Globalisation of technology captured with patent data. A preliminary investigation at the country level

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Abstract
This paper uses patent data to investigate the globalisation of technological activities as led by multinational enterprises since the early 1990s. Three questions are addressed: i) what are the major patterns in the globalisation of inventive activities? ii) what are the motivations of technological globalisation? and iii) what is the impact of globalisation on the inventive performance of the countries investing abroad in R&D and of those receiving the investment? Patent data give meaningful and rich insights into the globalisation of technology. Major findings are as follows. The share of cross border inventions in total inventions is increasing, reflecting the globalisation of R&D and technology. However, there is substantial variability across countries regarding the characteristics, motives and effects of cross-border R&D in terms of knowledge transfer. The dominant motive of MNEs in most countries for developing R&D abroad is to acquire lacking and complementary technological competences, expanding their knowledge base –

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while adapting products to local characteristics comes second only. Knowledge transfers from cross border inventions, both to the owner and to the inventor country, are high and rising steadily, in most countries.

Key words: globalisation, cross border research, patents.

Introduction

Productivity growth at the level of the firm is strongly influenced by the increase in technology implemented in the production processes. It can be newly produced knowledge (coming notably from R&D) or it can be existing knowledge, acquired from another party (technology transfer).

The two sources of knowledge are not independent of each other as newly produced knowledge is based on existing knowledge, some of which can be transferred from other parties.

The role of multinational enterprises (MNEs) is central to both dimensions for the development of innovation and productivity at the country level:

- They allocate their R&D across countries (foreign affiliates)
- They transfer knowledge across borders: between their central lab (if they have one) and their affiliates, among their affiliates.

Hence cross border flows of technology play an important role in innovation performance of countries, and there is evidence that these flows have been gaining importance over the past decades. The R&D expenditure in foreign affiliates of MNEs represented USD 67 billion in 2005, more than 10% of worldwide business R&D (it was USD 30 billion in 1993). In certain countries this share is much higher, so that foreign firms have decisive influence on these countries’ innovation patterns. Cross border patents (corresponding to MNEs inventions abroad) represented more than 17% of all patents (PCT) in 2003 (10% in 1990).

This new context raises particular policy challenges (OECD, 2007). The central debate has turned around the size and sharing of the benefits generated by these cross-border flows. What the the impact of MNEs foreign affiliates’ R&D, on innovation at large, on the host country, on the owner country? Because globalisation of research implies a two-way channel (through inward and outward activities), national policymakers are confronted to a twofold policy challenge: How to stimulate the internationalisation of domestic firms while ensuring the reinforcing of national innovation capabilities? How to attract innovative companies that will strengthen domestic capabilities?
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To date the evidence is not sufficient to discern how and to what extent globalisation of research will change the conditions for S&T production and its contribution to economic growth. One important limitation for answering these questions remains the lack of internationally comparable data addressing the different dimensions of globalisation. Patent data are in that regard a potentially fruitful source of information.

In that context, this study will address the following questions:

1. What are the major motivations for MNEs to conduct innovation activities abroad?

2. What is the impact of MNEs overseas’ R&D on:
   a. the efficiency of research (i.e. quality of R&D conducted abroad compared to research conducted at the home country);
   b. the owner country’s technology (“hollowing out” vs. expansion of national capacity);
   c. the host country’s technology (“knowledge drain” vs. local development).

This study is conducted at the country level, from countries’ perspective. There are advantages and drawbacks in conducting an investigation of this kind at the macro level. The investigation at the country level allow us to evaluate the overall effects in terms of knowledge transfer (inward and outward) associated to globalisation, regardless of the type of company. This is the best way to go when addressing the contextual aspects of MNEs’ strategy, the general determinants and impact of internationalisation. We acknowledge though that, in order to capture the microeconomic aspects and to reflect more directly the strategy of the MNEs, the firm level dimension has to be integrated into the analysis. This is the next step of our work, not reported here.

**Patent indicators of internationalisation**

In order to address the questions above we use patent data. Patents are exclusive rights over inventions, which are granted by national patent offices. Information reported in patent documents, hence that can be used in statistics, includes:

- The name and address of the applicant (owner company).

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1 Information from surveys on foreign affiliates’ activities (e.g. OECD-AFA Database) is currently providing important insights but their coverage remains still limited to few countries. Other indicators available from R&D statistics and trade include the share of R&D financed by abroad sources, trade in high-technology products, receipts and payments in technology; mobility and migration of S&T workers, etc. (i.e. OECD, 1998; 2005).
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- The name and address of the inventor (individual); it is most often the address of the laboratory where the invention was done.
- The technical field of the invention (international classification).
- Citations to prior art (antecedents, notably other patents).

The advantages of using patent indicators for tracking developments of technology are numerous. In spite of their drawbacks\(^2\) (OECD, forthcoming), patents offer important advantages to investigate technological activities: broad availability and international comparability, exhaustive coverage across countries and technology fields, readily access in electronic formats, amongst others.\(^3\) Furthermore, most significant inventions are patented; patents have a close (if not perfect) link to inventions. Patents provide a reasonably complete description of the invention, the technology field concerned, the inventor (name, geographical location, etc.), the applicant (ibid), cites to previous patents and scientific articles to which this invention relates to, amongst other things.

Patents used in this study are PCT (“Patent Cooperation Treaty”) patent applications, monitored by the WIPO. The PCT is a route for filing patent applications in nearly all patent offices in the world at the same time. The advantage of the PCT, from a statistical perspective, is that they are far less biased, in terms of country repartition, than other types of patents, which are all tied with a particular country or region.

Patents corresponding to “cross-border” inventions (made by foreign affiliates of MNEs) are defined as those whose the applicant (owner) and inventor reside in two different countries.

This is interpreted as a patent coming out of research conducted at a laboratory pertaining to an MNE and located abroad, in a different country than the headquarters. Following Guellec and Van Pottelsbergh (2001), using this information contained in patents, two indicators of cross-border ownership can be computed at the country or technology/regional level:

- Foreign ownership of domestic inventions: It takes the host (i.e. R&D performing) country’s perspective; it refers to patents which are applied by a company from abroad and which have at least one domestic inventor. The

\(^2\) Not all inventions are patented (and not all companies patent, some prefer secrecy, first to market strategies, etc.); the value distribution of patents is skewed, the propensity to patent differs across countries and industries, differences in patent regulations make it difficult to compare patent statistics across countries, etc (e.g. Griliches, 1990).

\(^3\) Patents cover a broad range of technologies and countries on which there are sometimes few other sources of data, patent data are available for a long time period (e.g. USPTO has been granting patents since 1836).
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The number of such patents can then be divided by the total number of patents invented domestically.

- **Domestic ownership of inventions made abroad**: It takes the owner (i.e. MNE’s headquarters) country’s perspective; it refers to patents which are granted to a country but whose inventions have been made abroad with at least one foreign inventor. The number of such patents can then be divided by the total number of patents owned by the country regardless of the country of residence of the inventors.

The first indicator reflects the extent to which foreign firms control domestic inventions. Symmetrically, the second indicator reflects the extent to which domestic firms control inventions made abroad, by residents of other countries.\(^4\)

Obviously, these indicators are not independent from each other. What is accounted as a foreign ownership in one inventor country implies a domestic owned invention abroad by domestic firms in another country.\(^5\)

The utility of patent indicators to measure globalisation are not however without shortcomings. A large part of the caveats have to do with the practical limitations in patents to properly identify companies’ countries’ of origin and their strategies for dispersion/location of ownership.

- **The owner country as identified in the patent document may be in some cases, not the country where the headquarter of the company is located (where the resources come from), but the country of the subsidiary in charge of management of international intellectual property (i.e. an intellectual property holding company). Certain companies have set up an IP-holding company which files patents on its behalf world-wide and which is located in a low tax country.**

- **A second issue concerns the actual economic meaning of the cross-border ownership.** A patent invented abroad may not necessarily mean a setting up of a R&D laboratory but rather from an acquisition or merger. Hence, such an invention would have become cross border only some time after it was made, and the cross border character could not have affected

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4 Some fraction of these patents subject to cross-border ownership might also represent a co-ownership between two companies located in different countries; but again this case more likely concern cases of co-ownership between headquarters and foreign subsidiaries. It represents however a very small share of total patents subject to cross border ownership.

5 Thus, the worldwide total of patents with foreign ownership of inventions is therefore the same as domestic ownership of inventions; total patents subject to cross-border ownership.
the invention process. Patent databases do not register such changes in the ownership of patents. Changes in ownership, in our database, are registered until the grant of the patent (on average 3 to 5 years after application), not later. So, this problem should not be too large.

- A third issue is that a patent can be taken directly by the local affiliate of the foreign MNE, without the MNE being mentioned in the patent filing. The consequences are that ownership in fact does not belong to “domestic” firms and therefore foreign ownership for some countries is underestimated (e.g. see the case of Belgium in Cincera et al, 2006); and symmetrically domestic ownership of foreign inventions is underestimated for the owner country.

While issue 2 might result in overestimating cross border inventions, issue 3 might lead to underestimate them. Casual evidence suggests that issue 3 is more widespread than issue 2, so that overall patent data tend to underestimate the degree of internationalisation of technology.

It has to be noticed that patent data used in this study come from the OECD Patent citations database, which was still experimental at the time of data extraction. Hence, certain figures presented herein are subject to possible revisions.

**Patterns of globalisation**

Numerous studies conducted since the early 1980s have documented an unambiguous rising trend in the globalisation of technological activities (e.g. Cantwell, 1992, Patel and Pavitt, 1999). The driving forces include changes in the global value chain by multinational companies (OECD, 2006), a fierce technology based competition, but also a greater flexibility in handling cross-border R&D projects (lowering coordination costs), amongst others. The tendency to internationalise research and technological activities has also been favoured by major policy changes, notably the international strengthening of intellectual property rights (e.g. TRIPs agreement) and the improvement of conditions for direct investment and technology transfer activities.

These factors have led multinational companies to disperse increasingly their sources of knowledge in an effort to integrate worldwide learning process (e.g. access to foreign centres of excellence, seek of strategic partnerships in innovation, etc.) and produce competitive technology at lower costs. These strategies take part of new innovation models (the ‘open-innovation’ model, e.g. Chesbrough, 2003) where external sources of knowledge play an increasing strategic role in the production of technology.\(^6\)

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\(^6\) These links include horizontal (competitors), vertical links (suppliers, clients) and public research organisations and universities, etc.
The figures based on patent confirm the expansion of globalisation of technological activities. Cross-borders inventions represented more than 17% of all patented inventions in 2003 world-wide; their share have been continuously increasing since 1990.

The host country’s perspective is reflected in foreign ownership of domestic inventions, i.e. inventions made in the country and owned by foreign entities. Among countries for which data are reported, this share varied, in 2000–2002, from 4% (Japan) to 62% (Luxemburg). Most countries are between 10% and 40%. Among the large counties, the UK comes first with 35%. Sweden is at 18%. Some patterns emerge from the cross country comparison (see Guellec and van Pottelsbergh 2001). Overall, countries with a higher share of domestic inventions owned by foreign MNEs are:

- Smaller countries: this reflects a quasi-mechanical effect of size, which affects all economic variables (trade, foreign direct investment etc.)
- Countries with lower own R&D capability (R&D over GDP): this is probably related to the ability of domestic firms to generate new inventions. The lower it is, the more the country relies on foreign entities to set up such capabilities. As a matter of fact, most countries which experienced a decline
in the share of foreign owned inventions are those which experienced an increase in their national capabilities (Eastern European countries, non-OECD countries).

It has also to be noticed that, in view of their size and R&D intensity, Japan and Korea feature very low, and it is also the case of Finland and, although to a lesser extent, Sweden. This relative insulation could be related to the openness of the capital market, in the case of Japan and Korea. For Finland, linguistic factors could play a role.

The owner country’s perspective is reflected in domestic ownership of foreign inventions, i.e. inventions made abroad and owned by domestic entities. This share varies from 4 % (Japan) to 82 % (Luxemburg). As for domestic inventions owned by foreign entities, the size factor plays a visible role. But the domestic R&D capability plays a role which is opposite: Countries with higher R&D intensity own a larger share of inventions made abroad. Hence, R&D intensive countries will in general have a higher share of their owned inventions made abroad than of their domestic inventions owned by foreign firms. That explains for instance the higher ranking of Sweden and Finland, or also Switzerland. It also explains the fact that the EU, considered as a single zone, has only 7 % of its inventions made abroad whereas the US has 11 %. Again, Japan and Korea feature the lowest, despite their high R&D intensity. MNEs from these two countries prefer to conduct their R&D at home.

**What motivates cross border R&D?**

Two main explanations (not exclusive of each other) have been given for MNEs to locate their R&D overseas:

- Knowledge sourcing (or “asset expanding”, “tapping talents”): the MNE intends to use (tap in) knowledge capabilities of the host country in order to expand its own knowledge capabilities. Hence the core knowledge of the firms is enriched by overseas’ R&D.
• Product adaptation (“asset exploiting”, “market access”): the MNE uses local competences in order to adapt some of its products to local tastes, regulation etc. Core knowledge is transferred from the MNE to its local affiliate.

We test the relative importance of these two motives on the basis of the following assumptions:
• Knowledge sourcing is associated with host country inventions as a source of cross-borders inventions.
• Product adaptation is associated with owner country inventions as a source of cross-borders inventions.

The sources of a particular inventions can be tracked through patent citations. Any patent is published together with a search report, drafted by a patent examiner at the patent office, which includes references to the prior art, i.e. other inventions (most often other patents) which can be seen as a background for the invention. We can therefore track the use of inventions done in the host country in foreign owned inventions (how often they are cited) and the use of the owner country inventions in inventions it owns but made abroad (how often they are cited). We use the share of backward citations (average reported by patent) made to inventions produced by the host country (sourcing), and inventions produced at the home owner country (exploiting), in total backward citations made by patents produced with inventors located abroad.7

**Figure 4**  
**Knowledge Sourcing**

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7 This raw citation shares provide useful information on the gross flows of knowledge between the recipient and investor economies (totals). Further investigation at the partner-partner level, would allow to establish the intensity of such knowledge relationships across countries or regions, taking into account their size (e.g. number of patents). By looking by partner country, we should be able to compute the citation frequency, a measure of how intensively patents in one country cite patents from another after controlling for the size of the potential pool of citations between the two. In simple terms, it is the number of citations from country A to country B divided by the product of the potential number of citing patents in country A and potential number of citable patents in country B.
The identification of the use of knowledge originated at home and originated at the host country in cross border inventions provides some insights. First, the two objectives are present, together, but knowledge sourcing seems to be dominant OECD-wide. For inventions made during 2000–02, citations to the host country represent around 36% of citations in cross border patents (average share by patent), whereas owner country citations represent 37% only – despite the fact that the owner country is generally more advanced technologically than the host country. Thus, the two objectives co-exist; on average, same importance. There has been little change in that regard between 1990–92 and 2000–2002. It should be noticed tough that knowledge sourcing was bit more important in the early 1990s (39% vs. 36%).

The importance of knowledge sourcing is particularly clear in the case of EU MNEs. At the opposite, in the case of the US it is the exploiting knowledge motivation which seems to dominate: US MNEs do R&D abroad more for adapting their products. Lastly, Japanese MNEs appear as being driven by the two motivations: they locate research abroad for both reasons, to exploit knowledge assets as much as for tapping knowledge. It should be noticed though that for Europe as a single zone (15) both motives have relatively low importance apparently, as compared with the rest of reported countries.

The fact that the knowledge sourcing motive has not gained in relative importance over this period of time seems to contradict a claim often made in the literature and in policy discussions. But this has to be qualified however: first, this motive was very important already in the early 1990s; second, if one takes into account the increased share of cross border inventions in total inventions, then the role of knowledge sourcing in innovation systems, in absolute terms, have strongly increased over this period, although no more than product adaptation.
The relative quality of inventions

This section investigates the quality of research conducted abroad compared to research made and owned within national boundaries. We measure and test the importance of cross-border inventions based on the citation impact of inventions, which is considered in the literature as a measure of technological importance and an indicator of economic value. It has been consistently reported in empirical studies that patents that receive more citations than the average are more valuable patents; are more likely to be renewed and opposed in tribunals. Our questions are the following: Are cross-border inventions different in quality as compared with domestically made inventions? How this difference has changed over time?

The quality of inventions made overseas compared to the quality of domestic inventions can be interpreted as a measure of the efficiency of R&D activities conducted abroad. A decreasing gap in quality may explain in part the rising of international research activities. It would suggest that companies are becoming more able to overcome technology transfer costs (related to geographic and cultural distances) and other inefficiencies related to dispersion of knowledge (e.g. leakage-out, integration into host national innovation systems, etc.).

Different factors might contribute to make research activities abroad more efficient and with higher quality. It has been recently argued that the traditional shortcomings related to decentralisation of research might be less severe. Multi-location firms compensate inefficiencies with gains related to integration of diversified knowledge on a worldwide basis. Kogut and Zander (1993), Almeida (1996) or Singh (2006) have shown that subsidiaries may successfully tap into external knowledge sources geographically distant. Accordingly, MNEs implement formal and informal mechanisms (i.e. intra-firm mobility of experts, inventors with extensive social networks), which allow them to cross-regionally integrate dispersed knowledge and overcome coordination problems.

Relying on forward citations, different approaches can be implemented to investigate the quality differential of cross-border inventions. A first approach

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8 Forward patent citations have been proven to be good indicators of economic value. Numerous studies have consistently corroborated the correlation between the citations received (notably no-self citations) and the economic value of patents as perceived by inventors, the likelihood of patent opposition or renewal (e.g. Harhorff et al, 2003). Further, patents being more frequently cited, as they have a strong technological impact, they are also more highly valued by investors in the stock market (Hall et al, 2001).

9 Singh (2006) has recently tested three of these informal mechanisms on the value of patents for multinational firms. He finds that while distribution of R&D appears to be negative associated to the average value of innovations; patents reporting knowledge sourcing from other R&D units (e.g. patent citations), having at least one inventor with cross-regional ties, and having at least one inventor that has recently moved from another region; all seem to have higher quality.
consists in comparing the citation impact of domestically made inventions and cross-border inventions.

- The **citation impact** (Hall et al, 2001) is an indicator on the quality of inventions. It is the number of times a patent is cited compared to the average number of citations received by a patent regardless in the same technology field (4 digit IPC class) and having the same invention date (priority date).\(^{10}\)

- The **relative citation impact** (ibid) compares then the quality of cross border inventions relative to the quality of inventions made uniquely within domestic boundaries.\(^{11}\)

### Figure 6 Relative Citation impact

We examine the average relative citation impact across inventions for our sample of countries. It appears that overall cross border R&D has a technological impact as big as R&D conducted at the home countries (by the same owner country). The difference is particularly elevated for Sweden (60 %) and for the US (above 50 %). For the US, the gap has increased sharply since the early 1990s. For large European countries the gap is not significant, reflecting probably the fact that most foreign R&D owned by European countries is made in other European countries, which are not that different from doing R&D at home. It is pretty much the same level of quality between cross border and home made inventions between the two periods. The UK is the only country in the sample which has experienced a sharp drop in the relative quality of R&D conducted abroad. Finally, Japan used to have its MNEs R&D conducted abroad of lower impact than the one conducted domestically, but the two have converged since.

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10 This approach permits to control for the differences in citation frequency across technology fields and the truncation effect related to time (earlier patents having an intrinsic lower probability of being cited, see Hall et al, 2001).

11 It is a measure of advantage or disadvantage the country has in performing research abroad compared to the home country: an index superior (inferior) to one indicates that companies from that country produce inventions with higher (lower) quality average than those produced at home.
The impact of cross border R&D on the owner country’s inventions

It is sometimes argued that MNEs, by investing abroad, would be detrimental to their home country, as they reinforce the technological capacity of competing countries instead of their own. On the other hand, it can be argued that by investing abroad, MNEs strengthen the technology base controlled by entities of their home country, a base which can then serve for value creation appropriated by the home country.

A second hypothesis explaining the expansion of internationalisation of technological activities concerns the increase in efficiency of global research activities. In other words, international technological activities become easy to conduct as the ability of companies to integrate knowledge developed abroad has increased and companies become more competent in transferring knowledge back to headquarters (Criscuolo et al, 2004). This reverse knowledge transfer is achieved through different means: companies’ knowledge management practices, mobility of experts within the network, increased flexibility in the management of information, etc. Indeed, opportunities for cross-border learning have been enhanced by an increased take-up of ICT technologies (Cantwell, and Santangelo, 1999).

This argument is in line with the idea that companies and so, investor countries can benefit from having technology “listening posts” in foreign countries. It is important to mention as well that the benefits of reverse knowledge transfer through multinational companies might be higher for the host economy as spillover-backs can be also disseminated to other companies into the source country. There might be some costs however associated to a growing delocalisation of technological activities; so far not yet confirmed. It has been argued that increasing off-shoring of technological activities may lead to an erosion of domestic capabilities (hollowing out), and employment and economic losses if results are only exploited outside the home market.

It has to be noticed however that most arguments in favour of the “hollowing out” theory ignore the non rivalry of knowledge: the fact that one piece of knowledge, even if used in one place, can also be sued in other places, by different entities, at the same time. It is therefore not contradictory to have knowledge being used both in the owner and in the host country.

We test here the extent to which cross border inventions are used as a source of knowledge for further inventions in the owner country. We use the share of backward citations (average reported by patent) made to inventions made abroad in inventions made exclusively with domestic inventors. This indicator reflects
the weight of imported owned knowledge among inputs to the production of new knowledge.

Figure 7  Reverse Knowledge Transfer

Citations to cross border inventions in domestic (owner country) inventions have been increasing since the early 1990s, although at a reduced pace in the late 1990s–early 2000s. Their share has grown from 2 % to 3 %. The level is particularly high for the US, Germany and Switzerland. It is very low France, Sweden, Denmark and Japan. In the UK, this share has been declining. Hence such imported knowledge plays a significant role in further inventions in the owner country.

Figure 8  Reverse Knowledge Transfer

The impact of cross border inventions on host country’s inventions

Arguments exchanged around the effect of cross border R&D on the host country’s inventive capacity mirror those exchanged on the effects on the owner country. On the one side it has been claimed that foreign owned R&D would
drain local resources, picking some of the best researchers, creating value from local research of which domestic companies are then deprived. This “knowledge drain” argument is in fact a variant of the “knowledge sourcing” theory of cross border R&D, a variant which denies any benefit to the host country (all benefits being appropriated by the owner country). On the other side, it has been argued that foreign MNEs R&D facilities can be a source of local spillovers, allowing technology transfers from the owner entity (then owner country) to the host country.

We examine here the influence of cross border inventions on domestic inventions, in the host country by looking at the extent of knowledge transfer to local inventions. We measure it by the share of citations to cross border inventions in domestic inventions of the host country.

**Figure 9  Knowledge Spillover from Foreign owned inventions**

Such citations represented about 3.6 % of total (backward) citations in OECD in 2000–2002, against 2.5 % in 1990-1992, reflecting the growing spillovers which accrue to the host country. The growth in citations to cross border inventions is observed particularly in the US, where its level is also the highest in the triad. The EU 15 countries has barely changed, while Japan has experienced a significant increase, but keeps at the lowest level in the triad, just before Denmark.

**Conclusion**

- Patent data give meaningful and rich insights into the globalisation of technology.
- There is substantial variability across countries regarding the characteristics, motives and effects of cross border R&D.
• Increased share of cross border inventions in total inventions, reflecting the
globalisation of R&D and technology.
• The dominant motive of MNEs in most countries for developing R&D abroad is to acquire lacking or complementary technological competences, expanding their knowledge base – while adapting products to local characteristics comes second only.
• For numerous countries, there has been upsurge in the efficiency of research conducted abroad, which indicates a higher ability to deal with inefficiencies related to dispersion and transfer of knowledge.
• Knowledge transfers from cross border inventions, both to the owner and to the inventor country, are high and rising steadily.

Further investigation will be conducted in the future at the company level (microdata). It will also make use of harmonised data on patent citations: hence results presented in this study should be considered as provisional.
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