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Abstract : The purpose of this paper is to participate in the discussion of the effects of outward FDI in R&D on the home country. The main possible threat for home economies is the relocation of R&D activities to foreign regions and, as a result, the loss of technological capacity. This study contributes to this issue by analysing the role played by the home country in the development of the multinational enterprises' innovative activities. Three different elements will be evaluated: the extent of R&D activities operated outside the home country; the compared value of foreign and home R&D activities; and the role of the home country as a source of knowledge. These elements are investigated through an analysis of patents and patent citations of 71 Swiss MNEs issued between 1978 and 2006.

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Introduction

The subject of this paper forms part of a wide-ranging debate on the economic consequences of globalisation. While studies on this issue have generally focused on the effects of foreign direct investment (FDI) on host countries (see, for example, Aitken and Harrison, 1999; Caves, 1974; Kokko, 1996; Blomström et al., 2003; Buckley et al., 2006), this paper concentrates on the effects of FDI on home countries: what happens if domestic firms increasingly operate in foreign locations?

As high-value-added activities such as R&D services were undertaken mostly at home (see for example Patel and Pavitt, 1991), research studies on outward FDI have principally explored the effects of FDI in production activities or in low-value-added activities. Indeed, many companies in industrialized countries have moved domestic plants to low-cost countries, creating concerns among population about production or employment at home[2]. Studies on this issue often conclude that investing abroad may cause an expansion of skilled-intensive activities such as R&D services and the demand for qualified labour at home, while labour-intensive activities are transferred to cheap-labour countries (see Barba Navaretti and Venables, 2004, for a discussion on the effects of MNEs on home countries).

However, evidence from recent studies indicates that activities in R&D operated abroad have increased, limiting the argument of non-globalisation of high-value-added functions. For example, between 1993 and 2002, the R&D expenditure of foreign affiliates worldwide have doubled (from an estimated $30 billion to $67 billion, UNCTAD, 2005). As R&D plays a part determining for the competitiveness of national economy, this trend towards the internationalisation of R&D has an ever larger impact on the policy makers' agenda and has been the subject of official reports (see for instance UNCTAD, 2005).

Discussions on this issue have involved different points. On the one hand, the geographical dispersion of innovation facilitates the technological development of the firm and influences its productivity (Braconier et al., 2001; Van Pottelsberghe de la Potterie and Lichtenberg, 2001; Branstetter, 2000). These effects derive from the idea that knowledge remains to some extent localized and that MNEs must install subsidiaries in this localisation to benefit from this knowledge. Furthermore, with research facilities abroad, they may be able to take advantage of different specializations in foreign locations, and establish favourable cross-border interactions between them (Cantwell and Narula, 2001, p. 160).

[2] See articles about the effects of FDI on production structures, home country export or employment at home (Kokko, 2006; Castellani et al. 2007), or on the productivity of the firms (Helpman et al., 2004).

Home countries can profit from this dispersion, if foreign subsidiaries transfer their technological knowledge within the multinational network (the so-called "reverse technology transfer", see Criscuolo, 2002; Frost and Zhou, 2005).

On the other hand, this internationalisation of R&D leads to concerns from both MNEs (depleting their proprietary technologies by interacting with foreign partners), and home countries (loss of technological capacity, the "hollowing out" effect). Indeed, R&D is one of the main sources of innovation and, for this reason, plays a part determining for the competitiveness and the growth of a national economy[3]. In this context, parts of the population in the country of origin fear that firms will displace R&D from their country to foreign locations and affect their economic welfare (Hollenstein, 2006, p. 3). For example, the Swiss pharmaceutical company Novartis has moved its R&D headquarters from Basel in Switzerland to Cambridge, Massachusetts, in the United States, resulting in concerns about a potential relocation of national R&D.

Summing up, the internationalisation of R&D offers opportunities, as well as threats, to the economic future of home countries. The study contributes to this debate through an empirical investigation based on a firm-level panel data of 71 Swiss MNEs. The paper is structured as follows. As it is essential to determine the nature of foreign R&D activities to evaluate the potential impact on home countries, the determinants of foreign activities in R&D will be provided by the OLI (Ownership, Location and Internalization) paradigm. Then, research methods and results from an econometric analysis of patents and patents citations will be presented. The main objective of this analysis is to evaluate the risk of the "hollowing out" of domestic R&D, i.e. the possibility that firms decrease domestic R&D activities while increasing foreign activities. This issue will be evaluated in different elements: the extent of R&D activities operated outside the home country; the compared value of foreign and home R&D activities; and the role of the home country as a source of knowledge.

R&D activities in foreign locations

As MNEs tend to internationalise R&D activities for similar motives as traditional elements of the value-added chain, although not at the same rate, nor to the same extent (Narula and Zanfei, 2003, p. 7), studies on the internationalisation of R&D by MNEs result from the theory of international business. The leading theory is the eclectic paradigm of Dunning, first put forward in 1976 at a presentation in

[3] There is an extensive literature estimating the size of the impact of R&D on productivity: see reviews by Griliches, 1994 ; Nadiri, 1993.

Stockholm on the *International Allocation of Economic Activity* (Dunning, 1977). In Dunning's view, international production is determined by the configuration of three sets of advantages possessed by enterprises simultaneously. *"Enterprises engage in production abroad whenever they possess net competitive advantages over firms of other nationalities which can best be exploited by foreign rather than domestic production, and which are more profitable to internalize than to sell or lease to other enterprises"* (Dunning, 1979, p. 289). First, foreign firms must possess competitive or "ownership" advantages over their rivals, in order to compete with local firms. Ownership advantage relates to the possession of firm specific assets that give the firm a competitive advantage. These O-advantages must be sufficient to compensate for the cost of setting up and managing a geographically dispersed organisation. Competitive advantages can be particular unique intangible assets (such as firm-specific technology), or complementary assets (such as the ability to create new technologies, or to coordinate cross-border activities effectively) (Cantwell and Narula, 2001, p. 157).

In theories of international business, MNEs were generally expected to exploit abroad their competitive advantages developed in their home country (see Hymer, 1960; the traditional product cycle theory, Vernon, 1966; or Caves, 1974). According to Rugman (1982, p. 20): "the key factor influencing the location of multinational branch offices is the ownership advantage developed in the home nation and exploited abroad to satisfy local markets". These traditional approaches to the multinational growth argued that learning of knowledge consists predominantly of a one-way movement of technologies from headquarters to affiliates. In centralising R&D activities in their home country, MNEs can benefit from economies of scale, and can facilitate the coordination and the control of R&D investments, which are expensive and risky (Vernon, 1977). Besides, MNEs are embedded in their home country, where they are familiar with the environment. Therefore, firms were supposed to operate technological activity mainly in the home country, and exploited these technological capabilities in foreign location to adapt product or technology to local conditions. According to Patel and Pavitt (1999a, p. 94), "Even very large corporations in most cases perform most of their R&D at home. As a consequence, companies' innovative activities are significantly influenced by their home country's national system of innovation."

However, this centralized R&D approach is somewhat outdated for two reasons: *"First, as more and more sources of potentially relevant knowledge emerge across the globe, companies must establish a presence at an increasing number of locations to access new knowledge and to absorb new research*

results from foreign universities and competitors into their own organizations. Second, companies competing around the world must move new products from development to market at an ever more rapid pace." (Kuemmerle, 1997, p. 61). Thus, a new potentially important source of competitive advantage is the capacity of foreign subsidiaries to generate innovations based on host country's technological competences. In summary, initial firm-specific technology developed at home can be exploited abroad in order to adapt products or processes to local conditions ("home-base exploiting activities"). In this context, core activities are concentrated in home countries, and foreign activities enhance the technologies developed at home. Domestic R&D activities, however, are not the only sources of knowledge that MNEs exploit. They can also access foreign sources of knowledge to complement their R&D activities at home, or to acquire or create new unique intangible assets, for example, by gaining access to the O advantages enjoyed by firms in that location ("home-base augmenting activities"). In this strategy, the core of innovation activities may be decentralised and important innovations are produced abroad.

The second condition for international production developed in the eclectic paradigm is that it must be in the best interests of enterprises which possess competitive advantages to transfer them across national boundaries within their own organizations, rather than by contractual agreements with foreign-based enterprises (Dunning, 1988, p. 3). MNEs retain control over their assets because of the "internalization" advantages (I-advantages) of doing so. The traditional literature emphasizes that R&D activities are generally internalized and confined to foreign affiliates, rather than externalized. Indeed, the possibility of imitations and the high cost of transmitting information from seller to buyer make market contracts for R&D problematic (for a literature review, see Rao et al., 2006). Incidentally, in 2001, contracted R&D accounted for less than 5 percent of total company-funded R&D and this ratio has changed very little during the past ten years (Rao et al., 2006, p. 8). However, recent literature provides support for a trend towards the externalization of MNEs' R&D (Jankowski, 2001; Engardio and Einhorn, 2005). The recipient countries for outsourced R&D are increasingly developing countries, especially in Asia (UNCTAD, 2005, p. 168). Nevertheless, R&D outsourcing has its limits and firms are unwilling to externalize critical activities as the core of their technological advantage (UNCTAD, 2005, p. 169). Only "commodity" R&D activities can be outsourced without damaging the competitiveness of the company and its reputation for innovation.

The third facet of the eclectic paradigm tackles the location issue. The motive to move abroad is to use the firm's competitive advantage in conjunction with factor advantages in a foreign country (L-advantages). These location-specific advantages are available to all firms but are specific to a particular location (Dunning and Narula, 1995, p. 41). Through these factors, the MNE amplifies the profits derived from its firm-specific advantages. The significance of the variables influencing the location destination varies with the type of FDI and the stage of development of both the investing and recipient countries (Dunning, 1993, p. 143). The literature distinguishes two main types of foreign R&D activities: home-base augmenting or home-base exploiting activities (Kuemmerle, 1997). The former gains access to localized knowledge sources that might improve the technological capacity of the firm, whereas the latter exploits the knowledge transferred by the parent company or taking place elsewhere in the MNE. According to Gammeltoft (2006, p. 192), “home-base-augmenting sites should be located in regional clusters of scientific and technical excellence, whereas home-base-exploiting sites should be located close to large markets and manufacturing facilities”.

Many studies suggest that the most frequent motivation for foreign R&D is the customization of existing products and technologies to local market needs (“home-base-exploiting sites”, see Love, 2003; Balcet and Evangelista, 2005; Rose and Volker, 2005). Thus, R&D activities located in foreign regions mostly adapt the technology or products to the local markets. Though, “while asset-exploiting activities still predominate as a motivation, the tendency for firms to invest abroad in order to augment their existing assets is now also substantial, and forces scholars of international business to rephrase their enquiries.” (Cantwell and Narula, 2001, p.158. See also Pearce, 1999).

Concerning Swiss MNEs R&D activities, studies have generally concluded that asset-exploiting activities are the prevalent type of foreign R&D (see Arvanitis and Hollenstein, 2007). Yet, asset augmenting strategies are becoming increasingly important and create concerns about the technological capacity of Switzerland. Indeed, asset-exploiting activities use and enhance technologies developed at home, as core activities are concentrated in home countries. Conversely, asset-augmenting activities have created mixed effects on home countries: on the one hand, MNEs access foreign knowledge and may make home countries profit from this new source of knowledge. On the other hand, the core of innovation activities could be decentralised and important innovations may be produced abroad, leading to a potential relocation of R&D. However, this concern cannot be

upheld in the face of the facts. Swiss MNEs tend to consider Switzerland the ideal place for highly qualified functions (BCG and AmCham, 2007, p. 36). They can thus profit from the strengths of this country, which takes the leading position as the world's most competitive economy in 2006–2007 according to *The Global Competitiveness Report 2006-2007* (Lopez-Claros et al. 2006): world class capacity for innovation; highly sophisticated business culture; well developed infrastructure for scientific research; strong intellectual property protection; well-developed institutional framework; and excellent infrastructure facilities.

Then again, other countries are getting better at competing with Switzerland in skilled-labour areas and the risk of losing high-value-added functions of companies to other countries is increasing (BCG and AmCham, 2007, p. 8). The reasons could be found in the difficulty of hiring highly skilled personnel, such as engineers and scientists, and the smallness of the economy. For example, when Novartis moved its research headquarter to Cambridge, Paul Herrling, Head of Corporate Research in Novartis, said that "Basel was traditionally our biggest and most productive site and attracted the best people from Europe, but we think we've achieved the critical mass size there and there's a danger of it becoming too big." (Nature Medicin, 2002). At the same time, Joerg Reinhardt, Chief Executive Officer of Novartis Vaccines and Diagnostics, told Nature Medicine, "We don't plan to diminish activities in Basel and we will continue to maintain that site. But Cambridge is a highly attractive site in terms of scientists and academic network." As a result, this internationalisation of R&D cannot be considered a weakness in the national innovation system but a logical consequence of small size (Heikkilä et al., 2004). Indeed, firms from small developed countries have conducted R&D abroad to overcome the constraints of their domestic economy (such as relatively small and/or specialised pools of knowledge and skills) (UNCTAD, 2005, p. 121). However, this situation could lead to a displacement of R&D if the Swiss innovation system does not compensate for these disadvantages. The next section will consider this risk in evaluating the role of Switzerland as a source of knowledge for R&D centers.

Empirical analysis

The purpose of this paper is to participate in the discussion of the effects of outward R&D on home countries. As described previously, the main potential hazard is the relocation of R&D and the resulting loss of technological capacity. The case of Switzerland was chosen, because Swiss MNEs have internationalised their R&D activities to a great extent and have created concerns among policy

makers. Furthermore, in contributing 34 percent of the total GDP in 2004 (BCG and AmCham, 2007, p. 8), MNEs represent an important part of Switzerland's economy, and play a dominant role in the innovation activities of Switzerland (87% of private expenditures in R&D in Switzerland are made by large firms, Swiss Federal Statistical Office, 2006). Moreover, as Swiss MNEs seem to suffer of the relative lack of high skilled labour in the home country, the concern about the loss of R&D activities is a reality in Switzerland.

The study will seek to contribute to this issue by analysing the role played by the home country in the development of MNEs' innovative activities. The main objective of this analysis is to evaluate the possibility that firms decrease domestic R&D activities while increasing foreign activities. In order to do so, I will first compare the level of innovative activities undertaken in the home base and abroad by Swiss MNEs. Then, I will evaluate how much Swiss MNEs value R&D activities generated in Switzerland and in foreign countries. This will allow describing the position of Swiss R&D activities in the development of technologies. Finally, I will analyse the role play by the home country as a source of knowledge for Swiss MNEs' innovative centers.

a) Trends in the internationalisation of R&D activities amongst Swiss MNEs

This section presents the extent of Swiss MNEs innovative activities operated outside the home country. Patents are frequently used to reflect the inventive performance of countries, regions, firms, as well as other aspects of the dynamics of the innovation process (OECD, 2006, p. 6). Advantages and disadvantages of using this indicator have been largely discussed (e.g. Griliches, 1990), and most authors tend to conclude that patent statistics can be useful indicators: "*In spite of all the difficulties, patents statistics remain a unique source for the analysis of the process of technical change. Nothing else even comes close in the quantity of available data, accessibility, and the potential industrial, organisational, and technological details.*" (Griliches, 1990, p. 1702).

In this section, I use the number of patents as an indicator for the level of the global innovative activities of Swiss MNEs. First, patents are a good indicator of the technological production of the firms, because they use patents as legal protection for their most valuable innovations (Filippaios et al., 2007, p. 6). Secondly, patent records include the name and the address of inventor(s), as well as the name and address of the applicant(s). Assuming that the address of the inventor coincides with the geographical location of invention (proxy measure used by Cantwell, 1992; Le Bas and Sierra, 2002; Patel and Vega, 1999 and many others), this information allows us to identify where the technology

underlying the innovation was mainly carried out.

The MNEs included in the data set are headquartered in Switzerland and are the most innovative firms (only firms with a minimum of 20 patents during 2004-2006 were included in the analysis). A total of 71 firms were investigated. The ownership and affiliates structure of the firms were constituted with annual reports and web sites. There may be some errors introduced by the fact that we do not have the complete ownership data for the full period. Spelling mistakes on firms name were verified in a manual process. I was able to identify a total of 39281 patents applied at the European Patent Office during the period 1978-2006.

Every patent lists the addresses of the inventors as well as the names of the applicants. Patents were selected by their applicants (i.e., the multinational firms groups), but I identified the location of the invention by looking at the inventor's address. Using this information, I was able to identify a total of 96651 inventors, including 36918 inventors in Switzerland and 59733 inventors from 70 different foreign countries. This number of inventors exceeds the number of patents (39281), as some patents have multiple inventors. In this case, I use a fractional counting method (see OECD, 2006b, Criscuolo et al., 2002; Verspagen and Schoenmakers, 2004). For example, if there are *p* inventors in Germany, and *q* inventors in France for the same patent, Germany is attributed *p/(p+q)* of the patent, and France *q/(p+q)*.

Table 1 reports that 16 enterprises (22.5%) in our sample have more than 50% of their patents originating from foreign subsidiaries, and 19959 patents (50.8%) have more that 50% of foreign inventors. The highest values are found for Clariant (95.8%), Serono (89.9%), Endress + Hauser Flowtec (85.2%), Roche (82.7%), Oerlikon (82.5%), and Bücher (82.4%). These are the companies with more than 80% of their patenting activity abroad. In any cases, even if the company has only 25% of R&D activities undertaken abroad, I can argue that Swiss companies are engaged in undertaking R&D activities outside the home base.

Table 1. Share of patents invented in foreign regions, 1978-2006

	Share of patents invented in foreign regions				Total
	<25%	25-50%	50%-75%	>75%	
Number of firms	25	30	9	7	71
Number of patents	3925	15395	9763	10196	39281

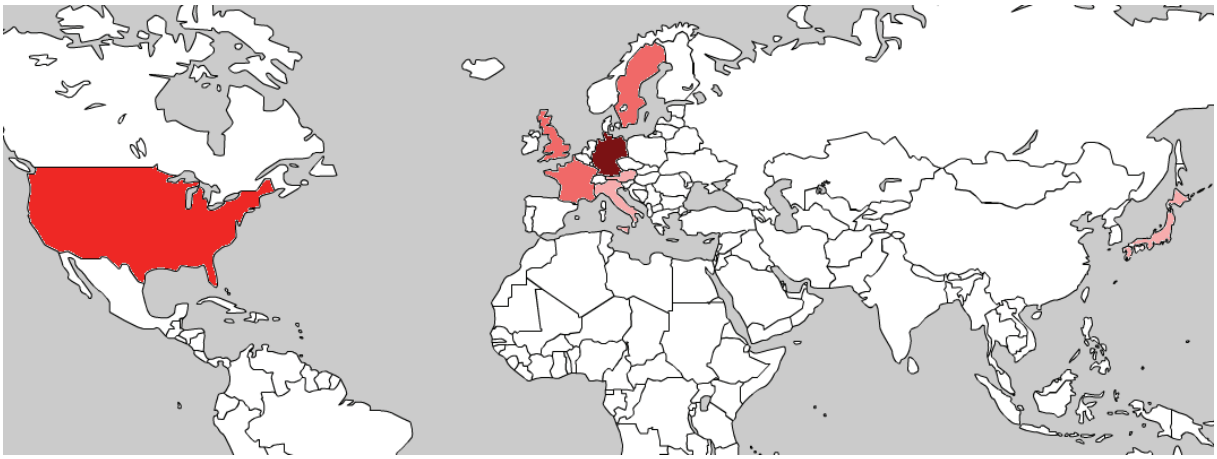
What's more, the data in Table 2 show that there has been a strong increase in the level of internationalisation of Swiss innovative activities. Swiss MNEs patents generated in foreign subsidiaries amounted to 43.6 percent of the total Swiss MNEs patents in the 1980s, to 54 in the 1990s, to 61.8 between 2000-2006. These results confirm that Swiss MNEs locate a growing part of their R&D activities outside the home country. The argument that R&D activities are centralised in the home country is thus no longer valid.

The breakdown by partner country reports that Germany (DE), the United States (US), France (FR), United Kingdom (GB), Sweden (SE), Japan (JP), and Italy (IT) are the main partners for Switzerland (see map above). In considering only patents invented abroad, Germany accounted for 40.7 percent of all patents, the United States 23.2 percent, France 8.3, United Kingdom 7.1, Sweden 5.9, Japan 3.4 and Italy 3.3.

Table 2. Location of inventors of Swiss MNEs' patents, 1980-1989, 1990-1999, 2000-2006

Periods	CH	%	DE	%	US	%	FR	%	GB	%	Others	%	Total patents
1980-1989	4550	56.4	1374	17.0	879	10.9	278	3.4	470	5.8	519	6.4	8070
1990-1999	4094	46.0	2301	25.9	1014	11.4	351	3.9	296	3.3	841	9.5	8897
2000-2006	8434	38.2	5266	23.9	3197	14.5	1193	5.4	791	3.6	3171	14.4	22052
1980-2006	17078	43.8	8941	22.9	5090	13.0	1822	4.7	1557	4.0	4531	11.6	39019

Figure 1. Main foreign locations by Swiss MNEs



In comparing these results with others studies, I find that Swiss MNEs are strongly engaged in R&D abroad. In Verspagen and Schoenmakers (2004) analysis of 52 European based MNEs, the mean of the share of patents originating from foreign regions with a priority date in 1997 was 0.18. Patel and Vega (1999) showed that European firms have 22.7 percent of their patents granted from foreign subsidiaries (evidence based on US patent statistics). Cantwell and Kosmopoulou (2001) have shown that 11.27 percent of US patents of the world's largest firms were attributable to research in foreign locations during the period 1991-1995. According to Le Bas and Sierra (2002), 58.5% of patents of 13 Swiss firms from their sample were based on R&D activities undertaken abroad (1994-1996). This share was very high in comparison with the 19.5 percent from the total firms of their sample. The overall share of US patents attributable to foreign locations was around 15% in Criscuolo and Patel (2003) study (1996-2000), and Switzerland has the highest share of technological activity abroad (68.3%).

In conclusion, the percentage of patents owned by Swiss MNEs and invented in foreign subsidiaries has increased (from 43.6% between 1980-1989 to 61.8% between 2000-2006). Foreign inventors are also concentrated in a few countries: 72 percent of patents invented in foreign subsidiaries were localised in Germany, in the United States and in France. Is this a form of offshoring, i.e. has the creation of R&D centres abroad by Swiss firms been accompanied by the closure of centres in Switzerland? According to the number of patents invented in the main countries, it seems that Swiss MNEs have not reduced their activities at home and Switzerland remains the country where Swiss

MNEs do most of their innovative activities (1412 inventions were generated in Switzerland in 2005, 736 in Germany, 560 in the United States and 207 in France, see Table 3). However, this has not been sufficient to discard fears that Swiss R&D is being marginalised at the world level, as the percentage of total foreign inventors has increased at a higher rate (12 percent) compared to Swiss inventors (6.7 percent) or to the overall inventions (9.2 percent) during the period 1980-2005 (see Table 3). Furthermore, the number of patents invented in all foreign countries accounted for 2231, while the number of patents invented in Switzerland accounted for 1412 in 2005. In other words, the inventions of Swiss MNEs made at home have not decreased, but have grown at a lower rate than their overall inventions.

Table 3. Annual average growth rates of number of patents by inventor's location, 1980-2005

	Period	CH	DE	US	FR	GB	Total foreign countries	Overall patents
Number of patents	1980	299	44	41	15	27	146	445
Number of patents	2005	1412	736	560	207	161	2231	3643
Annual average growth rate in %	1980-2005	6.7	12.5	11.5	11.6	7.7	12.0	9.2

So far, it has been shown through patents data that R&D activities of Swiss MNEs are highly internationalised. This could be a sign of weakness of the Swiss innovation system. However, other issues must be discussed to detect a potential risk of "hollowing out" of home R&D activities. Indeed, the activities in Switzerland have not decreased and Switzerland still remains the most innovative country for Swiss MNEs. In order to evaluate more precisely the place of Switzerland in this geographically dispersed R&D, I will use patent citations in next sections. In fact, one of the most important disadvantages of patent indicators is that the value distribution of patents is skewed as many patents have no industrial application whereas a few are of substantial value (OECD, 2006, p. 7). Thus, patents do not take into account differences in the quality of innovations, unlike patent citations (Criscuolo, 2002, p. 9). The next section will use patent citations to overcome this issue and evaluate the quality of the R&D made at home and abroad, providing information about the level of technological capacity of the home country, Switzerland.

b) Value of R&D activities

The previous section has shown that there has been an expansion of Swiss MNEs R&D undertaken in foreign subsidiaries. It seems reasonable to assume that home and foreign sites are not only complementary, but also compete with each other. In order to remain at the head of this international competition, Swiss R&D centres must provide a specific contribution to the international network of R&D (Fleisch Elgar et al. 2007, p. 21). This section will evaluate the contribution of Swiss R&D activities in analysing the value of the inventions made in Switzerland.

To measure the economic and technology value of a patent, I use the number of citations received by this patent (proxy used by Criscuolo and Patel, 2003; Harhoff et al, 1999). Most patent applications include a list of citations to earlier patents that capture "prior art". These citations determine the boundaries of a patent's claims of novelty, inventive activity and industrial applicability (OECD b, 2006, p. 38). A range of indicators based on patent citations have been developed, providing insights into knowledge flows and value of patents[4]. According to Criscuolo et al. (2002, p. 9), "the assumption is that a reference to a previous patent indicates that the knowledge in the latter patent was in some way useful for developing the new knowledge described in the citing patent." In this section, I will identify the most highly cited patents to examine the quality of the foreign technological activities compared to the home country technological activities.

This study builds upon a database constructed by the OECD, named "OECD/EPO patent citations database". The data set includes patent applications to the European Patent Office (EPO), from 1978 to 2006. For each published patent application, tables contain information about applicants and inventors (name, country and city), information about the patents (publication and application date and number, IPC code), and information about citations and cited patents (document type, citation lags, for further information, see Webb et al., 2005).

The EPO citations have been chosen because they are less noisy than the citations from the United States Patent and Trademark Office (USPTO). Indeed, in EPO applications, the applicant may optionally supply a list of references to patents. As a result, most of the citations (over 90%) have been added by the examiner. Their philosophy is to keep the number of citations to a minimum. Conversely,

[4] For a more detailed discussion of patent citation analysis, readers are referred to Jaffe, Trajtenberg and Henderson (1993); Jaffe and Trajtenberg (1999); Branstetter (2000); Almeida (1996); Frost (2001); Hall, Jaffe and Trajtenberg (2000) among others.

in the USPTO, applicants are legally required to provide a list of prior art. Thus, applicants tend to quote every reference even if it is only remotely related to what is to be patented (Michel and Bettels, 2001, p. 192).

Table 4 describes the origin of inventor(s) of cited patents by Swiss MNEs' patents (sample described in the previous section). Suppose a patent X applied for by a Swiss firm cites another patent Y. This last patent Y is a cited patent, and the patent X is the citing patent. In case of multiple cited patents, a fractional counting method is used. For example, if a patent cites 3 different patents A, B, and C, then a fraction (1/3) of the citing patent is assigned to patents A, B, C. With this method, a total of 6620 citations have been enquired from the 39281 patents described in the previous section[5]. Then, if the patent A has 2 inventors, every inventors accounted for 1/3 * 1/2.

The table shows, for example, that the share of cited patents invented in Germany (cited by patents of Swiss MNEs) was 21.9 percent. According to the results, cited patents were mainly invented in Switzerland (24.7%). In other words, it appears that R&D activities in home country have a substantial value for the development of Swiss MNEs innovation activities.

Table 4. Origin of inventor(s) of cited patents, 1978-2006

Country	Frequency	Percent	Cumulative Percent
CH	1637	24.7	24.7
DE	1449	21.9	46.6
US	1282	19.4	66.0
JP	849	12.8	78.8
FR	382	5.8	84.6
GB	379	5.7	90.3
IT	186	2.8	93.1
NL	102	1.5	94.7
Others	354	5.4	100.0
Total	6620	100.0	

Table 4 presented the origins of patents cited by every Swiss MNEs citing patents. Table 5 describes the origin of patents cited by foreign subsidiaries of Swiss MNEs. It shows, for example, that the share of cited patents invented in Germany (cited by Swiss MNEs' foreign subsidiaries) was 29.7 percent

[5] Citations received by a patent vary over time: an older patent might receive more citations than a younger patent, because it has been existed for a longer period (Criscuolo and Patel, 2003, p. 23). This effect was not controlled in this paper.

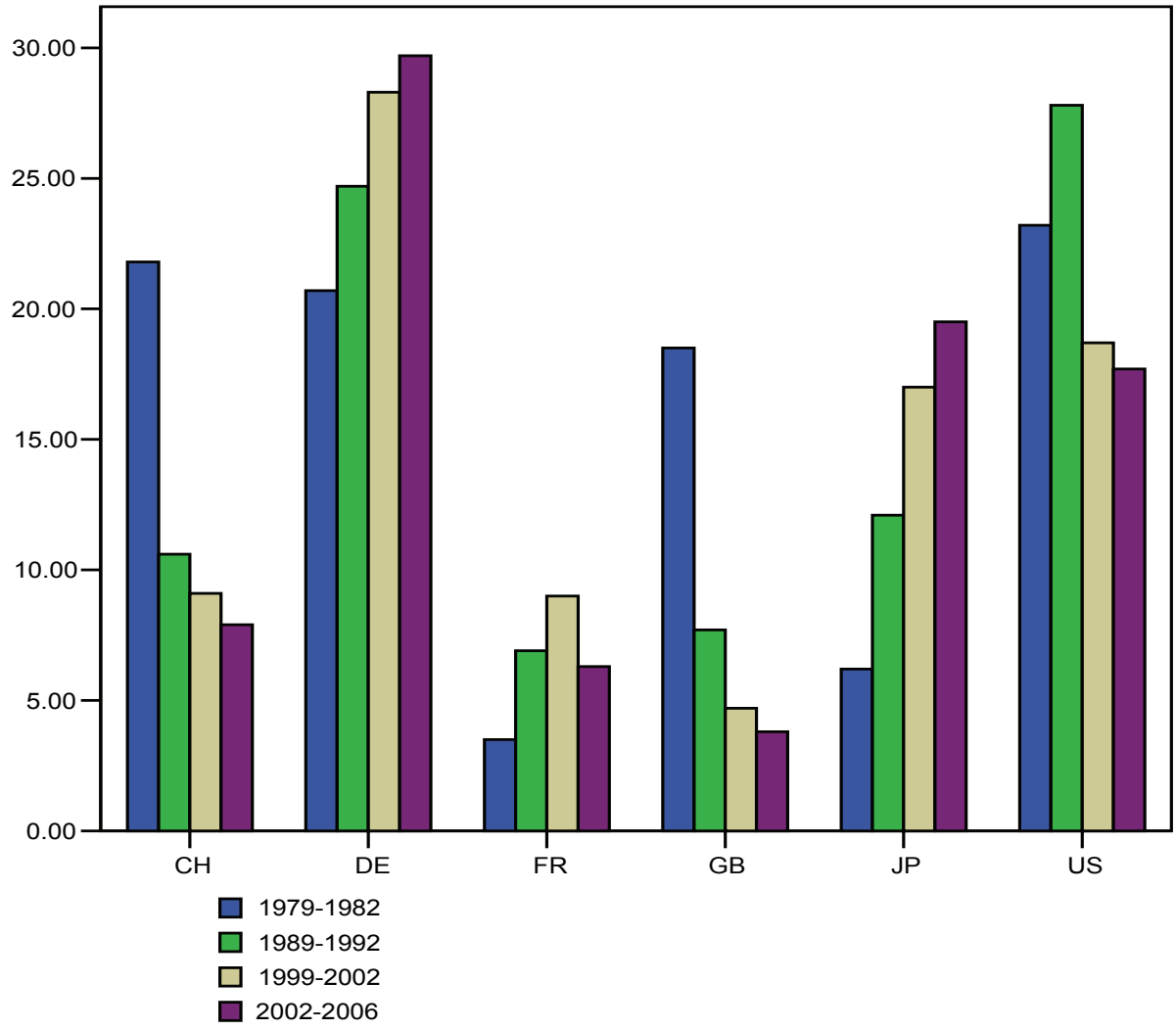
during 2003-2006. According to the results in Table 5, foreign subsidiaries of Swiss MNEs use foreign inventions to a greater extent than inventions made in the home base. Indeed, patents invented in Switzerland accounted only for 7.9 percent of cited patents in 2003-2006. Furthermore, the share of Switzerland in the origin of cited patents is decreasing : from 21.8 percent in 1979-1982 to 7.9 percent in 2003-2006. Figure 2 confirms these results and points up that Swiss MNEs' foreign subsidiairies are starting to show a growing interest in Germany and Japan, and a decreasing interest in Switzerland. In other words, it appears that R&D activities in home country have a lesser value for the development of Swiss MNEs innovation activities abroad.

Table 5. Trends in the geographical distribution of patents cited by foreign subsidiaries, 1979-2006

	1979-1982		**1989-1992**		**1999-2002**		**2003-2006**	
	Country**	%	Country**	%	Country**	%	Country**	%
Originating location of cited patents*	US	23.2	US	27.8	DE	28.3	DE	29.7
	CH	21.8	DE	24.7	US	18.7	JP	19.5
	DE	20.7	JP	12.1	JP	17.0	US	17.7
	GB	18.5	CH	10.6	CH	9.1	CH	7.9
	JP	6.2	GB	7.7	FR	9.0	FR	6.3

* cited by subsidiary patents, ** first five

Figure 2. Origin of patents cited by foreign subsidiaries, in percentage.



I identify the origin of the most highly cited patents to examine the quality of the foreign technological activities compared to the home country technological activities. I define highly cited patents as patents which have been cited twice or more. The 290 highly cited patents amount to 9.3% of overall cited patents. The following table presents the highly cited patents by foreign subsidiaries. It shows that the most highly cited patents come from foreign regions. These results confirm those found in the previous table: foreign subsidiaries give a higher value to inventions made abroad than in Switzerland.

Table 6. Origin of the inventor(s) of highly cited patents by foreign subsidiaries, 1978-2006

Country	Frequency	Percent	Cumulative Percent
US	46	32.5	32.5
DE	34	23.9	56.4
JP	17	11.7	68.2
CH	16	11.3	79.5
GB	9	6.4	85.9
FR	6	4.1	90.0
IT	6	3.9	93.9
SE	4	2.5	96.4
Others	5	3.7	100.0
Total	143	100.0	

Our results indicated that important innovations are not only produced in the home country but also abroad. The next section will evaluate more precisely where foreign inventors draw on their ideas: in their local environment or in the home country. It will assess the role of home country as a source of knowledge.

c) Localisation of sources of knowledge

This section evaluates the role of home versus foreign sources of knowledge. Table 7 allows us to investigate whether subsidiaries draw on local sources of innovation or exploit innovation developed in the home country. For example, German subsidiaries of Swiss MNEs (“citing”) have 1511 citations, of which 642 were invented in Germany (“cited”), 260 in the United States, 180 in Japan and 157 in Switzerland. We can assume that subsidiaries in Germany draw on local sources of innovation. Swiss patents invented in the United States have 662 citations, whose 359 were invented in the United States, 78 in Japan, 69 in Germany and 52 in Switzerland. These results indicate that knowledge originates mainly from the immediate geographic locale. Thus, foreign activities do not simply adapt their products to local conditions, but rather tend to tap into local sources of knowledge.

Table 7. Distribution of citing patents' origin and cited patents' origin, 1978-2006

		Cited												
		AT	CH	DE	FI	FR	GB	IT	JP	NL	SE	US	Others	Total
Citing	AT	**13**	**4**	7	0	3	3	0	7	0	0	11	1	**49**
	CH	18	**1298**	573	13	154	160	73	406	48	21	508	100	**3372**
	DE	14	**157**	**642**	4	79	68	39	180	23	6	260	39	**1511**
	FI	0	**1**	1	**3**	1	0	0	3	0	0	1	0	**10**
	FR	2	**57**	55	1	**83**	12	10	31	13	2	38	8	**312**
	GB	0	**17**	38	0	10	**83**	4	24	2	1	38	4	**221**
	IT	3	**17**	19	1	16	3	**38**	14	2	1	12	3	**129**
	JP	0	**7**	14	0	3	4	1	**72**	0	0	23	7	**131**
	NL	0	**5**	7	0	1	1	1	7	**6**	0	3	3	**34**
	SE	1	**5**	10	0	7	4	1	13	1	**19**	12	4	**77**
	US	2	**52**	69	1	21	35	13	78	8	4	**359**	20	**662**
	Others	0	14	13	0	4	2	6	11	0	0	15	11	**76**
	Total	53	1634	1448	23	382	375	186	846	103	54	1280	200	6584

Hitherto, patent citations data were used in order to determine whether foreign subsidiaries rely on their home base or on their host region for scientific inputs. The evidence shows that subsidiaries tend to cite patents originating in the host region more heavily than patents from domestic regions. The objective has been to determine the role of the home country as a source of knowledge. Consequently, it can be assumed that the competitive advantage of Swiss MNEs increasingly stems from subsidiary-specific advantages that emanate from the location of units in multiple knowledge centres. Conversely, the innovative performance is in a less extent dependant on the home base, as foreign subsidiaries tend to use knowledge arising from their local environment. Switzerland is then not the main source of knowledge of the global R&D activities of Swiss MNEs.

However, fears of "hollowing out" must be put in perspective. Some R&D activities are transferred to foreign countries, but knowledge flows back (European Communities, 2007, p. 14). In our sample, we can see that Swiss MNEs' patents invented in Switzerland have cited foreign locations: 61.5 percent of the citations of patents of Swiss MNEs invented in Switzerland were invented abroad. This could be seen as a sign of reverse technology transfer[6]. Furthermore, 1634 cited patents were invented in Switzerland, compared to 1448 in Germany, and 1280 in the United States. This fact indicates that Swiss MNEs still rely on home region knowledge sources.

[6] To be more precise in the analysis of "reverse technology transfer", we must only focus on the cited patents invented in foreign subsidiaries, not in foreign locations. This will be the subject of an upcoming paper.

Conclusion

This paper provides empirical evidence for the hypothesis that home countries still matter in a context of high internationalisation of R&D, and that fears of "hollowing out" should be limited. Findings can be summarized as follows.

There appears to be a trend for Swiss MNEs to internationalise their R&D activities at increasingly high levels. Foreign activities are now as important as domestic activities (in 2000-2006, 61 percent of Swiss inventions were undertaken in foreign subsidiaries). Furthermore, the inventions of Swiss MNEs made abroad have grown at a faster rate than their overall inventions (the inventions made at home have grown at a slower rate than their overall inventions). This situation could be regarded as an indication of a weakness of the Swiss technological competitiveness. The examination of patent citations to estimate the value of home and foreign innovations seems to corroborate this result. Using the number of citations received by a patent to measure its technological value, I found that the most highly cited patents by foreign subsidiaries came from host countries. This result shows that foreign sites compete with those in Switzerland and important innovations are generated in foreign locations. Furthermore, patents citations were examined to reveal where foreign subsidiaries drew their knowledge from. According to the results, foreign subsidiaries rely more on their host location than on their home country.

This analysis refutes the idea developed in traditional theories that companies' innovative activities are only significantly influenced by their home country's national system of innovation. Even if Swiss MNEs have increased their innovative activities at home, they are significantly influenced by the host countries' national systems of innovation as well. This situation can lead to concerns about the relocation of R&D activities. However, what is important is the amount of innovation taking place in the home country and the capacity of the home country to benefit from international spillovers. In our sample, Switzerland still remains the most innovative country for Swiss MNEs, and the creation of R&D centres abroad by Swiss firms has not been accompanied by the closure of centres in Switzerland. Furthermore, some R&D activities are transferred to foreign countries, but much of the knowledge flows back (European Communities, 2007, p. 14). Indeed, a single national innovation system can not offer the full range of technologies required by MNEs. With research facilities abroad, they may be able to take advantage of different specializations in foreign locations. In our sample, we can see that inventions of Swiss MNEs untertaken in Switzerland have cited foreign locations. This

could be seen as a sign of reverse technology transfer. In this case foreign R&D activities may provide access to foreign technologies and therefore can represent a channel for transferring knowledge back to the home country. However, this has not been sufficient to dispel fears that Swiss R&D is being marginalised at the world level. The results have illustrated the weakness of the lead held by Switzerland in terms of scientific, technological and innovative capacity. This phenomenon supports the conclusion that innovation system in Switzerland still matter, but at a decreasing level. An unexplored question is to analyse in which technological fields foreign activities are involved. It would allow evaluating if host countries are specialised in cutting edge technologies and if Swiss MNEs profit from foreign specialisations. Furthermore, the reverse technology transfer must be further examined to complete the analysis about the effects of FDI in R&D on home countries. These issues will be the subject of a following paper. Nevertheless, policy implications based on the first results of our analysis can already be advanced.

As R&D jobs are vital to developed countries, Switzerland must find ways to retain high-value-added activities. In order to do so, political makers should not try to dissuade Swiss MNEs to invest abroad, as Switzerland and Swiss MNEs can benefit from dispersed activities (e.g. tap into other sources of knowledge; enhance access to foreign markets; reverse technology transfer), but they ought to improve the Swiss innovative system. According to a study from the Swiss-American Chamber of Commerce and the Boston Consulting Group, one of the areas that Switzerland must address to retain key functions of Swiss MNEs is to supplement local skilled and specialized labour (make it easier for skilled foreign labour to work in Switzerland and make major efforts in education to improve the domestic pool of knowledge of know-how, BCG and AmCham, 2007, p 9). However, it may be difficult to significantly raise the real amount of domestic R&D in the short run because the supply of researchers is relatively inelastic (evidence suggested by Jaumotte and Pain, 2005). This is why internationalisation of R&D should be seen as an opportunity to overcome this constraint.

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