly skilled labour but can facilitate or hinder it. Specific policy instruments focus on grants, immigration legislation and tax issues. But the critical mass present in excellent research centres remains a vital condition to attract experienced researchers.

- Immigration legislation can be instrumental in the drive to attract, retain, and develop human resources. In recent years, the focus of immigration policy in most OECD countries has shifted from "immigration stop" to "smart immigration". Smart immigration entails a shift towards highly skilled persons and an increased use of temporary skilled immigrant workers.

- Significant differences in compensation and reward can be major pull and push factors for mobility among highly skilled workers. Tax discounts are now provided by many countries to lure foreign skilled workers to local labour markets. For instance, in Denmark, foreign experts receive a *tax reduction* for their first three years of residence. In the Netherlands, foreign highly skilled workers (including EEA workers) benefit from a 30 per cent discount on income tax for a period of 10 years. In the UK, non-domiciled residents get tax refunds upon filing for relocation.

- Increasingly governments are competing for talent by enacting S&T legislation. This is most notable in science legislation related to ethics (life sciences), safety (food science), and intellectual property. The variations between the various national legislation governing emerging S&T areas with potential strong controversial application are increasingly being cited as drivers of attracting or losing important talent (eg stem cell research).

- In order to facilitate the inflow of foreign talent, especially that of engineers and medical personnel, and assure its quality, many countries increasingly adopt accreditation regimes for qualifications obtained from foreign educational and training systems.

- Cultural/structural barriers often result from the internal structures and local traditions that characterize the innovation systems of certain countries. For instance, UK universities are known for enjoying high degrees of autonomy in their hiring policies and tend to make larger use of temporary academic staff from abroad than their continental counterparts. This allows for greater temporary inflows and circulation of talent.

3.3. Overall assessment of policies towards internationalisation of R&D: the need for an integrated policy approach

Although many of the instruments needed are already in place in most countries, they need to be mobilized better to fit into a coherent, systemic policy approach to face the challenges of internationalisation of R&D. The analysis suggests the need for an integrated policy approach towards internationalisation of R&D. Policy instruments should not be considered in isolation. Rather, they should be part of a coherent and consistent policy approach. A balanced policy mix will benefit from cross-policy synergies among the different policy levers. An integrated policy approach requires *horizontal coordination* across the different policy areas (education, RTD and innovation) but also linking to other policy areas like macro, trade, competition, taxation, employment…

Only few countries have so far developed an integrated policy strategy to address issues enhancing the inward R&D activities for foreign companies. Ireland provides an example for such an integrated approach (see Box 1). Nevertheless, this does not mean that other countries were less successful in devising specific measures. The USA and the UK are countries that are attractive for inward FDI in R&D. In these countries the overarching, strategic orientation of policy is to support world-class excellence in science based on the perception that generates sufficient attractiveness for FDI by MNEs. Also the emergence of China on the global S&T scene is backed by elements of an integrated policy strategy (see Box 2).

Box1: Ireland

In contrast to other European countries, Ireland's rapid economic development has been strongly based on industrial policy and substantial investments in innovation measures. Although business expenditure on R&D remains low, 80% are accounted for by foreign-owned MNEs. Therefore, Ireland is commonly regarded as a success story in terms of inward investment policy that due to its proactive stance, headed by the Industrial Development Authority (IDA), gained international reputation, mainly for its emphasising policy independence, continuity and consistency (Tekes 2004).

In order to attract new investments, from the end of the 1990s on, Ireland has used a very bold and expensive set of instruments, upgrading the physical infrastructure of the universities and making massive investments in strategic research in biotechnology and ICT. The Science Foundation Ireland (SFI), an agency of the industry ministry, offers very large grants to foreign-based researchers willing to move to Ireland and establish research groups, followed by smaller grants, open to nationals as well as those abroad. Other incentives include inward mobility schemes for individual researchers and those with key skill, and reduced fees for non-EU post-graduate students. Furthermore, there is an innovation support programme aimed especially at strengthening the capabilities of Irish plants, and corporation taxes are still low.

Box 2: China

China's plan to become a major innovation economy by 2020 resulted in a launch a series of reforms and strategic projects to make research and innovation the motor of its new economic development strategy. The current build up of Chinese S&T capacity is supported by a targeted *S&T policy*, increasing and focusing public R&D funding to a limited number of excellence centers and specific areas where the contribution of the public R&D to private R&D and growth can be most assured. R&D spending by all sources is targeted to rise to 2.5% of GDP by 2020. By 2010 it should have reached 2% of GDP, 40% of which is coming from central government R&D. Increased funding for basic research and education at universities and research institutes is accompanied by a program of reforms to increase the efficiency of its spending. A persistent legacy of the pre-reform S&T systems in China is that links between the R&D institutions and universities, on the one hand, and business and industry, on the other, remain underdeveloped. China has adopted new strategies to promote stronger industry-science relationships. A major challenge remains the weak level of investments in private R&D and innovation. China uses a range of measures to support R&D and innovation ranging from matching funds, tax incentives and procurement policy as well as measures to improve intellectual property protection. Although Chinese leadership is increasingly emphasizing the importance of developing indigeneous innovative capacity, China equally recognizes the importance of opening up internationally to reach its ambituous goals. The opening-up of the Chinese economy was accompanied by a series of measures and policies which contributes highly to the internationalisation of China's S&T base. First, policies allowed for a growing share of business R&D financed by abroad (mostly Hong Kong, Macao and Taiwan). This accompanied a growing establishment of R&D-facilities of multinational companies. Most of these labs were active in ICT. Second, policies were designed to foster mobility of human resources in science and technology. The number of Chinese students abroad reached 24,000 persons in 1999 and boomed to 84,000 in 2001. The number of students returning to China grew by 13.4 % during the same period.

3.4. The EU Dimension

An integrated policy approach also requires *vertical coordination* between policy levels (EU/Member States (national and regional)). Most of the instruments are in the hands of the Member States. A decentralized policy approach implies more possibilities of adaptation to local specific needs in order to better align the various complementary local actors. Nevertheless, decentralized RTD policy can be more effective if part of an internationally coordinated policy design. The challenge of the EU members is to devise a policy that does not weigh upon their neighbours (eg avoiding competition in providing incentives to lure foreign investors), but internalizes positive spillovers from national/regional policies (see also Foray (2006)).

The EU therefore has a role in *coordinating* and facilitating Member State policy, in S&T policy in general but also more specifically for internationalisation of R&D, particularly in areas like taxation, subsidies, immigration legislation, S&T legislation, accreditation. But apart from this indirect coordinating role, the EU also has *directly* a number of instruments at its disposal to improve the attractiveness of the EU for locating R&D investments.

Since closeness-to-markets remains an important location factor for R&D investments, providing firms access to a large and dynamic market is important. For this the *Single Market* and *Competition Policy* are pivotal instruments. To support environments conducive to innovation, EU funding through R&D *Framework programs* or *regional/structural funds*, can be mobilized. But also national funding can be influenced through *state aid and internal market regulation control*, guarding non-discrimination in funding and procurement. Finally, the EU can help to ensure that the opportunities from openness are not jeoparidised by practices distorting international trade. Multilaterial/bilateral *trade negotiations* should defend open markets and an improved enforcement of intellectual property rights protection, norms and standards.

> "In sum, there is an urgent need to mobilize all existing elements of the future European research and technology area (FP, TP)… as mutually and reciprocally interdependent forces, so that they may exhibit

cross-catalytic reinforcement toward consistent policy objectives, such as creating more critical mass and competition in the European Research Area… " (Foray (2006), p 5)

Summary

Increasing cross-border flows of R&D are a major trend and feature of the world economy. Gross flows are rising, and in many economies significant shares of domestic R&D are performed by affiliates of foreign firms. Likewise, firms are performing increasing amounts of R&D outside their home base. An important emerging dimension of these trends is a change in extra Triad relations. R&D and innovation activity are moving to a number of rapidly developing economies where R&D, and particularly FDI-related R&D, is growing rapidly. The transition is not just in the changing scale of the internationalisation of R&D and its destinations, but also in its drivers. In the past, firms undertaking FDI tended to keep their major technology-creation activities in or close to their home bases. Firms appear to be relocating R&D to benefit from knowledge capabilities that are distributed across countries, either in partner companies or in public sector knowledge infrastructures.

This development raises complex policy issues. Few countries have fully recognised the implications of the current internationalisation of R&D. In part this is because the full implications are not yet clear, and this is certainly an area in which further research and analysis is required. The increasing mobility of R&D is accompanied by the increasing mobility of highly skilled scientists and engineers. This has implications not only for education policies, but also for a wide range of policy arenas – tax policies, regulatory frameworks and standards setting, among others. Although many of the instruments needed are already in place in most national and supra national policy levels, they need to be mobilized better to fit into a coherent, systemic policy approach to face the challenges of internationalisation of R&D. Only few countries have so far developed an integrated policy strategy.

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The IBM Case

The IBM group employs 3 000 people in its eight laboratories throughout the world. Over half of them now work in the oldest laboratory, which was opened in New York in 1961. A variety of disciplines have been developed there with regard to semi-conductors but also mathematics, computer sciences and physics. Ten years later, another laboratory was created in Israel in 1972, reserved for fundamental research in applied mathematics, computer sciences and engineering. The laboratory set up in Zurich, Switzerland became known thanks to Nobel prizes in two fields: superconductivity and scanning tunnelling microscopy. The laboratory opened in Beijing employs more than 70 persons and was set up to create technologies and systems for emerging e-business markets, including e-business mobiles, and also to create technologies to enhance the value of ITs in China. The most recent laboratory was created in Delhi, India in the spring of 1998. Its purpose is to explore weather forecasting, electronic commerce and distance education.

The R&D structure of the IBM group is fairly centralised. IBM's R&D projects are managed and financed very substantially by the parent company in the United States. In addition, with regard to the ownership and management of intellectual property for IBM affiliates, IBM itself owns the patent portfolio of all its affiliates and administers it centrally.

IBM: R&D network at the world level, 2006

	Country and region of location	Year of inauguration	R&D staff
1.	United States – New York	1961	1 700
2.	United States – Almaden Lab. (California)	1986	480
3.	United States – Austin Lab. (Texas)	1995	40
4.	Switzerland (Zurich)	-	180
5.	Japan (Tokyo)	1982	170
6.	Israel (Haifa)	1972	280
7.	China (Beijing)	1995	70
8.	India (Dehli)	1997	-

Adapted from OECD (2006)