DISCUSSION PAPER SERIES

No. 4945

ASSESSING THE FOREIGN CONTROL OF PRODUCTION OF TECHNOLOGY: THE CASE OF A SMALL OPEN ECONOMY

Michele Cincera, Bruno van Pottelsberghe
and Reinhilde Veugelers

INDUSTRIAL ORGANIZATION

Centre for Economic Policy Research

www.cepr.org

Available online at: **www.cepr.org/pubs/dps/DP4945.asp**

ISSN 0265-8003

ASSESSING THE FOREIGN CONTROL OF PRODUCTION OF TECHNOLOGY: THE CASE OF A SMALL OPEN ECONOMY

Michele Cincera, DULBEA and Université Libre de Bruxelles and CEPR
Bruno van Pottelsberghe, Université Libre de Bruxelles and CEPR
Reinhilde Veugelers, European Commission, Katholieke Universiteit Leuven and CEPR

Discussion Paper No. 4945
March 2005

Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

CEPR Discussion Paper No. 4945

March 2005

ABSTRACT

Assessing the Foreign Control of Production of Technology: The Case of a Small Open Economy*

International R&D activities have grown significantly over the last two decades. Both the number of actors involved, as well as the importance of the technological activity carried out abroad, has considerably increased. We aim to quantify the international generation of knowledge for the case of Belgium, using indicators based on EPO and USPTO patent data (1978-2001). We distinguish among Belgian applicants, affiliates of foreign firms located in Belgium as well as Belgian based firms with affiliates abroad. This approach allows improvement of existing indicators of internationalization of technology based on patent data. The results are consistent with what can be expected for a small open economy such as Belgium. A large part of patents with Belgian inventors are assigned to Belgian affiliates of foreign firms. Hence our more complete indicator of foreign ownership gives a substantially higher foreign control of Belgian inventors. Relatively more knowledge generated by Belgian inventors flows out of the country towards foreign owners of technology, than knowledge generated abroad is owned by Belgian patent applicants. But the share of foreign inventors to Belgian assigned patents is increasing considerably over time, especially in the subcategory of Belgian firms with foreign affiliates.

JEL Classification: F23, O30, O33 and O57
Keywords: Belgian economy, internationalization of R&D and patent statistics

Michele Cincera
ULB-DULBEA-CERT
Université Libre de Bruxelles
50 Avenue F D Roosevelt
1050 Bruxelles
BELGIUM
Tel: (32 2) 650 4151
Fax: (32 2) 650 3825
Email: mcincera@ulb.ac.be

Bruno van Pottelsberghe
Université Libre de Bruxelles
50 Avenue F D Roosevelt
1050 Bruxelles
BELGIUM
Tel: (32 2) 650 4899
Email: bruno.vanpottelsberghe@ulb.ac.be

Reinhilde Veugelers
Department of Applied Economics
Katholieke Universiteit Leuven
Naamsestraat 69
B-3000 Leuven
BELGIUM
Tel: 326 908
Fax: 326 732
Email: reinhilde.veugelers@econ.kuleuven.ac.be

*The authors are grateful to the Federal Science Policy for supporting this research. Veugelers acknowledge support from the European Commission Key Action ‘Improving the socio-economic knowledge base’ through contract No. HPSE-CT-2002-00146, and the Flemish Government (SOOS and FWO-WOG), KUL (OT/2005/X) and DWTC (IUAP P5/11/33). The usual disclaimers apply. This Paper is produced as part of a CEPR-managed Research Training Network on 'Competition Policy in International Markets', funded by the European Commission under its Fifth Framework Programme through the Improving Human Potential activity (EC Contract no. HPRN-CT-2002-00224).

Submitted 20 February 2005

1. Introduction

The trend towards R&D internationalisation is nowadays recognised as the most important feature of the world's technological landscape. International R&D activities have grown significantly over the past 15 years. Both the number of firms involved, as well as the importance of the technological activity carried out abroad, has considerably increased (Bartlett and Ghoshal, 1989; Dunning, 1994; Cantwell, 1995).

Taking into account the importance of this R&D internationalisation, keeping up with its evolution and trends is of crucial interest for policy makers. This paper aims to quantify R&D internationalisation for the case of Belgium. We develop an indicator of the internationalisation of technology based on patent data (with EPO and USPTO patent data from 1978 to 2001). Beyond the typically considered patents with Belgian inventors and foreign assignees, our approach is based on the identification of the Belgian subsidiaries of foreign multi-national enterprises (MNEs), and considering them as also being part of the 'foreign' ownership of inventions made by Belgian inventors. Our indicator thus reflects a more complete picture of the internationalisation of technology. Likewise, Belgian firms owning foreign affiliates abroad are identified, allowing us to analyse whether these firms own patents whose inventors are located abroad.

The paper is structured as follows. The next section presents a summary of the existing literature attempting to measure the degree of internationalisation of technology. Section 3 presents the patent information used for the empirical analysis as well as basic statistics. Section 4 presents our indicator for internationalisation of the production of technology. The results on the extent to which patented inventions made by inventors with Belgium as country of residence are controlled by foreign firms are presented in Section 5, while Section 6 analyses the extent to which firms based in Belgium control inventions that originate from foreign countries. The concluding remarks are presented in Section 7.

2. Literature review

2.1. Changing international R&D strategies by MNEs

Globalisation has been one of the most hotly-debated topics in economics. It involves the growing integration and interaction of economies and societies around the world, through the growth in international trade, investment and capital flows. During earlier periods of the 20th century globalisation trend (1960's and 1970's), companies built up their sales, distribution and assembly operations in foreign countries. As such, the production of manufactured products has been a global affair for years.

In the 1980's, the internationalisation of R&D activities has become an important component of the globalisation trend, following the internationalisation of production. Even though R&D activities are still less internationalised than those relating to production, they have nonetheless grown relatively significantly over the past 15 years. This trend is witnessed by a large number of firms involved, and by the growing importance of the technological activity that is carried out abroad (Bartlett and Ghoshal, 1989; Dunning, 1994; Cantwell, 1995).

Statistical evidence and survey results on R&D internationalisation indeed confirms that although most research still remains at corporate headquarters, the percentage of R&D carried out abroad is increasing rapidly (Granstrand et al., 1993; Caves, 1996; Serapio and Dalton, 1999; Meyer-Krahmer and Reger, 1999). The pharmaceutical industry is typically top in terms of having the most internationalised R&D. The rapid growth of non-home R&D is realised through acquisitions of local firms, but also the research intensity of foreign based production increases (Patel, 1995; Dunning, 1988). Furthermore, the motives for locating

R&D abroad have shifted. As multiple national innovation systems and knowledge centres are being built around the world, the incentives for multinational companies to start sourcing technological know-how globally get stronger. As opposed to exploitation and adaptation of centrally-developed, home country based technologies "home-base exploiting" (HBE) (Kuemmerle, 1996), foreign-based R&D labs have become more involved in exploration and advanced development. Competence centres are established at different geographical locations and intense market and technology interaction takes place. These decentralized R&D activities have been defined as "home-base augmenting" (HBA) (Kuemmerle, 1996) or "asset-seeking" R&D activity (Dunning and Narula, 1995). The shifting motives for establishing R&D units abroad and the main factors in selecting locations have been examined in various empirical surveys. Although 44% of the 296 sample subsidiaries in Pearce and Singh (1992) report that they predominantly function as internationally interdependent labs, on average 60% regularly worked to adapt to local markets, 70% developed new products for local markets, while 45% developed new products also used in other markets. The authors conclude that, while on average adapting is still an important task, development of products also used in other markets is gradually becoming more widespread. Florida (1997), on a sample of 187 foreign R&D labs in the US, finds that although both technology and market driven motives are important, access to human capital and technological expertise is becoming a major force. Florida's results have been confirmed by a more recent survey by Kuemmerle (1999). Reger (2001), on an international sample, finds no single dominant motive since both product adaptation and learning from lead markets go hand in hand with access to skilled researchers.

More recently the empirical literature on technology transfers has turned to using patent citation information to trace *technology transfers from local sources to foreign subsidiaries* in search of a technology sourcing motivation[2]. A higher than expected level of citations by foreign subsidiaries to sources in the host market are suggestive of a technology sourcing motive for locating R&D abroad. Almeida (1996), Branstetter (2000), and Frost (2001) analyse the citations contained in a sample of major patents granted by the USPTO to foreign MNEs in the US and finds that 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, suggestive of technology sourcing. Griffith, Harrison and Van Reenen (2004) estimate the effects of domestic and foreign R&D spillovers on UK 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. 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.

2.2. Measuring a country's internationalisation of the production of technology

With the evidence suggesting a more active role for subsidiaries in the global technology sourcing strategies of multinational firms, countries are witnessing important shifts in the geographic location of the "ownership" of inventions made by their firms and/or on their

[2] The use of patent citation information for measuring knowledge spillovers has been pioneered by Jaffe, Trajtenberg and Henderson (1993). They use patent citation data to 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.

territory. An increasing share of technology is owned by firms from a different country than the one of the inventors (which mainly reflects that companies have research facilities abroad).

The internationalisation of the generation of knowledge for countries has been analysed and measured through two different and complementary approaches: firm-level analyses and macro-level analyses based on patent data. The first one focuses on the internationalisation of research and development units of large firms. Major contributions to the measurement of the internationalisation of R&D activities have been performed by Cantwell and Harding (1998) for German companies, Cantwell and Iammarino (1998) for Italian companies and several authors for multinational companies from various countries (Cantwell and Janne, 1999; Patel and Pavitt, 1991; Patel and Vega, 1999; Zander, 1999; and Gassman and von Zedtwitz, 1999 and 2002).

The second approach focuses mainly on patent data at the country level. For instance, Guellec and van Pottelsberghe (2001, 2004) analyse the extent to which all the patents invented in a given country are controlled by foreign firms. Their indicator is based on the publicly available information (in patent data) regarding the country of residence of the inventors and the country of residence of the assignees. The authors show that the countries that are larger and the countries that are more intensive in R&D are less "internationalised".

The company-level approach is able to capture aspects such as the industry to which the concerned actors belong, it is unambiguous about the nationality of the patentee (the firm) at one point in time. The country level approach cannot address issues such as how internationalisation relates to the corporate strategy (Is multinational firms' research abroad related to their core activities or to complementary activities?), which is treated in depth in certain firm level studies (Zander, 1995; or Cantwell and Janne, 1999). On the other hand, the country level approach is exhaustive, as all patents are treated, whoever the patentee, instead of a selection of large companies.

In the next section we develop a 'mix' methodology that consists of using both micro-level information about the nationality of the firms, and the country level approach that consists of using all the patents that have been invented in a country.

3. Data and summary statistics

In order to examine the trend of R&D internationalisation for Belgium, we will make use of indicators that are based on patent data. There is a considerable debate among scholars about the essence of what exactly patent statistics measure, but an almost unanimous agreement about the importance of these data. Patent statistics provide several insights into the process of technological progress. As Griliches (1990) states,

> "In the desert of data, patent statistics loop up as a mirage of wonderful plenitude and objectivity. They are available, they are by definition related to inventiveness and they are based on what appears to be an objective and only slowly changing standard."

Patent data are considered nowadays as a unique, broadly available and reliable source of statistic material if one's aim is to measure technological progress. Economists have used many patent-based measures of innovation: simple counts of patents, counts weighted by forward citations, years of renewal (Pakes, 1986) and number of patent claims (Tong and Frame, 1994).

However, some limits associated with the use of patent data have to be mentioned. A first weakness of patent data is that not all innovative activity is captured, and this for several reasons. First, not all inventions are patented/patentable. Second, not all patents lead to innovations. Third, not all innovations are based on patented inventions. A second weakness is that patented inventions differ greatly in quality, in the magnitude of inventive output

associated with them (Griliches, 1990; Lanjouw and Schankerman, 1999). It is not always easy to interpret the meaning of patent indicators and to know which underlying activity it reflects.

In the present study the analysis has been conducted on a database of patents applied for at the European Patent Office (EPO) during the period 1978-2001 and at the US Patent and Trademark Office (USPTO) over the period 1978-1999. An important difference to be mentioned between these two patent databases, is that EPO patents refer to patent applications, while US patents have already been granted. Both are however classified by date of application because long time lags might take place between a patent's application and its potential grant.

Table 1 provides an overview of the number of patents included in our sample. We focus on the patent applications at EPO (or grant at the USPTO) that have been invented in Belgium (country of residence of the inventors) with assignees that applied for at least three patents throughout the period of observation. Patents that have been applied for by private individuals have also been excluded.

With a cut–off value at three, i.e. we only examine those patents that have at least one assignee which applied for at least three patents throughout the observation period, we keep 348 different Belgian assignees (24 per cent of the total number of assignees) that did however apply for 89 per cent of all patent applications at the EPO with inventors based in Belgium. These figures reflect a high concentration of innovations, as a limited amount of companies represent the majority of patent applications. This is a reflection of the fact that the Belgian innovation system is largely dominated by a few large firms that perform the bulk of R&D and apply for a majority of patents.[3]

Table 1. Number of patents applied or invented in Belgium

cut off 3 patents (assignees no private persons)	**EPO**		**USPTO**	
	1978-2001		**1978-1999**	
Belgian inventor,	12,301		7,871	
Belgian inventor and foreign assignee	5,300	*43.0%*	3,671	*47.0%*
Belgian assignee	8,954		4,623	
Belgian assignee and foreign inventor	2,364	*26.0%*	788	*17.0%*

Two main indicators of internationalisation are used to measure the extent of cross-border ownership of inventions. The first one is the share for a given country of patents with a domestic inventor and a foreign applicant in the country's total domestic inventions (**SHIA**). It reflects the extent to which foreign firms control domestic inventions or **inward R&D-FDI**. 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 (**SHAI**). It reflects the extent to which domestic firms control foreign inventions or **outward R&D-FDI**.

There have been 12,301 (7,871) patent applications at the EPO (patents granted at the USPTO) by firms with inventors based in Belgium in the considered sample. Out of these patent applications, 43 (47) per cent were applied for by foreign firms (country of residence of the assignee) outside Belgium. These ratios are larger than the 32 per cent ratio observed by Guellec and van Pottelsberghe (2001) for the mid 1990s because the latter focused on all patent applications at the EPO (including individual assignees).

The number of patents applied for at the EPO (8,954) (and 4,623 granted by the USPTO) by assignees based in Belgium was lower than the number of patents invented in Belgium. This is mainly due to the fact that foreign companies perform R&D activities in Belgium to a

[3] The top 10 Belgian patenting companies consist of Agfa-Gevaert, Janssen Pharmaceutica, Solvay, Alcatel, Picanol, Bekaert, New Holland, Tyco, Totalfina and Innogenetics.

much larger extent than Belgian companies perform R&D abroad. This is witnessed by the share of patents invented abroad in the total number of patent applications at EPO (USPTO) by Belgian assignees: 26 (17) per cent.

4. Foreign ownership of patents invented in Belgium

Patent information regarding the country of residence of the assignee and of the inventor provides a useful, but incomplete, insight into the ownership of patented inventions. It is incomplete because there is no information about the ownership structure of the Belgian assignees. In the previous section we consider as 'Belgian' the assignees which are based in Belgium. However they might be controlled by foreign MNE's, and should therefore be considered as a foreign ownership of domestic inventions.

Affiliates of foreign MNEs are pervasive in the Belgian economy, not only in terms of production, but also with respect to R&D. As documented by the OECD (2004), the importance of foreign owned affiliates in the R&D expenditures varies according to country, but has been increasing in all countries, also in Belgium, where foreign affilaties carry out relatively more R&D than national firms. Hence, given their importance in R&D activities, identifying these firms among patent assignees is important to get a more complete picture of the foreign control of inventions.

This section aims at measuring the extent to which knowledge (at least partially) invented in Belgium, is owned by foreign firms not only directly, through the assigneeship of a foreign enterprise, but also indirectly, through the assigneeship of a Belgian subsidiary of a foreign firm. This identification of Belgian subsidiaries represents a contribution to the existing literature measuring inward R&D-FDI through patent information, which focuses mainly on the public information on assignees provided in patent data. Similarly, for the outward R&D-FDI, we can identify the type of Belgian firms owning inventions abroad. Next to the pure local firms, we can spot the contribution of Belgian MNEs with production locations abroad, as well as the Belgian affiliates of foreign firms located in Belgium.[4]

5. Inward R&D-FDI: Foreign ownership of patents invented in Belgium

The analysis will be performed for the patents invented in Belgium and for the patents with assignees based in Belgium. The measure of the extent to which inventions with at least one Belgian inventor are either directly or indirectly owned by a foreign party is presented in Table 2. It reveals the contribution of foreign firms to Belgian patent activities.

The first part of Table 2 shows that, 5,300 out of 12,301 (or 43%) EPO patents with Belgian inventors, filed between 1978 and 2001, are directly owned by a foreign assignee. This leaves 7,477 patents with Belgian inventors assigned to at least one applicant with residence in Belgium.

[4] The 3rd S&T indicator report of the EU also reports for a number of countries, the share of invented patents applied by multinational firms with affiliates in the country of invention. This approach differs from ours in several dimensions. It is only based on EPO data, and is only available for one year 1999 and hence cannot document the trends. It also provides no split in technology areas. It identifies only the larger firms with at least seven patents. Being focused only on MNEs at corporate level, the report makes no distinction between whether the MNE applies for the patent from abroad or through its local subsidiary. It ignores patents with foreign assignees without local subsidiaries, while we distinguish whether the applicant is foreign or local. It would be interesting to merge both approaches since this would allow to check in our sample whether the foreign applicants to Belgian inventions have foreign subsidiaries in Belgium, in which case they do not apply for patents through these affiliates.

Table 2. Measuring the 'foreign' ownership of patent invented in Belgium

cut off 3 patents	EPO 1978-2001		USPTO 1978-1999		
	12,301	*100%*	6,730	*100%*	
Belgian inventor and FOR assignee	5,300	*43.0%*	3,241	*48.2%*	**A**
Belgian inventor and BE assignee	7,477	*57.0%*	3,489	*51.8%*	
BE local as assignee	2,224	*18.1%*	703	*10.5%*	
BE MNE as assignee	920	*7.5%*	559	*8.3%*	
BE FORSUB as assignee	3,612	*29.4%*	2,014	*29.9%*	**B**
state institution as assignee	45	*0.4%*	10	*0.2%*	
Univ./resid. as assignee	757	*6.2%*	203	*3.0%*	
BE/FORSUB co-assignees	296	*2.4%*	69	*1.0%*	**C**
Total share of foreign ownership (A+B-C)	8,616	*70.0%*	5,186	*77.1%*	

When disentangling the assignees located in Belgium according to ownership, it can be seen that no less than 3,612 patents (or 29% of all patents invented in Belgium) are applied for by Belgian subsidiaries of foreign MNE's. If these patents are added to those that are directly controlled by foreign firms, we reach a share of 70% of patents with Belgian inventors and owned by foreign firms, either directly, through foreign assignees, or indirectly, through a Belgian subsidiary of a foreign multinational company[5]. This represents an astonishing amount of foreign ownership of Belgian inventions. Similar figures are found when the patents granted by the USPTO are analysed (see the second part of Table 2). The share of foreign ownership of domestic inventions is even higher, with 78% of patents with Belgian inventor owned by foreigners either directly or indirectly.[6]

Figure 1 shows the evolution over time of the indicators presented in Table 2, for patent applications at the EPO. The share of patents invented in Belgium and owned (directly or indirectly) by foreign companies has increased from about 50% in the late 1970s to more than 70% in the late 1990's. The majority of these patents are 'directly' owned by foreign applicants. The share of patents with a Belgian applicant which is a subsidiary of a foreign MNE has remained stable, and shows a small decrease since the mid 1990's. Similar results have been found with the USPTO patent data. Hence, the increase in international ownership of Belgian inventions is mostly driven by more patents with assignees located abroad, rather then by a larger number of patents from Belgian affiliates. It would be interesting to trace the identity of the foreign applicants and more particularly whether they have any affiliates in Belgium, in which case the increase in foreign applicants and the relative stagnation or decrease of applications by foreign affiliates could be a shift within the MNE to move patent applications from subsidiary to headquarter or sister subsidiary.

[5] There are several cases of co-assigneeship (this is the case for the patents which have been applied by at least one applicant with a Belgian residence and at least one applicant with a foreign residence). The number of patent applications at EPO that were assigned by at least two assignees is 476. Out of these, 296 were assigned to Belgian subsidiaries of foreign MNEs, which correspond to 62 per cent of all co-assigned patents. These patents must be accounted for in order to avoid the double counting of foreign-owned patents in Table 3. While on average international co-assignees are not very frequent, local assignees have the highest frequency of international co-assignees with 15% of their patents being foreign co-assigned, for Belgian subsidiaries of foreign MNEs this is 8% and for Belgian MNEs this is only 3%.

[6] The EU 3rd S&T report (2003), using the percentage of patents from MNEs with a Belgian subsidiary as measure of "foreignness" reports 81% for Belgium for 1999, the highest percentage among all EU-15 Member States (the EU average being 14%).

Figure 1. Direct and indirect ownership of patented inventions in Belgium (EPO, 1978-2001)

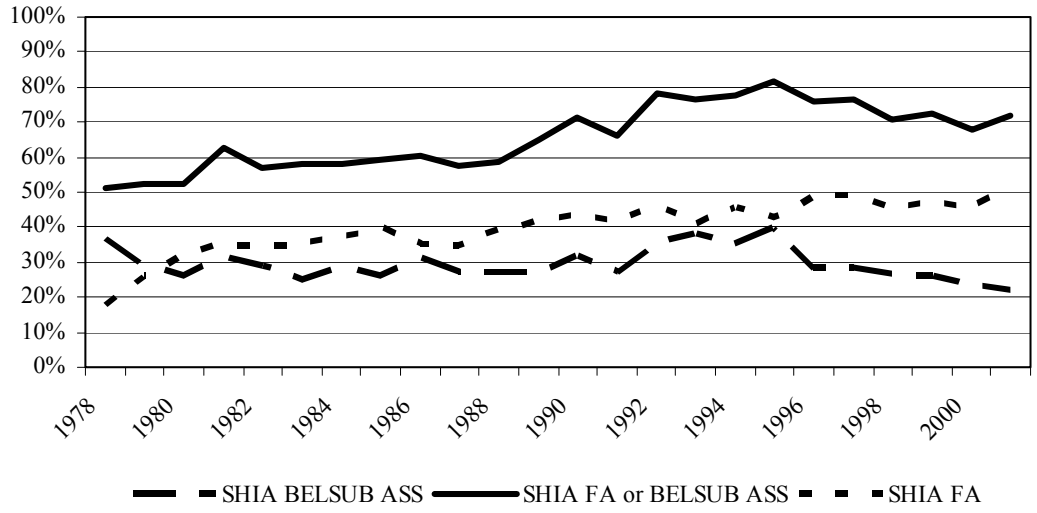
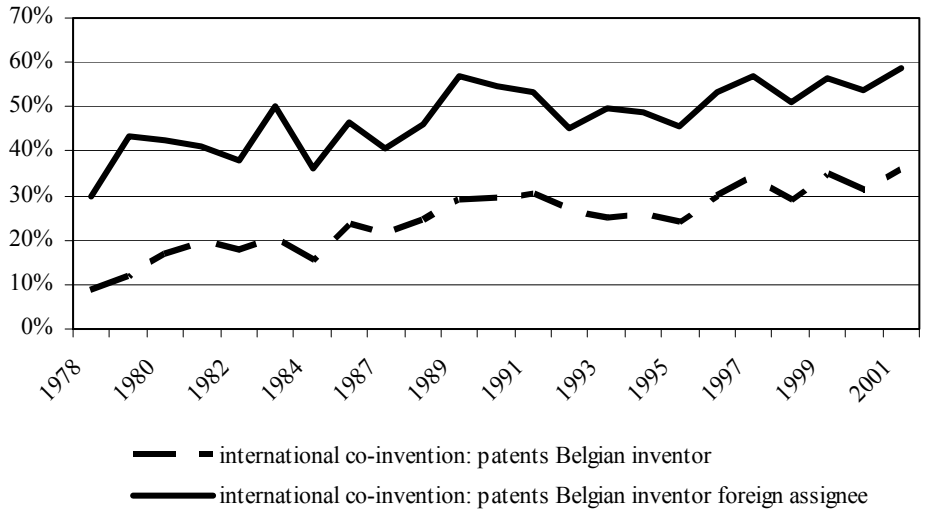


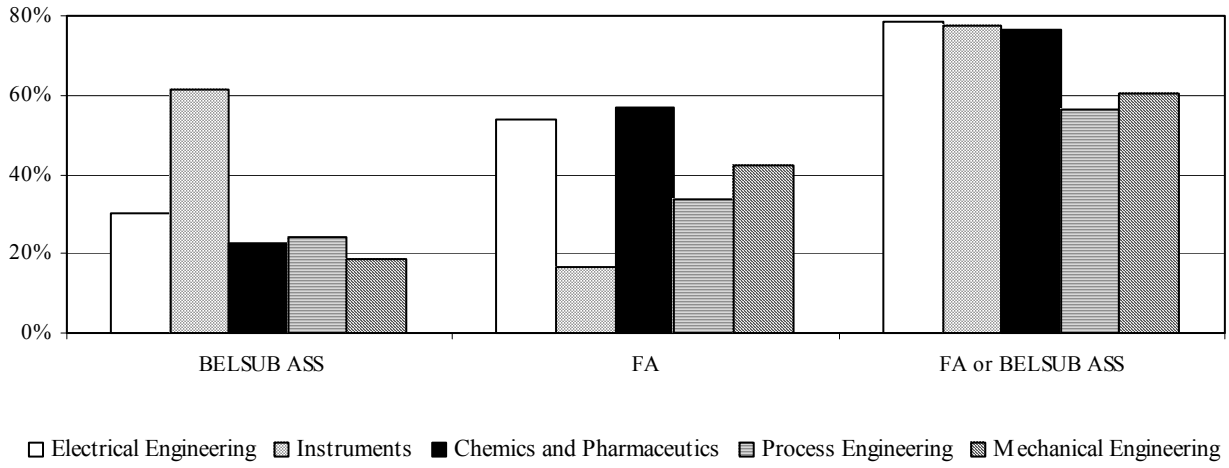
Figure 2. The share of international co-inventions in Belgium (EPO, 1978-2001)



This very high level of foreign ownership might induce a high propensity of international collaboration between inventors of different countries. Figure 2 shows the share of patents that were invented through international collaboration (i.e., at least one inventor from Belgium and at least one inventor from abroad). For the total number of patents invented in Belgium, the share of patents invented through international collaboration went from about 10% in the late 1970s to more than 30% in the late 1990s. This ratio is quite high and might be due to the large number of patents invented in Belgium but foreign owned. This idea is validated by the share of international co-inventions that took place under the umbrella of a foreign ownership. Indeed, Figure 2 clearly shows that the share of international co-invention is much higher within the sample of patents that were invented in Belgium but applied by foreign firms. About 40% of these patents were invented through an international collaboration in the early 1980s. This share has grown over time to reach a level of more than 50% in the late 1990s.

The extent of cross-border ownership in five broad technological areas is illustrated in Figure 3. The highest levels of foreign ownership are in the fields of Electrical Engineering, Instruments and Chemicals and Pharmaceutics. In each of these fields, almost 80% of all patents with Belgian inventor are owned, indirectly or directly, by foreign assignees.

Figure 3. Foreign ownership of patented inventions, Belgium, by sector (EPO, 1978-2001)



Further decomposition shows that patents with a foreign assignee are mostly to be found in "Chemicals and Pharmaceuticals" and "Electrical Engineering". For these two technological areas the large foreign MNEs that are based in Belgium clearly favour an application of patents by the headquarter. Belgian subsidiaries of a foreign MNE are most likely to apply for patents in the field of Instruments.

The geographical origin of assignees that applied for patents involving at least one Belgian inventor over the period 1978-2001 can also be identified. In this part of the analysis, only the 5,300 patents with a direct foreign assignee are included, as we do not have information on the geographical origin of the foreign multinationals, the subsidiaries of which have applied for patents with Belgian inventors. Almost 1 out of 2 EPO patents with a Belgian inventor and a foreign assignee, has at least 1 US assignee. The high share of the US is consistent with the high share of production FDI with the US as home country. Belgium's main neighbours at the same time appear to be of considerable importance. This is also consistent with Guellec and van Pottelsberghe (2001), who found that both the geographical distance and the sharing of a common language are important factors that explain the direction of cross border ownership of patents. The geographic pattern turns out to be very stable over time and is similar with USPTO patents, but varies significantly across the broad technological areas. US assignees of patents invented in Belgium seem to be highly specialised in the field of chemicals/pharmaceutics. Dutch and British assignees are also heavily specialised in this sector. France and Switzerland are more specialised in electrical engineering. However, despite these different specialisation patterns, the US is the largest foreign owner of patents invented in Belgium in all technological areas, except "Electrical engineering", which is much more "controlled" by companies based in France (see Cincera et al., 2005).

6. Outward R&D-FDI: Belgian ownership of patents invented abroad

The second dimension of the internationalisation of R&D activities concerns the patents invented abroad and controlled by firms based in Belgium. This dimension reflects the extent

to which Belgian firms engage in R&D in foreign countries (outward R&D-FDI). In this analysis, we use the group of patents with Belgian assignee and foreign inventors. This indicator corresponds to the SHAI indicator (the share for a given country of patents with a foreign inventor and a domestic applicant in the country's total domestic applications) developed by Guellec and van Pottelsberghe (2001). We count only the patents of the assignees who have applied at least for three patents between the period 1978-2001.

Table 3 shows that 2,364 out of 8,954 EPO patents with Belgian assignee have at least one foreign inventor. This means that 26% of patents applied for by Belgian applicants are at least partially invented abroad. Although this share is significant and quite high, it is still considerably smaller than the share of patents invented in Belgium and applied by foreign assignees, discussed in the previous section. Figure 4 presents the evolution in the SHIA indicator, which clearly documents an increasing trend.

Table 3. Measuring the 'Belgian' ownership of patents invented abroad

	EPO		USPTO	
cut off 3 patents	**1978-2001**		**1978-1999**	
Belgian assignee	8,954	*100%*	3,864	*100%*
Belgian local assignee	3,207	*35.8%*	773	*20.0%*
Belgian MNE assignee	1,184	*13.2%*	608	*15.7%*
Belgian subsidiary of foreign MNE as assignee	4,099	*45.8%*	2,269	*58.7%*
Belgian uni/res as assignee	782	*8.7%*	204	*5.3%*
Belgian state institution as assignee	34	*0.4%*	10	*0.3%*
Belgian assignee and FOR inventor	2,364	*100%*	710	*100%*
Belgian local assignee	780	*33.0%*	88	*12.4%*
Belgian MNE assignee	323	*13.7%*	105	*14.8%*
Belgian subsidiary of foreign MNE as assignee	1,192	*50.4%*	485	*68.3%*
Belgian uni/res as assignee	59	*6.7%*	31	*4.4%*
Belgian state institution as assignee	3	*0.1%*	1	*0.1%*

Note: the USPTO patent data set on Belgian assignees, being constructed from the Belgian inventor dataset, excludes the case that Belgian assignees would have all their patents without any Belgian inventors.

Figure 4 shows that the assignees based in Belgium are increasingly sourcing their technology abroad. Despite a drop in 1991-1993, the importance of patents with Belgian assignee and foreign inventor in the total group of patents with Belgian assignee has risen from 20% in the mid-1980's to about 30% in the late 1990's. USPTO patent data would illustrate a similar trend.

936 patents assigned to firms based in Belgium have been invented through an international collaboration (at least two inventors in different countries of residence), or 10.5% of patents with Belgian assignees have at least one Belgian inventor and one foreign inventor. This implies that relative to the 2,364 foreign invented patents, 40% are co-invented with inventors based in Belgium. Patents with a Belgian MNE or a Belgian subsidiary as assignee, have a slightly higher degree of international co-invention than Belgian local assignees, but the differences are small.

The extent to which firms based in Belgium control foreign inventions varies across technological fields. Figure 5 shows that Belgian patent applications in the field of mechanical engineering (34.4%), chemicals and pharmaceuticals (31.1%) and process engineering (27.7%) have a higher than average propensity to have at least one foreign inventor.

Figure 4. Evolution of the share of foreign inventors in the total number of patents assigned to firms based in Belgium (EPO, 1978-2001)

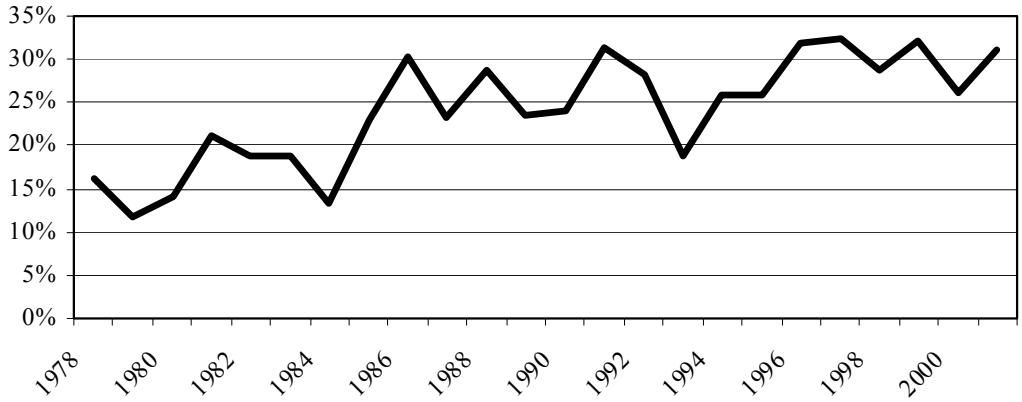
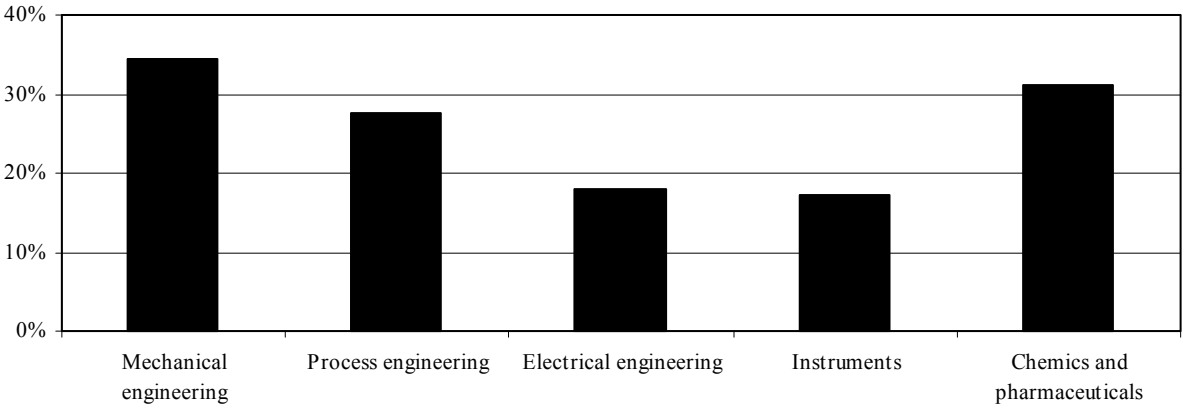


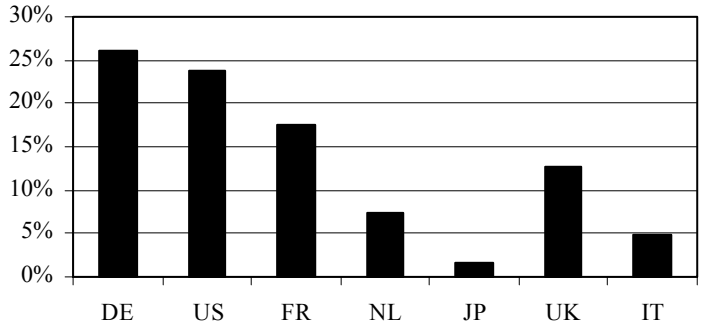
Figure 5. Share of foreign inventors in the total number of patents assigned to firms based in Belgium per technological area (EPO, 1978-2001)



This SHAI per technology area is different from the SHIA indicator (cf. supra), which is relatively lower for 'mechanical engineering' and 'process engineering', reflecting a relatively stronger advantage of Belgian firms in these technologies as compared to other technologies. The high internationalisation in the field of chemicals and pharmaceutics can also be observed from the USPTO patent analysis. However, patents in the field of mechanical engineering seem to be less internationalised in the USPTO data.

Figure 6 presents the geographical origin of the foreign inventions controlled by firms based in Belgium. As for the technological areas, the distribution is different from the one of the geographical origin of foreign firms controlling inventions made in Belgium. In the latter case, a clear majority of the patents invented in Belgium and controlled by foreign firms were held by US firms. In Figure 6, the majority of foreign inventions controlled by firms based in Belgium originates from Germany (26%) and is followed by the US (24%), France (17%) and Great Britain (13%). USPTO patents roughly show the same geographic pattern. US firms are much more active in Belgium than Belgian firms are in the US.

Figure 6. Geographical origin of foreign inventors in the total number of patents assigned to firms based in Belgium (EPO, 1978-2001)



The analysis of patents invented abroad but assigned to firms based in Belgium has so far focused exclusively on all assignees based in Belgium. However, the group of Belgian assignees applying for a patent consists of a very heterogeneous group of firms in terms of firm ownership and nationality. The group of Belgian assignees can be split in three main sub-groups: the local Belgian firms, Belgian multinational enterprises (BE MNE's) and Belgian subsidiaries of foreign multinationals (FORSUB).

A research question that is of particular interest here is which mechanisms firms can use to source technology abroad: does FDI, i.e., owning local production affiliates, facilitate access to technology abroad, in which case Belgian Multinational Firms would be most active in having foreign generated inventions, or, whether local Belgian firms also source technology abroad. In addition, we also identify subsidiaries of foreign firms located in Belgium as assignee to foreign invented patents. This allows us to examine whether these subsidiaries are using their corporate worldwide network of divisions to source technology worldwide. Table 4 shows the share of patents invented abroad (at least one foreign inventor) in the total number of patents assigned to firms based in Belgium, for each of the three categories.

Table 4. Share of patent with at least one foreign inventor in total number of patent assigned to firms based in Belgium, for three categories of firms

	EPO Patents				USPTO Patents			
Belgian assignee: SHAI	**Belgian local assignees**	**Belgian MNE assignees**	**Belgian subsidiaries of foreign MNE as assignees**	**TOTAL**	**Belgian local assignees**	**Belgian MNE assignees**	**Belgian subsidiaries of foreign MNE as assignees**	**TOTAL**
TOTAL (1978-2001)	*24.3%*	*27.3%*	*29.1%*	*26.4%*	*11.4%*	*17.3%*	*21.4%*	*18.4%*
Average 1981-1985	*16.9%*	*15.6%*	*24.0%*	*19.0%*	*12.5%*	*9.6%*	*24.2%*	*17.9%*
Average 1995-1999	*26.8%*	*36.7%*	*32.7%*	*30.2%*	*8.4%*	*25.8%*	*21.5%*	*20.5%*

The highest ratio of foreign invented patents is found for foreign subsidiaries and the lowest for local firms. A similar ranking in internationalisation is found between the different groups of Belgian assignees irrespective of the dataset used: EPO or USPTO. Nevertheless, based on USPTO patents, the difference between the different subgroups of firms is more pronounced than with the EPO data, with the Belgian MNEs having an important growth in the share of foreign inventions. Belgian MNE's, although not numerous, play an important role in owning

knowledge generated abroad. Finally, Belgian local assignees, although they have the lowest SHAI among the three types considered, are nevertheless significantly internationalised. EPO data suggest that these local firms might be more involved in internationalisation than one might think at first. These firms appear more active in international patenting through EPO than through USPTO. Local innovative firms will find more easily their way to file a patent application at the EPO than at the USPTO.

Although the share of Belgian assigned patents invented by at least one foreign inventor increases over time for all categories, there are some differences. Until the end of the 1980s, patents assigned to the Belgian subsidiary of a foreign firm had a higher chance to be invented abroad. But since the second part of the 90s, patents assigned to Belgian MNEs have the highest share of foreign sourcing. This reflects a stronger increase in internationalisation of the R&D activities of Belgian MNEs in the 1990's. A similar evolution is observed with the USPTO data.

7. Concluding remarks

The objective of this analysis was to measure the extent to which Belgian patenting activities are internationalised. We analysed two main dimensions of internationalisation with patent data. The first one is the extent to which patents invented in Belgium are assigned to firms based abroad (to what extent do foreign firms rely on Belgium's innovative output) (inward R&D-FDI). The second one is the extent to which the patents assigned to firms based in Belgium have been invented abroad (to what extent does Belgium rely on foreign technology) (outward R&D-FDI). The literature typically uses only information included in patent data, looking at the country of residence of the inventors and the country of residence of the applicants (or assignee). This method suffers from a potentially important drawback: the country of residence of a firm is not automatically related to the nationality of the firm. This means that if subsidiaries of foreign MNEs apply themselves for a patent, they will be considered as 'local' assignees, whereas they should be considered as foreign controlled. Being able to distinguish whether Belgian applicants are affiliates of foreign firms located in Belgium, or Belgian based firms with affiliates abroad, allowed us to improve existing indicators of internationalisation of technology based on patent data.

Our results suggest that taking into account the nationality of ownership of the firm changes the measured degree of internationalisation substantially. For instance, taking only into account the information provided in patent data, we find that 40% of the patent applications invented in Belgium (the country of residence of the inventor in Belgium) are assigned to foreign companies (the country of residence of the applicant is not Belgium). This level of internationalisation is quite high, among the highest for the OECD member countries. However, the extended picture, taking into account foreign control, is even more striking. If the Belgian subsidiaries of foreign MNE's are considered as a 'foreign' control over the patents invented in Belgium, the ratio of domestic patented inventions controlled by foreign firms reaches a level of 70%. This total level of foreign ownership of patented inventions made in Belgium has been increasing over the past 20 years. It varies across technological fields, and more than 50 per cent of these foreign assignees come from the US.

The reverse picture, namely the extent to which assignees located in Belgium source technology abroad, i.e. have foreign inventors, is less pervasive. The share of inventions made by foreign residents in the total number of patent assigned to firms based in Belgium is 'only' about 30% in the late nineties. About half of these patents are controlled by Belgian subsidiaries of foreign MNEs. But the type of firms with the highest growing internationalisation of inventions are the Belgian Multinational Firms. The major source of foreign inventions comes from Germany and is followed by the US and France.

The worldwide restructuring of R&D in multinational companies clearly affects research resources in individual national locations, especially in small open economies such as Belgium. To assess the technological capacity of a national economy requires an understanding of how this restructuring of R&D in multinational enterprises affect a country's innovative and productive potential.

The high proportion of foreign ownership of Belgian knowledge is an important dimension to take into account by Belgian policy makers, as this might reflect the sensitivity of the country's technological competitiveness to international trends, particularly since our analysis has shown that although outward R&D-FDI is rising, particularly through Belgian owned MNEs, the inward R&D FDI is nevertheless more prominent.

References

Almeida, P. (1996), 'Knowledge Sourcing by Foreign MNEs: Patent Citation Analysis in the US Semiconductor Industry', *Strategic Management Journal*, pp. 155-165.

Andersen, E. and B.-A. Lundvall (1988), 'Small national systems of innovation facing technological revolutions'. In: Freeman, C. and B.-A. Lundvall (eds.), *Small Nations Facing Technological Revolutions*, London, Pinter.

Bartlett, C.A. and S. Ghoshal (1997), 'Managing innovation in the transnational corporation'. In: Tushman, M. and P. Anderson (eds.), *Managing Strategic Innovation and Change*, Oxford: Oxford University Press, pp. 452-476.

Branstetter, L. (2000), 'Is FDI a channel of Knowledge Spillovers: Evidence from Japanese FDI in US', NBER Working Paper, no. 8015.

Cantwell, J. (1989), Technological Innovation and Multinational Corporations, New York, Blackwell.

Cantwell, J. (1995), 'The globalisation of technology: What remains of the product life cycle model', *Cambridge Journal of Economics*, vol. 19, no. 1, pp. 155-174.

Cantwell, J. and R. Harding (1998), 'The internationalisation of German companies' R&D', *National Institute Economic Review*, vol. 163, pp. 99-124.

Cantwell, J. and S. Iammarino (1998), 'MNCs, technological innovation and Regional Systems in the EU: Some evidence in the Italian case', *International Journal of the Economics of Business*, vol. 5, no. 3, pp. 383-408.

Cantwell, J. and O. Janne (1999), 'Technological globalisation and innovative centres: the role of corporate technological leadership and locational hierarchy', *Research Policy*, vol. 28, pp. 119-144.

Caves, R. (1996), *Multinational Enterprise and Economic Analysis*, Cambridge, Cambridge University Press.

Cheng, J.L.C. and D.S. Bolon (1993), 'The management of multinational R&D: A neglected topic in international business research', *Journal of International Business Studies*, pp. 1-18.

Cincera M., B. van Pottelsberghe and R. Veugelers (2005), 'The Internationalisation of the Production of Technology: A More Complete Picture for Belgium', forthcoming in P. Teirlinck and A. Spithoven (Eds.), Beyond Borders: Internationalisation of R&D, Elsevier Science.

Dernis, H., D. Guellec and B. van Pottelsberghe (2001), 'Using patent counts for cross-country comparisons of technology output', *OECD STI Review*, no. 27, pp. 129-146.

Dunning, J.H. (1988), 'The eclectic paradigm of international production: A restatement and some possible extensions', *Journal of International Business Studies*, vol. 19, pp. 1-31.

Dunning, J.H. (1994), 'Multinational enterprises and the globalization of innovatory capacity', *Research Policy*, vol. 23, pp. 67-88.

Dunning, J.H. and C. Wymbs (1999), 'The geographical sourcing of technology-based assets by multinational enterprises'. In: Archibugi, D., J. Howells and J. Michie (eds.), *Innovation Policies in a Global Economy*, Cambridge, Cambridge University Press, pp. 185-224.

Florida, R. (1997), 'The globalization of R&D: results of a survey of foreign affiliated R&D laboratories in the USA', *Research Policy*, vol. 26, pp. 85-103.

Frost, A. (1998), *The geographic sources of innovation in the multinational enterprise: US subsidiaries and host country spillovers*, 1980-1990, PhD Sloan School of Management, MIT.

Gassman, O. and M. von Zedtwitz (1999), 'New concepts and trends in international R&D organisation', *Research Policy*, vol. 28, pp. 231-250.

Gassman, O. and M. von Zedtwitz (2002), 'Market versus technology drive in R&D internationalisation: four different patterns of managing research and development', *Research Policy*, vol. 31, pp. 569-588.
Granstrand, O., L. Häkanson and S. Sjölander (1993), 'Internationalization of R&D - A survey of some recent research', *Research Policy*, vol. 22, pp. 413-430.
Griffith, R., R. Harrison and J. van Reenen (2004), 'How special is the special relationship? Using the impact of R&D spillovers on UK firms as a test of technology sourcing', CEP Discussion Paper 659.
Griliches, Z. (1990), 'Patent Statistics as economic indicators: A survey', *Journal of Economic Literature*, vol. VIII, pp. 1661-1707.
Guellec, D. and B. van Pottelsberghe (2001), 'The internationalisation of technology analysed with patent data', *Research Policy*, vol. 30, no. 8, pp. 1256-1266.
Guellec, D. and B. van Pottelsberghe (2004), 'Measuring the internationalization of the generation of knowledge – an approach based on patent data'. In: Moed, F., W. Glänzel and U. Schmoch (eds.), *Handbook of Quantitative Science and Technology Research – The use of publication and patent statistics in studies of S&T systems*, Kluwer Academic Publishers, pp. 645-662.
Jaffe, A., M. Trajtenberg and R. Henderson (1993), 'Geographic localisation of knowledge spillovers as evidenced by patent citations', *Quarterly Journal of Economics*, pp. 577-598.
Kogut, B. and U. Zander (1993), 'Knowledge of the firm and the evolutionary theory of the multinational corporation', *Journal of International Business Studies*, vol. 24, pp. 625-645.
Kuemmerle, W. (1997), 'Building effective R&D capabilities abroad', *Harvard Business Review*, pp. 61-70.
Lanjouw, J.O. and M. Schankerman (1999), 'The quality of ideas: measuring innovation with multiple indicators', NBER Working Paper, no. 7345.
Lichtenberg, F. and B. van Pottelsberghe (2001), 'Does foreign direct investment transfer technology across borders?', *Review of Economics and Statistics*, vol. 83, no. 3, pp. 490-497.
Meyer Kramer, F. and G. Reger (1999), 'New perspectives on the innovation strategies of multinational enterprises: Lessons for technology policy in Europe', *Research Policy*, vol. 28, pp. 751-776.
Niosi J. (1999), 'The internationalisation of industrial R&D: From technology transfer to the learning organisation', *Research Policy*, vol. 28, pp. 107-117.
Pakes, A. (1986), 'Patents as options: Some estimates of the value of holding European patent stocks', *Econometrica*, vol. 54, pp. 755-784.
Patel, P. (1995), 'Localised production of technology for global markets', *Cambridge Journal of Economics*, vol. 19, no. 1, pp. 141-154.
Patel, P. and K. Pavitt (1991), 'Large firms in the production of the world's technology: An important case of non-globalization', *Journal of International Business Studies*, vol. 22, no. 1, pp. 1-22.
Patel, P. and M. Vega (1999), 'Patterns of internationalization of corporate technology: Location vs. home country advantages', *Research Policy*, vol. 28, pp. 145-155.
Pearce, R.D. (1989), The Internationalisation of Research and Development by Multinational Enterprises, London, MacMillan.
Pearce, R.D. (1999), 'Decentralised R&D and strategic competitiveness: globalised approaches to generation and use of technology in multinational enterprises (MNEs)', *Research Policy*, vol. 28, pp. 157-178.

Pearce, R. and S. Singh (1992), 'Internationalization of R&D among the world's leading enterprises: survey analysis of organization and motivation'. In: Granstrand, O., L. Hakanson and S. Sjolander (eds.), *Technology Management and International Business*, Chichester: Wiley and Sons, pp. 137-162.

Reger, G. (2001), 'Differences in the internationalization of research and technology between Western European, Japanese and North American companies', mimeo, University of Brandenburg.

Serapio, M. and D. Dalton (1999), 'Globalisation of industrial R&D: An examination of FDI in R&D in the US', *Research Policy*, vol. 31, pp. 569-588.

Tong, X. and D. Frame (1994), 'Measuring national technological performance with patent claims data', *Research Policy,* vol. 23, pp. 133-141.

Zander, I. (1995), 'Technological diversification in the multinational corporation - Historical evolution and future prospect'. In: Schiatarella, R. (ed.), *New Challenges for Europe and International Business*, Rome, Cofindustria.

Zander, I. (1999), 'How do you mean 'global'? An empirical investigation of innovation networks in the multinational corporation', *Research Policy*, vol. 28, pp. 195-213.