Tracking the internationalization of multinational corporate inventive activity: national and sectoral characteristics

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ABSTRACT

This paper introduces a unique database, the Corporate Invention Board (CIB). The CIB combines patent data from the PATSTAT database with financial data from the ORBIS database about the 2289 companies with the largest R&D investments. We illustrate the database by showing a comprehensive overview of national and sectoral patterns of R&D internationalization by multinational corporations in the period 1993–2005. The results show heterogeneity in sectoral and national patterns of internationalization. These patterns have remained relatively stable over the 1993–2005 period. China is among the least internationalized countries and European countries, especially the UK and the Netherlands, are among the most internationalized countries. The largest countries in terms of patent production, such as Germany and the US, have internationalization profiles that can be very well predicted based upon their sectoral composition. Other country profiles, however, diverge significantly from the prediction based on sectoral profile. Asian countries are on average less internationalized than would be expected, whereas the European countries and Canada are more internationalized. We find that while national level indicators explain a large part of the variance observed in the ability of countries to attract R&D from foreign multinationals, there are significant differences between sectors and this has large implications for the design of foreign R&D and innovation policies. The CIB opens up a wide array of opportunities to study the internationalization strategies of firms and countries.

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1. Introduction

The ongoing internationalization of the R&D activities of firms is a subject of considerable interest to policymakers (UNCTAD, 2005; OECD, 2005), as innovation is recognized as a main driver of productivity and growth for countries, as well as a vital resource in addressing societal challenges. Policy concerns focus on the potential loss of jobs and economic benefits, the potential loss of competitiveness of domestic firms, and the impoverishment of the local knowledge base associated with the increasing local R&D presence of foreign-owned firms and the decreasing presence of R&D by domestic firms (Dunning and Lundan, 2009; Moncado-Paternò-Castello et al., 2011; Carlsson, 2006). Especially the increasing importance of Asian countries as R&D location (Heimeriks and Boschma, 2014) leads to a growing concern among policy makers for hollowing out the national innovation system (Narula and Zanfei, 2005). Many countries therefore have policies in place to enhance their R&D climate, promote inward foreign direct investment in R&D (FDI), and absorb the benefits of both inward and outward FDI. Any policy making in this area starts from the availability of adequate data on the internationalization of the R&D of multinationals.

Empirical research into the drivers of the internationalization of corporate invention in recent years has identified R&D internationalization as a very heterogeneous process where, in addition to national and company related considerations, sectoral considerations are important. More specifically, significant differences in the international dispersion of innovative activity across sectors and countries have been identified. Some small economies, such as Belgium, the Netherlands and Switzerland have internationalized their innovative activity at a faster rate than their production

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activities (Narula and Zanfei, 2005). This is not case for all countries, which emphasizes the continued importance of national and regional institutions and arrangements (Storper, 1993; Crescenzi et al. 2007, 2012). Likewise, there are also considerable industry-specific differences that encourage or discourage concentration in as few locations as possible (Cantwell, 1989). However, there is currently insufficient evidence to identify general patterns of internationalization of corporate invention with respect to sectoral and national characteristics.

Moreover, while these previous studies have yielded many valuable insights, their level of analysis is usually the multinational company rather than the (national) innovation system, which makes it more difficult to extract policy implications(Archibugi and Iammarino, 2002; Cantwell and Piscitello, 2000). In addition, earlier studies suffer from limitations in data quality. In this paper we follow earlier researchers in using patents, a measure of the output of inventive activity, to identify the internationalization of the inventive activity of multinationals. While several important contributions have used patents to study the globalization of R&D, the data quality of existing patent databases has caused these studies to either use only a subset of multinationals, or all patents (including those from non-multinational actors) in their analysis. Or as Picci and Savorelli stated regarding cleaning data on the entire set of multinational actors: "it would be prohibitively costly to do so" (Picci and Savorelli, 2012). As a result, there is currently insufficient evidence to identify the internationalization of corporate invention with respect to sectoral and national patterns. Informed innovation and (foreign) R&D policies do however critically depend on (1) a good and precise overview of the R&D of multinational enterprises, and (2) insights into the relevance of global, national, and sectoral drivers of *inward* and *outward R&D* flows on the national level. Both are currently lacking.

The aim of this paper is to introduce a unique and previously unavailable database, the Corporate Invention Board (CIB). The CIB combines patent data from the PATSTAT international patent database with financial data from the ORBIS database about the 2289 companies with the largest R&D investments. Merging the two datasets required substantial cleaning and disambiguation of the firm data available in the PATSTAT database. The industrial corporations included in the CIB account for 80% of world total private R&D[1], of the 2289 MNC's, 730 have their corporate headquarters in Asia, 1002 in Europe and 538 in northern America. This unique database allows us to characterize the nature and the extent of technological internationalization, and to analyze the transformation of global patent portfolios of multinational corporations in the last decades. As a measure for the internationalization of R&D, we use transnational priority patents, patents that have been applied for in at least two countries. The sample used in this paper consists of the 712 333 transnational priority patents applied for by the 2289 CIB companies in the period 1993–2005. The (CIB) database has been designed specifically for studying the internationalization of R&D.

As such, the CIB allows for a more evidence based approach than most existing studies that rely on surveys (Gorg and Strobl, 2001), or on a smaller sample of patents within a given sector (Almeida, 1996) or country (Patel and Vega, 1999). Our study is similar to recent studies (Picci and Savorelli, 2012; Picci, 2010), in that it uses worldwide patents. Their use of the PATSTAT database as the single source of data does however not allow distinguishing different types of actors, while the CIB enables to identify multinational corporations, their subsidiaries and link patents to these actors.

The paper proceeds as follows. First, in Section 2 we describe prior work in the area. Section 3 discusses the dataset, and the data

collection process and gives some descriptive statistics. The different patterns of internationalization are discussed in Sections 4 and 5, and their relative contributions in Section 6. Finally, Section 7 concludes.

2. The internationalization of R&D

The home country of a multinational corporation (MNC) is usually also its preferred R&D location. The R&D activities of firms seem more difficult to internationalize than other firm activities and the internationalization of the innovative activities of MNCs has lagged behind that of their productive activities (Pavitt, 2001). This centralization of R&D in the home country is explained both from the alignment and co-evolution of MNCs with the innovation system in their home country as well as from economies of scale and agglomeration in R&D. Furthermore, the national specificity of countries is reflected in the product life-cycle. New products are introduced to meet local (i.e., national) needs, and new products are first exported to similar countries, countries with similar needs, preferences, and incomes (Klepper, 1996). Patterns of internationalization thus, change over time.

The past decades have seen a notable increase in the internationalization of corporate R&D (Dunning and Lundan, 2009), increasing the relevance of research into the national and sectoral factors that determine foreign R&D investment. Research on locational factors distinguishes two sets of motives from a corporate perspective for international R&D (Kuemmerle, 1997). In the early literature, such R&D was mostly found to be of a home-base exploiting nature (Casson et al., 1992; Pearce and Singh, 1992). This type of R&D, also called product adaptive R&D, focuses on the exploitation of the home based capabilities of the MNC abroad. While the availability of R&D personnel in the host country does play a role in the location decision, the size of the host market (mostly measured in GDP) is the most important locational factor here.

In recent years, a rise in a second type of R&D internationalization has been observed. This type of R&D, termed home-base augmenting R&D, focuses at generating new knowledge and competencies for MNCs and has increased since the 1990s (Cantwell and Mudambi, 2005; Kuemmerle, 1999; Iammarino and McCann, 2013; Von Zedtwitz and Gassmann, 2002). Home-base augmenting strategies are argued to be particularly important for MNCs that seek to protect their global competitive position and cause firms to move their R&D into locations which have an advantage in a certain area of technology, Florida, (1997) calls this a 'technology-oriented posture'. The quality and character of national innovation systems (Lundvall et al., 2002) is thus important for this type of strategy, as is the sector specific need for technological knowledge.

The tendencies for R&D centralization and internationalization are not equally distributed among sectors. The importance of sectoral considerations is (implicitly) highlighted in the literature at the corporate level (Malerba and Orsenigo, 1996). Empirical evidence suggests that economic factors, such as profitability, capital intensity, and demand size and growth, have little explanatory power with regard to the observed variety of geographical patterns among sectors and that, in order to explain this variety, it is necessary to take into account the nature of technological knowledge in different industrial sectors (Marsili, 2001; Dosi et al., 2006).

Sectors are fundamentally shaped by the underlying conditions affecting the creation and reproduction of technological knowledge. These 'technological regimes' (Winter, 1984), play an important role in determining the interdependencies between industry characteristics and spatial agglomeration. (Nelson and Winter, 1982; Cantwell, 2001). Research focusing on the sector specific features of innovative activities and industrial dynamics, proposed categories that group sectors on the basis of the

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[1] http://iri.jrc.ec.europa.eu/scoreboard.html.

properties of the processes through which firms innovate (Malerba and Orsenigo, 1996; Breschi et al., 2000; Malerba, 2002).

While all commodities and services embody some knowledge, industries differ significantly in the extent to which they rely on R&D, just as the relationship between public or potentially generic knowledge and tacit capability differs across industries. Some sectors are shaped by a high degree of cumulativeness of knowledge, and high appropriability. In these cases, knowledge accumulation occurs mostly through sources inside the sector, such as in-house R&D, a pattern of industrial dynamics characterized by low entry and high geographical concentration is likely to prevail. If instead new opportunities come from sources outside the sector, such as academic research and generic and non-systemic knowledge, high entry and low geographical concentration are likely to be dominant.

These conditions affecting the creation and reproduction of technological knowledge have crucial implications for the internationalization of corporate research. There are several reasons why asset-augmenting R&D activities in high tech sectors would be hard to achieve at a distance. Most of these reasons are associated with the partly tacit nature of technological knowledge. When the technological knowledge relevant for innovative activities is located in a certain geographical area and it is "sticky", foreign affiliates engage in asset-augmenting activities in these areas in order to benefit from the external economies and knowledge spillovers generated by the concentration of production and innovation activities in specific regional or national clusters (Narula and Zanfei, 2005). While the marginal cost of transmitting codified knowledge across geographic space does not depend on distance, the marginal cost of transmitting tacit knowledge can be expected to increase with distance.

While many institutional and cultural factors may influence the transmission of knowledge, the importance of space in lowering the barriers and costs of knowledge sharing and transmission is related to the basic properties of knowledge and learning processes, most of all their degree of complexity and tacitness (Breschi and Malerba, 2005; Boschma et al., 2014). This can be expected to lead to the clustering of innovation activities, in particular at the early stage of an industry life cycle where tacit knowledge plays an important role (Audretsch and Feldman, 1996).

As a result of their different national characteristics and sectoral composition we expect that countries show very different levels of internationalization of R&D, even if we take into account the different sectoral composition of countries. Furthermore, we expect that incoming R&D reflects the relative comparative advantage of countries in different sectors, in particular at the early stage of an industry life cycle where tacit knowledge plays an important role. However identifying these patterns requires the construction of a comprehensive database on the internationalization of multinational R&D.

3. The Corporate Invention Board (CIB): a new dataset

3.1. Transnational priority patents as a measure of inventive activity

The CIB builds on patents as a measure of the inventive activity of multinationals. In general, patents provide a well-archived source of information for mapping developments in technological knowledge production. However, patents represent a heterogeneous set of inventions in technologies, applications, and processes. As such, they do not fully and accurately represent innovation (Archibugi and Pianta, 1992, 1996; Jaffe and Trajtenberg, 2002; OECD, 2009). Furthermore, not all inventions are patented and there are differences in patenting behavior across industries and countries, and over time. In addition, patented inventions differ in terms of their quality, and their economic significance. Concerns about the use of

patents as economic indicators have been further reinforced by the greater emphasis on strategic patenting in the literature (Hall and Ziedonis, 2001; Blind et al., 2006).

Part of this drawback can be overcome by using *transnational priority patents*, an approach adopted in this study. The use of transnational patents assumes that patents that are registered in more than one country, represent more important inventions that have a more global significance. Transnational priority patents present several advantages compared to patent indicators that are exclusively based on data from a small number of large patent offices (EP, WIPO, and USPTO) or a combination of them (triadic patent families). De Rassenfosse et al. (2013) identified three main advantages over indicators based on patents applied for at USPTO or at EPO.

First, counting priority patents regardless of the patent office in which the application is filed overcomes the strong national bias, which hampers indicators based on data from a single patent office, such as the often-used USPTO database. Second, counting all priority patents has the advantage of covering more inventions than counts based only on patents extended internationally through the Patent Cooperation Treaty (PCT) or on the very selective "triadic families". Third, the dates that are compiled (the application date of priority patents) are closer to the novelty creation event than the dates of later extensions applied for in one of the other large patent offices (whether USPTO or EPO). This provides a more precise view on the dynamics of corporate inventive patterns. Finally, priority patents better reveal the local nature of inventive activity and better reflect the inventive activity of developing countries.

The use of priority patents nevertheless has one main drawback. It suffers from an institutional bias as it treats patents originating from offices equally, while the rules for patenting show essential differences: cost of application, inventive level required or even the possibility to patent some types of inventions. The main consequence of this institutional bias is the very large share of Japanese and Korean patents in the world total (Laurens et al., 2014). In general, in Japan, patents have fewer claims, and the claims themselves are more narrow than in other countries. Consequently, inventions in Japan are protected by more patents than similar inventions in other countries (Jaffe and Trajtenberg, 2002; Cohen et al., 2002).

Using a measure of the importance of patents, such as in the CIB, counting transnational priority patents partially overcomes this institutional bias, without compromising the benefits of using priority patents as a measure of inventive activity.

3.2. Constructing the CIB

While the PATSTAT database is a very rich database it is provided in raw format and requires extensive cleaning and harmonization (Balconi et al., 2004; Lissoni, 2013). In order to provide an accurate and comprehensive overview of the internationalization of the R&D of multinational corporations, the CIB was built by combining several existing databases. Fig. 1 provides an overview of the main steps.

In step 1 we construct a set of multinational companies by combining different data sources. Our first data source is the "Industrial R&D Investment Scoreboard" (2008 edition). The Industrial R&D Investment Scoreboard analyses the performance of the 2000 industrial companies (1000 based within the European Union, 1000 outside) with the highest annual R&D investments. The CIB thereby covers a very significant share of private R&D investments: the industrial corporations studied in the project account for 80% of world total private R&D. The second source of data is the PATSTAT database. First, PATSTAT was used to complement the set of multinationals with 500 Indian and Chinese firms declaring R&D
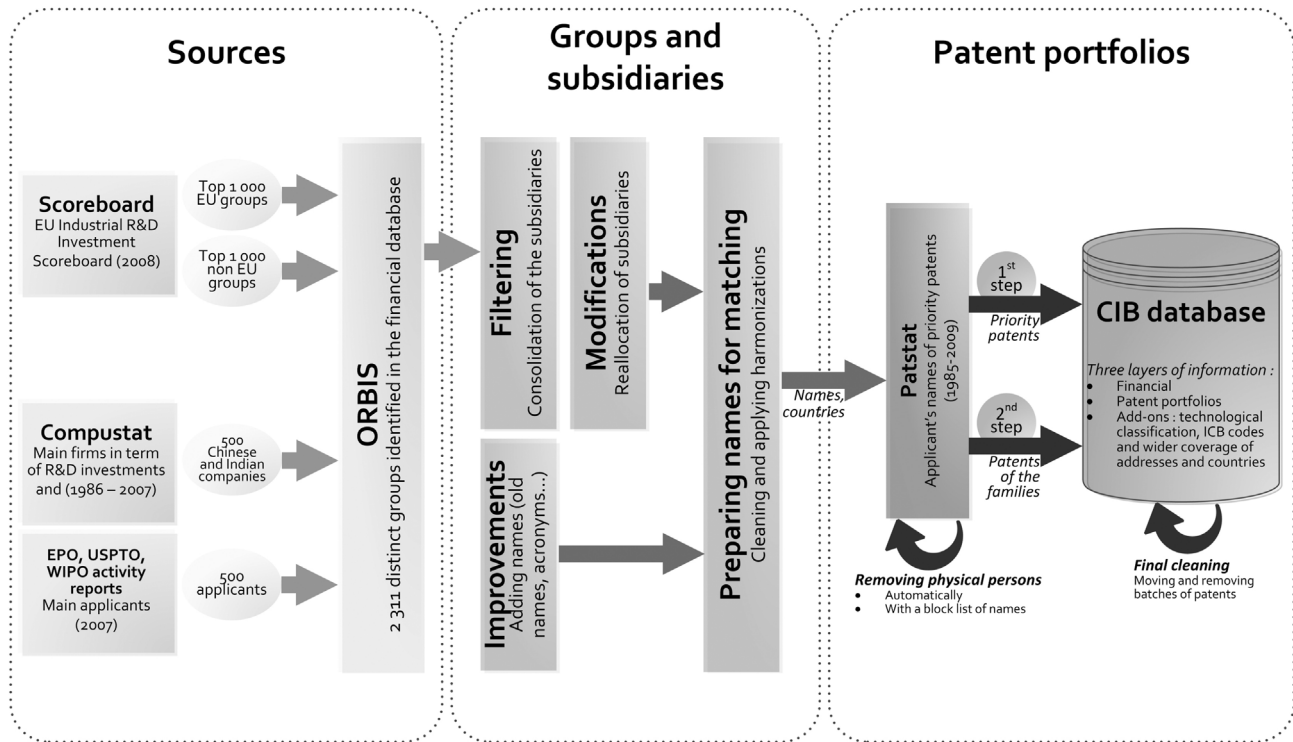
Setting-up the CIB database

Fig. 1. Overview of the CIB data collection and cleaning process.

investments in the Computstat database and with a list of the 500 most important assignees of WIPO[2], EPO, and USPTO patents.

In step 2 we then established the *global ultimate owner* (GUO) for each of the in total 2800 firms using the Orbis database edited by Bureau van Dijk Electronic Publishing. More specifically, we identified nearly 170 000 subsidiaries in which one of the GUOs in our dataset had more than 50.01% of shares. Finally, the home country of a GUO was defined according to the location of its head-quarters. An analysis of firm boundaries is pivotal as mergers and acquisitions are an important means of R&D internationalization (Guimén, 2009; Guimón, 2011). While the main advantage of our methodology is that it includes all technological competences of the MNC up until 2008, a limitation is that the approach is static and the boundaries of the firm are taken as constant for the period of analysis.

Finally, in step 3 of the CIB construction process we extracted the PATSTAT applications of the consolidated MNCs. Using the data cleaning methodology developed by Magerman et al. (2006) we matched the 170 000 entity names with the patent applicant name in PATSTAT. The final MNC database contains 5 127 129 priority patents applied for between 1986 and 2005 (58% of the total number of priority patents applied for worldwide). The core information in the patent data for studying the internationalization of R&D relates to the inventor (whose addresses provides the location of invention) and to the applicant, which relates to one of the 2800 firms, i.e., one of the corresponding 170 000 subsidiaries. Through patent statistics, we focus on the outputs of the R&D investments of the MNCs.

Our dataset contains the transnational priority patents applied for by these CIB firms in the period 1993–2005. In total, the CIB cor-porations applied for 3 714 179 patents between 1993 and 2005 of which 712 333 were classified as transnational patents (i.e., patents applied for in at least two countries). Fig. 2 shows the total num-ber of transnational patents applied for by the CIB corporations. CIB patenting thereby follows the trends also observed in other patent studies (Frietsch and Schmoch, 2010). Fractional counting was used to sum patents. For a detailed over view of CIB patenting on the firm level see Laurens et al. (2014).

The CIB includes 2289 multinational corporations (MNC) that have at least one transnational patent application between 1993 and 2005 and for which information on both inventor and applicant location is available. Of the 2289 MNC's, 730 have their corpo-rate headquarters in Asia, 1002 in Europe, and 538 in the northern America (1 in Africa, 7 in Latin America and the Caribbean, and 11
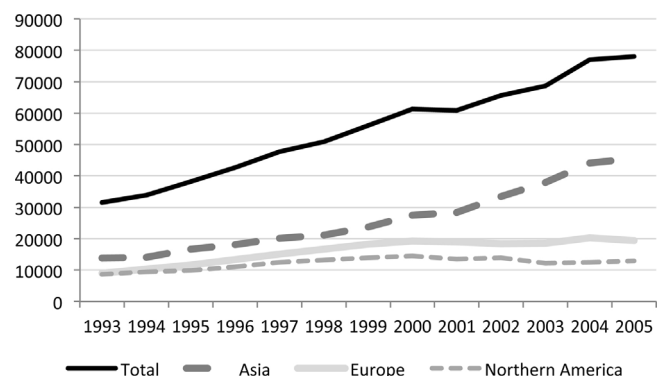

Fig. 2. Transnational priority patents by CIB corporations in the period 1993–2005.

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[2] World Intellectual Property Organization, the international organization that deals with all geographical patent extensions.

Table 1
Shares of worldwide transnational CIB transnational priority patents per country (showing countries with >2000 CIB patents). The total sample size for all CIB MNCs is 712 333 transnational priority patents.

Country	Nr. patents	Total patents (%)	National (%)	International (%)	Continent (%)
Japan (JP)	275 038	**38.6**	**96.4**	3.6	1.7
United States (US)	154 184	**21.6**	**78.3**	21.7	5.9
Germany (DE)	100 580	**14.1**	86.9	13.1	46.2
South Korea (KR)	52 871	7.4	**96.9**	3.1	38.9
France (FR)	37 064	5.2	64.8	35.2	**55.6**
Sweden (SE)	14 120	2.0	53.7	46.3	**61.0**
Taiwan (TW)	13 600	1.9	**83.8**	16.2	**53.1**
Netherlands (NL)	12 918	1.8	19.0	**81.0**	**72.3**
Finland (FI)	11 346	1.6	71.5	28.5	**68.4**
Switzerland (CH)	10 767	1.5	31.7	68.3	**74.3**
United Kingdom (GB)	10 704	1.5	20.0	**80.0**	50.2
Italy (IT)	4088	0.6	76.2	23.8	**61.6**
Canada (CA)	3773	0.5	53.1	46.9	30.3
Belgium (BE)	2327	0.3	47.6	52.4	**64.4**
China (CN)	1630	0.2	**98.9**	1.1	27.2
Denmark (DK)	1520	0.2	65.2	34.8	**52.2**
Austria (AT)	1370	0.2	53.1	46.9	**86.6**
Total	707 901	99.0	–	–	–

in Oceania). Our focus will be on the Asian, European, and north American firms as they make up the majority of our sample, in total our sample includes 117 countries, 45 of which host MNCs with transnational priority patents.

3.3. Characterizing internationalization profiles

The extent of internationalization of the inventive activities of the CIB corporations can be measured by comparing the home base of the MNC with the countries of residence of the inventors of the patents of that MNC. In line with earlier studies we thereby distinguish two types of patents. First, *national patents* are patents where all inventors have the same home country as the MNC, for example a patent owned by a French firm with only French inventors. Second, *international patents* are patents where at least one of the inventors has a different home country than the MNC. In order to provide more insight in the type of internationalization we

Fig. 3. The percentages of *inward* and *outward R&D* for the 17 countries with the largest patent portfolios (transnational priority patents) in the CIB. Size of the dots corresponds to the size of portfolio.

distinguish between international patents with inventors and MNC on the same continent, and international patents with inventors and MNCs on different continents. Of our total sample of 712 333 transnational priority patents, 594 899 (83,5%) are national. Of the 117 434 (16,5%) international patents, 38% are R&D cooperations between countries on the same continent and 61% are intercontinental cooperations.

For a particular country, *inward R&D* is measured by the share of the CIB transnational patents with a domestic inventor with a foreign MNC as applicant. Similarly, *outward R&D* is measured by the share of the transnational are patents applied for by domestic MNC that have a foreign inventor. Our analysis of the patterns of internationalization consists of the following steps. First, we calculate the prevalence of *inward R&D* and *outward R&D* for the countries in the CIB. Second, we then calculate the internationalization profiles of different sectors, distinguishing 10 different sectors: Oil & Gas Basic Materials, Industrials, Consumer Goods, Health Care, Consumer Services, Telecommunications, Utilities, Financials, and Technology. As our sector classification we use the Industry Classification Benchmark (ICB) – which comprises 10 industries, 18 supersectors, 40 sectors, and 114 subsectors[3]. Based on these internationalization profiles of sectors and the sectoral composition of the different countries, we then calculate whether a country is more or less internationalized than can be expected based on its sectoral profile. Finally, we perform a regression analysis taking into account national as well as sectoral factors associated with internationalization in order to establish the relative contribution of the different factors.

The unique CIB database thus allows us to characterize the nature and the extent of technological internationalization, and to analyze the transformation of global patent portfolios of MNCs in the last decades. In the next sections of the paper, we address the sectoral and national characteristics of internationalization of corporate R&D.

4. National patterns of internationalization

Table 1 shows the percentage of total CIB transnational priority patents for the 16 countries with the largest number of patents in our sample, together they cover over 99% of the transnational priority patents in our database. Japanese MNCs are responsible
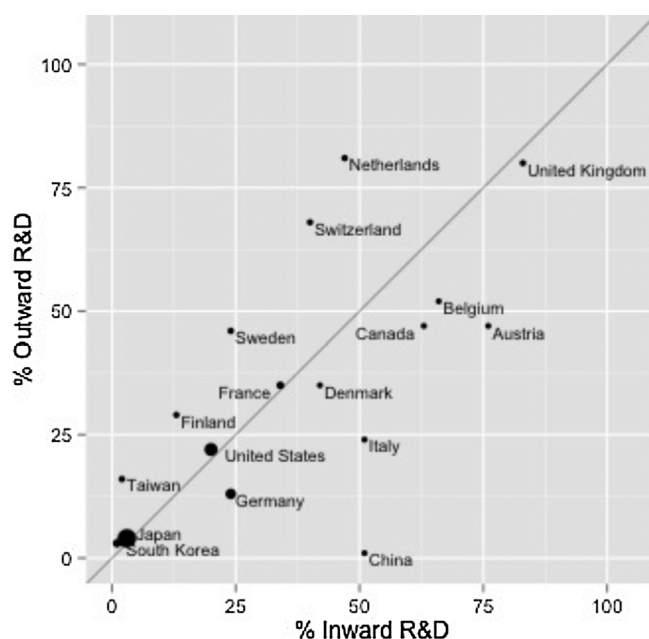
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[3] http://www1.nyse.com/about/listed/lc_all_industry.html.

Table 2
Internationalization patterns per sector. Column 2 gives the percentage of transnational priority patents in the CIB for each sector. Column 3 shows the distribution of international priority patterns over sectors and column 4 the percentage of patents within each sector that is international.

Sector	CIB Patents (%)	International CIB patents (%)	International within sector (%)
Oil & Gas	1.5	3.4	38.8
Basic materials	9.6	8.2	14.0
Industrials	30.6	32.2	17.4
Consumer goods	25.7	19.9	12.8
Health care	3.3	6.7	33.2
Consumer services	0.7	0.2	5.9
Telecommunications	1.3	2.0	24.8
Utilities	0.3	0.3	12.7
Financials	0.2	0.5	**41.6**
Technology	26.8	26.6	16.4
Totals	**100.0**	**100.0**	**16.5**

for 38.6% of all patents (transnational priority type) in our sample followed by MNC's in the United States (21.6%) and Germany (14.1%).

Table 1 shows that for MNCs in most countries, R&D is predominantly national, but that there are large differences in the level of internationalization between countries. On average, the larger countries in our sample (in terms of patents) are less internationalized than the smaller countries. European international R&D mostly takes place within Europe. The Asian countries are among the least internationalized, but their international R&D is global rather than focused on other Asian countries. This requires further investigation as life cycle explanations of R&D internationalization suggest that first international expansions take place into similar, often neighboring countries. The international priority patents represent *outward R&D*, where the inventor lives outside the home country of the MNC. In order to gain more insight in the internationalization profiles we also consider *inward R&D*, that is the patents from inventors in a country that are applied for by an MNC abroad.

Fig. 3 presents the general patterns of *inward* and *outward R&D* for these countries. These internationalization patterns have remained relatively stable over the 1993–2005 period as was also observed in Picci and Savorelli (2012). On the *y*-axis *outward R&D* as percentage of the transnational patents of the MNCs in a country that are international are depicted as and indicator of the internationalization profiles of the firms headquartered in a country. Similarly, the *x*-axis gives the *inward R&D* as the percentage of all transnational patents with an inventor in the country that are applied for by an MNC headquartered abroad as an indicator of the

attractiveness of the country to foreign R&D. The figure illustrates the existence of a *home base* advantage as most of the countries have a predominantly *national* patent portfolio, that is *outward R&D* is smaller than 50% for most countries. Note that the exceptions Belgium, the UK, Switzerland, and the Netherlands are all relatively small, European countries.

In line with results from Laurens et al. (2014) with a different type of data (all priority patents), we also observe a large heterogeneity in internationalization profiles. China is mostly attracting *inward R&D*, indicating the attractiveness of China as an R&D location or the difficulty of Chinese firms to internationalize R&D. Other countries combine incoming R&D with substantial outgoing R&D, suggesting more open economies. With the exception of Germany, MNCs in European countries are more internationalized than in Asian countries. For MNCs in European countries, a large part of the international patents concern European inventors and MNCs. But even within Europe the differences between countries in terms of internationalization are quite large. This is similar in northern America where the US and Canada have quite distinct internationalization profiles, although both are more internationalized than the Asian countries. Hereby we notice that the Asian countries, with the exception of China, the UK, and the US attract worldwide foreign R&D whereas the other countries mainly host inventors from MNCs on the same continent.

5. Sectoral patterns of internationalization

This section describes the sectoral internationalization profiles of countries, as earlier research has demonstrated that some

Table 3
Comparison of observed *outward R&D* (column 2) and observed *inward R&D* (column 3) with expected internationalization profiles (column 4) based on sectoral composition. Columns 5 and 6 give the difference between observed and expected percentages.

Country	Observed *outward R&D* (%)	Observed *inward R&D* (%)	Expected international (%)	Observed outward–expected	Observed inward–expected
Austria	47	76	16.8	30.1	59.3
Belgium	52	66	17.2	35.2	49.3
Canada	47	63	17.7	29.2	45.3
Switzerland	68	40	18.3	50.0	21.9
China	1	51	18.4	−17.3	33.0
Germany	13	24	16.0	**−2.9**	**7.9**
Denmark	35	42	18.2	16.7	23.5
Finland	29	13	16.4	12.1	−3.0
France	35	34	17.2	18.0	16.7
United Kingdom	80	83	17.8	62.2	65.0
Italy	24	51	17.2	**6.6**	33.4
Japan	4	3	15.5	−11.8	−12.8
South Korea	3	1	16.1	−13.0	−15.2
Netherlands	81	47	17.3	63.7	29.3
Sweden	46	24	17.1	29.2	**6.5**
Taiwan	16	2	16.7	**−0.5**	−14.6
United States	22	20	18.2	**3.5**	**2.1**

Table 4
Correlation between different country-level factors that were found to influence R&D internationalization in the literature.

Correlations	Transnational priority patents (applied)	Transnational priority patents (invented)	Number of MNC headquarters	GDP (2005 $)	Number of neighbors
Transnational priority patents (applied)	1	0.998	0.757	0.703	−0.133
Transnational priority patents (invented)	0.998	1	0.755	0.701	−0.115
Number of MNC headquarters	0.757	0.755	1	0.940	−0.095
GDP (2005 $)	0.703	0.701	0.940	1	0.009
Number of neighbors	−0.133	−0.115	−0.095	0.009	1

sectors and industries are more internationalized than others. Table 2 shows the patterns of internationalization per sector. As these are global averages we cannot distinguish between *inward* and *outward R&D.* The industrials sector is responsible for the largest share of patents. *Financials* is the most internationalized sector whereas *Consumer Services* is the least internalized.

These sectoral profiles function as a baseline to interpret and analyze the internationalization profiles of the MNCs in a particular country. If sectoral factors, such as the availability of specialized R&D knowledge and the presence of firms offering complementary product and services, are a main driver of the decision to internationalize R&D activities, country profiles can be expected to align with sectoral profiles. If firms attract more international patents than would be expected based on their sectoral profiles this is an indicator of the quality of the national system of innovation.

In order to test this we have calculated the expected internationalization profiles of countries based upon the sectoral profiles of countries and the internationalization profiles of sectors (Table 2). Comparing these expected values to the actually observed internationalization profiles in Table 3 gives an indication of the importance of sectoral factors in the R&D internationalization strategies of multinational corporations. The expected internationalization profile of country i is composed of the expected shares of international patents in the different sectors in which the multinationals of the country are active, that is how the transnational patents of the MNCs in a country are divided over sectors. More specifically $IntExp_{i,j}$ is calculated from the share of patents of country i in sector j, ($tp_{i,j}$), and the overall share of international patents in sector j, (s_j) (see Table 2) as follows:

$$IntExp_{i,j} = \sum_{i,j} tp_{i,j} s_j$$

So if the MNCs headquartered in a country in the Technology sector have applied for 100 patents then, based on the worldwide share of *international* patents in the Technology sector (see Table 2), the share of national patents is expected to be 83.6. If the actual share of national patents exceeds that percentage the country is an attractive R&D location for firms in that sector. Comparing the expected internationalization profile with the observed internationalization gives an indication of the importance of sectoral considerations. Results for the countries with the largest patent portfolio are shown in Table 3.

Table 3 shows that some countries, such as Taiwan, Germany, Italy, and the US have internationalization profiles that can be very well explained from their sectoral composition (this is of course expected for the larger countries). Other country profiles, however, diverge significantly from the prediction based on sectoral profile. The Asian countries are thereby on average less internationalized than would be expected whereas the European countries and Canada are more internationalized.

Table 5
Outcomes of the regression model for *outward R&D* on the country level.

	Estimate	Std. error	t	Pr(>|t|)
Log transnational priority patents (applied)	−0.04238	0.01502	−2.822	0.00763**
Number of neighbors	−0.03077	0.01326	−2.321	0.02592*

Residual standard error: 0.3116 on 37 degrees of freedom.
Multiple R-squared: 0.242, adjusted R-squared: 0.2011, F-statistic: 5.908 on 2 and 37 DF, and p-value: 0.005935.
* 0.05.
** 0.01.

6. The relative contribution of national and sectoral characteristics.

In order to further explain the patterns of R&D internationalization we analyze the flows of inventive activity between countries in more detail below. Factors that have been found to explain the internationalization of R&D on the level of the MNC are mainly factors related to the relative strength and weaknesses of the company, related to the relative strengths weaknesses of the sector in the home country, and related to the relative strengths and weaknesses of the country and the size of the market in a country. Indicators based on the size of the patent portfolio and indicators such as GDP were used to measure these relations. On the country level we see a high level of correlation between these different measures; Table 4 shows that there are extensive correlations between the different measures of the quality of the national innovation system. Our sample includes the 40 countries that host an MNC, and for each country we included the number of transnational priority patents applied for and invented in the country, the number of MNC headquarters in the country, the GDP of the country in 2005 dollars, an indicator of the life cycle stage of the country (as indicated in the global competitiveness report[4]) and the number of neighbors of the country.

Next we analyzed the contribution of the different factors to the country differences in *inward* and *outward R&D* share (between 0 and 1) using regression analysis. With regard to *inward R&D,* a simple model with only the number of transnational priority patents applied for by the MNCs in a country significantly predicted *inward R&D* percentages. As the distribution of patents over countries is very skewed we applied a log transformation to the patent count: $\beta = 0.07251$, $t(38) = −6.459$, and $p < 0.0001$, the model also explained a significant proportion of variance in *inward R&D* percentages $R^2 = 0.52$. While the country level variables thus explain 52% of the variance in *inward R&D*, these variables explain only 24% of the *outward R&D.* More specifically, Table 5 shows the outcome of the multiple regression model with the highest explanatory power for *outward R&D*, with a significant effects for the (log

[4] http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2012-13.pdf.

Table 6
Sector level model explaining the share of *inward R&D*.

	Estimate	Std. error	t
Log transnational priority patents (applied) per country per sector	−0.092***	0.0041395	−22.291
Basic materials	0.101.	0.056	1.806
Industrials	0.218***	0.056	3.860
Consumer goods	0.141*	0.056	2.533
Health care	0.066	0.055	1.202
Consumer services	−0.055	0.061	−0.912
Telecommunications	−0.125*	0.058	−2.132
Utilities	0.0004	0.067	0.007
Financials	0.004	0.065	0.058
Technology	0.2298073***	0.057	4.040

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.
Residual standard error: 0.2318 on 302 degrees of freedom (87 observations deleted due to missingness), multiple R-squared: 0.6296, adjusted R-squared: 0.6173, F-statistic: 51.34 on 10 and 302 DF, p-value: $<2.2e − 16$.

transformation) of the transnational priority patents applied for by the MNCs in the country, and the number of neighbors of the country.

While the attributes of the host country are found to be of importance for the decision of multinationals to outsource R&D, many drivers are also found in the relative strengths of the firm in the home country and in the world. As the focus of this paper is on factors that can be influenced by national policymakers we also investigate the relation between sectoral strengths and *inward* and *outward R&D*. On the sector level we have 400 observations (10 sectors for each of the 40 countries), and for each observation we again use *inward R&D* and *outward R&D* as our outcome variables and either the (log transformed) transnational priority patents applied for by the MNCs in a certain sector in a country, or the (log transformed) transnational priority patents applied for by the MNCs in a country as our explanatory variable in order to compare the relative contribution of national and sectoral factors.

For *outward R&D,* the best model has an adjusted R squared of 0.22 and uses the country level patent count as well as a sector dummy. Sectoral factors are however able to explain 63% of the variance in *inward R&D* on the country level. Table 6 shows the model results (with Oil and Gas as the base sector). The table shows significant effects for Industrials, Consumer goods, Telecommunications, and Technology. The most internationalized sectors do not show significant effects, suggesting that for these sectors the relevant innovation system is global rather than national or sectoral.

First, overall country level R&D strength and sectoral R&D strength are positively associated with *inward R&D.* The stronger the overall R&D in a country, the more likely it is that multinationals from other countries will do R&D in the country. This validates the choice for R&D policies that seek to reinforce the national innovation system, or existing strengths. However, a sectoral model is able to explain a larger part of the variance in *inward R&D*, suggesting that these national level policies could be complemented with sector specific policies.

Concerning *outward R&D,* however, the national level models have a higher explanatory power and no significant sector specific effects were found. The main effect for the *outward R&D* is that the stronger the overall R&D base in a certain country, the more likely the firms in that country are to outsource their R&D. This is in line with earlier findings that the main motivations for R&D internationalization are home-base exploiting rather than home base augmenting.

Summarizing, we see that while national level indicators explain a large part of the variance observed in the ability of countries to attract R&D from foreign multinationals, there are significant differences between sectors, this has large implications for the design of foreign R&D and innovation policies.

7. Discussion

The CIB provides a novel interface between patent data from the PATSTAT database with financial data from the ORBIS database. The CIB allows for a more evidence-based approach and complements existing studies that rely on surveys (Gorg and Strobl, 2001), on a smaller sample of patents (Almeida, 1996; Patel and Vega, 1999), or on the raw PATSTAT data (Picci and Savorelli, 2012). In comparison with earlier studies our sample includes worldwide patent data and is considerably larger than the samples used in earlier studies on the internationalization of R&D; Le Bas and Sierra (2002) focus on the 345 MNC's with the largest patenting activity in Europe and Patel and Vega consider the US patenting activities of 220 firms. Picci and Savorelli (2012) do include worldwide patents in their analysis of multinational patent by all types of applicants, not especially MNCs. Compared to these previous studies, the CIB, which was designed by IFRIS[5] from an Open Access perspective thus offers a more recent and more comprehensive dataset including Asian firms.

However, there are important limitations to the CIB data used in this paper, as discussed in Section 3. These limitations relate to the use of patents in general as an indicator of corporate R&D activity and that the boundaries of the firms are taken as constant for the period of analysis. While taking into account these limitations, the CIB data opens up a wide variety of new lines of research into analyzing patterns of internationalization of R&D. For example, the CIB data will allow us to understand better patterns of national R&D specialization, extending our understanding of how national and sectoral strengths are changing and evolving over time. Also on the firm level, the data allows for exploring significant nuances in the globalization of R&D and makes it possible to understand the role of all large firms in R&D globalization (Laurens et al., 2014).

Further research includes a global map of technology that characterizes the proximity and dependency of technological areas (Schoen et al., 2012). The global map allows to 'overlay' patents produced by a specific organization or country against the background of a stable representation of global technological invention and to produce comparisons that are visually attractive, very readable, and potentially useful for policy-making and strategic management.

8. Conclusions

Using the Corporate Invention Board (CIB), this paper presents a systematic analysis of the internationalization of R&D by

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[5] RISIS.

multinational corporations in the period 1993–2005. We introduced a unique database, the Corporate Invention Board (CIB). The CIB provides a novel interface between patent data from the PAT-STAT database with financial data from the ORBIS database about the 2289 companies with the largest R&D investments. The construction of the database involved substantive data cleaning and harmonization. By linking several previously unrelated databases, the CIB allows for the systematic analysis of R&D internationalization patterns, and the patenting behavior of multinationals and their subsidiaries. The industrial corporations included in the CIB account for 80% of world total private R&D.

Contrary to most existing studies on the internationalization of corporate R&D, we focused on the degree of internationalization on the national and sectoral level, thereby linking the micro level of patents and geography to more macro levels amenable to policy. Pavitt and Patel (1999) claim that national innovation systems are still key in understanding the creation of global comparative advantages for firms. Thus, for policy analysis it becomes important to understand the nature of the country-specific factors that have an influence in creating these advantages. Likewise, sectoral innovation systems are expected to provide insights in the sector specific patterns of internationalization of R&D (Malerba, 2002).

The results show heterogeneity in sectoral and national patterns of internationalization. These patterns have remained relatively stable over the 1993–2005 period. China is among the least internationalized countries and European countries, especially the UK and the Netherlands, are among the most internationalized countries. The analyses show that some of the largest countries in terms of patents, such as Germany and the US, have internationalization profiles that can be very well predicted based upon their sectoral composition. Other country profiles, however, diverge significantly from the prediction based on sectoral profile. Asian countries are on average less internationalized than would be expected whereas the European countries and Canada are more internationalized. Furthermore, we notice that Asian countries (with the exception of China), the UK, and the US attract worldwide foreign R&D whereas the other countries mainly host inventors from MNCs on the same continent. European countries also have a relatively high share of international patents with inventors on the same continent. This result is in line with previous studies (Niosi and Bellon, 1994, 1996) that concluded that the European Union appears to be the only major supranational scientific and technological block now emerging. However, within Europe the differences between countries in terms of internationalization are quite large.

We found that while national level indicators explain a large part of the variance observed in the ability of countries to attract R&D from foreign multinationals, there are significant differences between sectors and this has large implications for the design of foreign R&D and innovation policies.

In line with existing studies (Malerba and Orsenigo, 1996), the empirical evidence suggests the existence of differences across sectors and of similarities across countries in the patterns of innovative activities for a specific sector. Financials as well as Oil and Gas are among the most internationalized sectors, whereas Consumer Services is the least internalized. Significant sectoral effects were found for Industrials, Consumer goods, Telecommunications, and Technology sectors with a moderate level of internationalization. More specifically, our research suggests that for these sectors, the now mostly country level policies should be complemented with sector specific policies if countries seek to attract foreign R&D. Possible policies that have been suggested in the literature are to facilitate the inflow of foreign R&D personal in these sectors, and to stimulate clustering in these sectors.

The paper illustrates how the construction of the CIB enables the systematic study of internationalization patterns and opens up a wide variety of new lines of research into analyzing patterns of internationalization of R&D.

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