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Internationalization of Research & Development and Host-Country Patenting:

The Dynamics of Innovation and Trans-Border R&D Flows between Developed and Emerging Countries

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Executive Summary

The international business world has profoundly changed through globalization in the last years and decades. The cross-border exchange of products and people, as well as information, technology and capital has increased. Furthermore, companies are faced with an increasingly distributed knowledge base which means that one centralized Research & Development (R&D) base, usually at the headquarters is not sufficient and a company's success rather depends on its ability to identify and occupy selected locations across the globe for R&D activities.

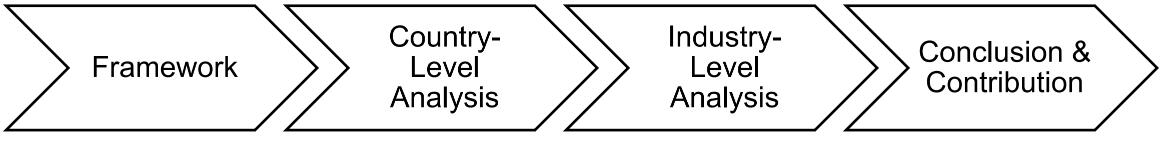
While the degree of R&D Internationalization of large multinational corporations (MNCs) has been increasing for the last decades, the group of source countries has remained small: the headquarters of the leading R&D-conducting MNCs have been largely based in the US, Japan and several European countries (e.g. Germany, Switzerland) and R&D Internationalization had been remaining within this group. Since the beginning of this millennium, however, several emerging countries (e.g. China or India) have entered the stage and increasingly attracted foreign R&D investments as target countries. R&D has therefore not only increased in intensity, it has also increased in breadth, i.e. the degree of target country diversification has grown.

This dissertation addresses and is driven by the following overarching research question:

> How can we capture even more precisely to what extent and in what fields MNCs conduct R&D abroad and how have the patterns changed in the time period 2000 – 2019?

Structural Approach

I structure this dissertation in four blocks, divided in eight distinct chapters, as outlined in the following:



Framework

1. Introduction & Literature Overview: What does the existing literature say about R&D Internationalization and its drivers? I outline and group the factors based on relevant literature over the last decades in four distinct groups:
   a. Pull-Factors: Influencing factors of the host-country (receiving country) for attracting or "pulling in" foreign R&D.
   b. Push-Factors: Influencing factors of the home-country (sending country) for "pushing out" R&D abroad.
   c. Industry-based factors: R&D Internationalization can differ across industries. I show the factors based on the relevant industry.
   d. Company-based factors: Even within the same industry R&D Internationalization can differ for respective companies, based on the respective culture, strategy and structure.
2. Methodology: How do we measure R&D activities? I outline my methodology and approach in analyzing R&D activities and its internationalization. With my approach, I built upon relevant literature and extend the current state of the art, namely by a strong analysis of R&D Expenditures and patent activities.

Country-Level Analysis

3. Global Development in R&D Expenditure: What are the patterns and developments of R&D Expenditure by Multinational Corporations (MNC) globally and in relevant countries? By combining relevant R&D data from international and national offices, I give a global overview of R&D Expenditures and of major relevant economies.
4. Outward Host-Country Patent Analysis: What are the patterns and developments of Host-Country Patents by MNCs globally, from relevant countries? I show in detail how R&D activities to and from relevant countries has developed over time. Furthermore, I show the concentration of patents on relevant technological fields. Differentiating patents by field can show specific concentrations and expertise by countries on relevant areas.
5. Inward Host-Country Patent Analysis: What are the patterns and developments of Host-Country Patents by MNCs globally to relevant countries? I take the inverse perspective to Chapter 4, in order to show the R&D activities and concentration of patents on relevant technological fields for the most-relevant target / receiving countries.

Industry-Level Analysis

6. Industry Analysis in R&D Expenditure: What are the patterns and developments of R&D Expenditure by MNCs in relevant R&D intensive industries? As the size and distribution of R&D varies across industries, I move downwards from the macro perspective, i.e. in this chapter I look in detail how R&D activities differ across relevant industries. Based on the data I develop a profile for relevant economies, outlining in which industries comparable strengths and weaknesses exist.
7. Industry Analysis in Patenting Activities: What are the patterns and developments of Host-Country Patents by MNCs in relevant R&D intensive industries? For the most relevant industries and R&D intensive technological fields, I scrutinize the respective patents. I show the developments over time and introduce quality measures to give insights into the R&D developments within the industries over time.

Conclusion

8. Conclusion & Outlook: I summarize my research and embed it into a broader research context. With the highly dynamic field of R&D Internationalization, the relevance and interest for further research will only increase for practitioners and researchers alike.

Contribution

This dissertation expands the current academic horizon as following:

1. Comprehensiveness: I scrutinize the current diverse research on R&D Internationalization and put it in a wider context. I show and retrace the uprise of particular industries and nations in terms of R&D activities on a broad and general, as well as on a detailed and precise scale, based on literature and data. This work can therefore serve to gain a general and current overview on R&D Internationalization, as well as finding precise data on relevant countries and industries.
2. Methodology: The two core indices I use to measure R&D activities are the amount of R&D Expenditure in a financial value and patent numbers in a count value.
    a. R&D Expenditure: By combining and analyzing relevant data I give precise insights on developments in recent years.

b. Patent Analysis: While patents are generally a readily available data-set, their actual purpose is not the academic analysis, but rather the protection of intellectual interests. With a detailed and methodological analysis and the combination of relevant data-sets, including patent quality indices and a measure for cultural distance to quantify internationality, I derive detailed and precise findings for the inventors, applicants and technological fields, as well as internationality.

Main Findings

Six major trends can be identified to answer the research question:

1. The share of R&D conducted abroad by MNCs in relation to their total R&D has increased in the last decades.
2. The number of target countries and their technological diversification degree has increased.
3. A select number of target countries, particularly ambitious emerging countries (China, India and partly some Eastern European countries) have significantly increased in relevance as a base for R&D activities.
4. Target countries attract foreign R&D in respective specific technological fields. Particularly the uprising emerging countries have built up competences in certain areas and participate in R&D in these fields on a relevant global degree.
5. A strong shift across the R&D-conducting industries can be observed. Particularly high-tech industries (e.g. pharma and biotech) and new technologies (IT, internet, software) have significantly increased in relevance compared to classic manufacturing industries and account for an increasing share of R&D activities across all industries.
6. Conducting R&D abroad generally pays off compared to purely domestic R&D, although there is indication that too much internationality can be detrimental as well.

Content Overview

Contents

1. Introduction and Research Outline

The international business world has thoroughly changed through globalization in the last years and decades. The cross-border exchange of products and people, as well as information, technology and capital has grown and conducting Research & Development (R&D) and sourcing innovations globally has continuously progressed.

However, still in the year 1991 Patel and Pavitt concluded that R&D is highly concentrated at the home-base and dependent on the respective country's systems of innovation, which they called "the non-globalization of large firms' innovative activities".[1] More recent research, has revised that conclusion and outlined the importance of internationalizing R&D: Companies aim to tap into knowledge at selected places outside of the respective home-country in order to increase their innovative performance and thereby gain and maintain competitiveness.[2]

Initially companies only conducted less important R&D abroad which requires lower-level capabilities and non-core knowledge, while keeping strategically relevant R&D, requiring advanced capabilities and core knowledge at home.[3] With the beginning of the 21st century, Multinational Corporations (MNCs) started to build up R&D in emerging countries.[4] These countries, including China, India, Brazil, Russia, showed growth potential and cheap access to knowledge and human capital. While previously practically irrelevant in terms of R&D investment, emerging countries increasingly attracted investments from MNCs located in the 'Triad countries', i.e. the historically big economies of the U.S., Western-Europe (mostly Germany and Switzerland) and Japan. Companies from these countries have diversified their target countries for R&D investments in the last decades.[5]

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1 Cf. Patel and Pavitt (1991) & Pavitt and Patel (1999). Other prominent authors, e.g. Porter (1990) and Hu (1992) come to the same result with R&D being deeply rooted in the respective home country. Hu even argues that the term "multinational corporation" is an exaggeration as a company has only one distinct home which remains relatively more important to other countries. See also a discussion about this term in Kennelly (2000).

2 Cf. OECD (2008a, p. 17ff); Hall (2011, p. 179f); Chen, Huang, and Lin (2012). Companies face this internationalization often rather with "resignation than with pleasure" (De Meyer and Mizushima, 1989, p. 139) due to a multitude of unpredictable factors. Regular challenges are unplanned cost explosions, loss of economies of scale due to information asymmetries in coordination and thereby unintentional duplication of research at the different locations and difficulties to reach a critical mass.

3 Cf. Gerybadze and Reger (1999), who analyze 21 MNCs located in Europe, U.S.A. and Japan. They outline the increasing complexity of the globally distributed R&D. See also Schasse et al. (2014) & Criscuolo, Narula, and Verspagen (2005).

4 In academia, the terms Multinational Enterprise (MNE), Transnational Corporation (TNC) and MNC are used mostly interchangeably. In this analysis the latter term will be used.

5 Cf. von Zedtwitz and Gassmann (2016); Patel and Pavitt (2013); Gerybadze and Merk (2014).

The emerging countries have shown an unprecedented international growth and expansion[6], increasing their share of global R&D. The increasing speed of innovation combined with a growing global interlacing of business activities requires meticulous analyses.

In this chapter I will show, discuss and categorize factors from academic literature affecting R&D Internationalization.

1.1. Internationalization of R&D by MNCs

The increasing R&D Internationalization is mainly driven by MNCs, which therefore will be the focus of the dissertation's analysis.[7] R&D Internationalization on a public institution and not business level (e.g. universities, public research centers) will only be regarded if explicitly indicated.

While some early research suggests that R&D Internationalization started in the 1950s, only product adaptions, i.e. applied research can be observed at this time.[8] In fact, this early research did not thoroughly distinguish between the different kinds of R&D, which is relevant when discussing R&D Internationalization, e.g. the three kinds according to the OECD: basic research, applied research and experimental development[9].

R&D Internationalization up until in the 1970s was rather small, as knowledge was concentrated on an international center, e.g. the US in many fields or Western Europe for example for chemistry.[10] Ronstadt (1978) provides one of the first relevant systematic

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[6] In the last years big companies from emerging countries have gained relevance in certain fields, sometimes even at the "technological frontier" (Amann and Cantwell, 2012). As these "Emerging-Country MNCs" (EMNCs) have followed a completely different process of growth, strategy and internationalization compared to "Advanced-Country MNCs" (AMNCs), they will not be regarded in detail in this dissertation. Cf. Giuliani et al. (2014); Awate, Larsen, and Mudambi (2015); Guillén and García-Canal (2009).

[7] In the 1980s & 1990s R&D Internationalization was "largely restricted" to MNCs (Gassmann and von Zedtwitz, 1999). In 2002, 98% of the 700 largest R&D spending companies were MNCs, which account for 46% of the world's R&D Expenditure or 69% of the world's business R&D Expenditure (UNCTAD, 2005, p. 151). Similar findings are being made as well in more recent reports: e.g. Hervás, Siedschlag, and Tübke (2014); UNCTAD (2017).

[8] An early analysis by Dunning (1958) breaks down foreign ownership and R&D efforts in British companies. In this analysis it was found that U.S. manufacturing affiliates in the U.K. employed less than 10% of its total staff in R&D in the 1950s – compared to ca. 31% in 1989: Cf. Dunning (1999); U.S. Department of Commerce (1992). Safarian (1967) makes similar findings with U.S. investment in Canada. However, this research, often cited as one of the first internationalizations of R&D, e.g. by Lee (2013), does not accurately mark the start of real R&D Internationalization, as the analyzed businesses solely adapted their production to their respective local environments.

[9] OECD (2015b, p. 26): The FRASCATI manual, published by the OECD, has grown to be the internationally accepted document for defining standards and procedures for R&D analysis. Other classifications have been developed as well, which will be discussed in the Methodology Chapter 2.

[10] Cf. Bartlett and Ghoshal (1990).

analyses of international R&D, here of seven US-based MNCs. Following studies focused on US firms as well.[11] Mansfield (1984) summarizes and unites these first findings.

Until the 1980s the R&D Internationalization gradually shifted towards a polycentric structure, meaning that several global centers for knowledge-intensive fields exist.[12]

The topic of R&D Internationalization as a global phenomenon was only gained momentum in the late 1990s, partly through researchers affiliated with the OECD[13] and partly through relevant conferences and publications. Up until the 2000s, there was insufficient documentation on global R&D Activities. Relevant conferences such as organized by the EIBA (European International Business Academy) or AIB (Academy of International Business) promoted the nascent R&D research and lead to a special issue in the journal 'Research Policy', nowadays one of the most prestigious academic journals for innovation, in 1999 on the topic "The Internationalization of Industrial R&D". A number of still relevant research has been published in that special issue, e.g. by Gerybadze and Reger (1999)[14].

Figure 1-1 illustrates the increase in relevance of R&D Internationalization in academia over time, by counting the number of relevant publications per year.[15]

11 Cf. Mansfield, Teece, and Romeo (1980); Lall (1980).

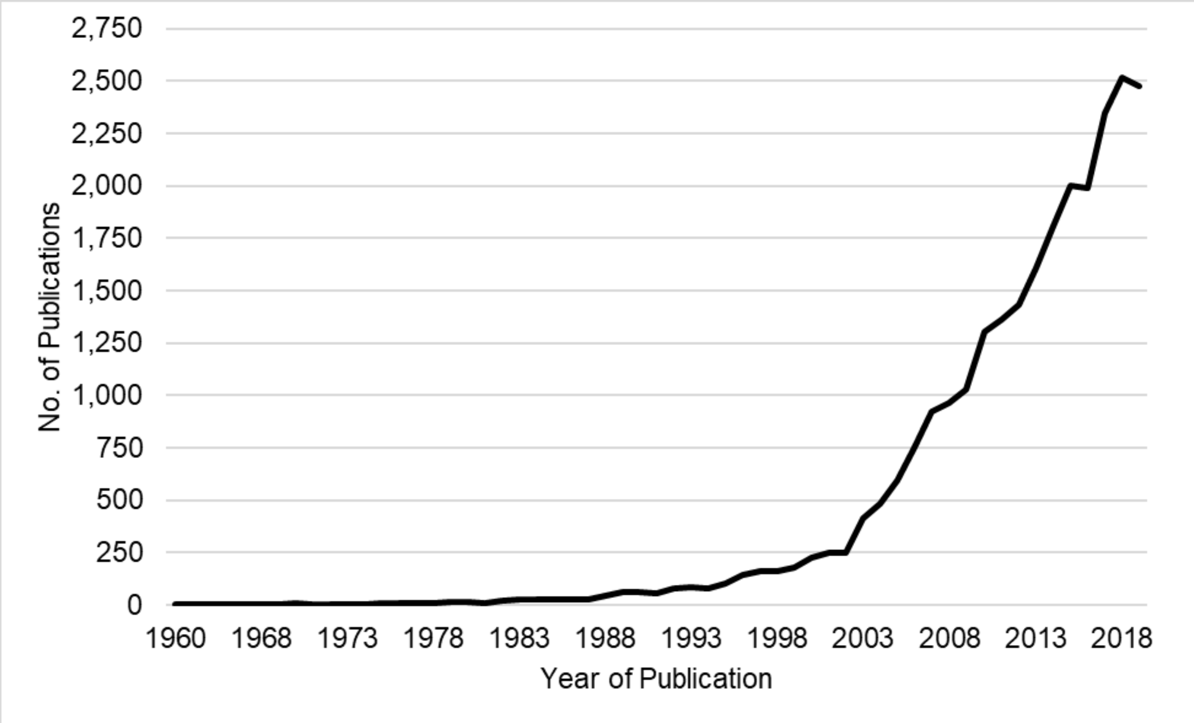
12 Cf. Gerybadze, Meyer-Krahmer, and Reger (1997).

13 Cf. Hatzichronoglou (2008); OECD (2008a, 2008b, 2008c, 2008d), for an overview of R&D Internationalization.

14 Other relevant publications by authors who continued to shape the discussion on R&D Internationalization are i.a. by Gassmann and von Zedtwitz (1999); Kuemmerle (1999b) or Patel and Vega (1999).

15 A meta-analysis by Paul and Feliciano-Cestero (2020) of research on foreign direct investment (FDI) by MNCs shows a similar development and outlines the high relevance of FDI for international business research.

Figure 1-1: Development of Publications on R&D Internationalization[16]



We can divide the recent publication history broadly into three phases. 1990 – 1999; 2000 – 2009; 2010 – 2020.[17] The respective top-cited articles are shown in the following tables.

16 Own illustration based on SCOPUS (2020). Publication search for 'R&D' and 'Internat*' or 'Global*'. Last updated on 12. Sep. 2020.

17 Own illustration based on SCOPUS (2020). Methodology similar, as outlined in footnote 16, but limited to respective publication years. Last updated on 21. Nov 2020.

Table 1-1: Top Five Publications by Citations in 1990 - 1999[17]

Rank	Author & Year	Title	Journal	Citations
1	Florida (1997)	The globalization of R&D: Results of a survey of foreign-affiliated R&D laboratories in the USA	Research Policy 26(1), pp. 85-103	367
2	Nobel and Birkinshaw (1998)	Innovation in Multinational Corporations: Control and Communication Patterns in International R&D Operations	Strategic Management Journal 19(5), pp. 479-496	359
3	Gerybadze and Reger (1999)	Globalization of R&D: Recent changes in the management of innovation in transnational corporations	Research Policy 28(2-3), pp. 251-274	273
3	Gassmann and von Zedtwitz (1999)	New concepts and trends in international R&D organization	Research Policy 28(2-3), pp. 231-250	273
5	Pearce (1999)	Decentralised R&D and strategic competitiveness: Globalised approaches to generation and use of technology in multinational enterprises (MNEs)	Research Policy 28(2-3), pp. 157-178	258

Four out of this Top Five publications and several other publications at lower ranks come from the aforementioned special issue in Research Policy, underlining the relevance of this particular journal issue.[18]

[18] Cf. relevant authors, as shown in footnote 14.

Table 1-2: Top Five Publications by Citations in 2000 - 2009[17]

Rank	Author & Year	Title	Journal	Citations
1	Oxley and Sampson (2004)	The Scope and Governance of International R&D Alliances	Strategic Management Journal 25(8-9), pp. 723-749	510
2	von Zedtwitz and Gassmann (2002)	Market versus technology drive in R&D internationalization: Four different patterns of managing research and development	Research Policy 31(4), pp. 569-588	443
3	Narula (2004)	R&D collaboration by SMEs: New opportunities and limitations in the face of globalisation	Technovation 24(2), pp. 153-161	312
4	Asakawa (2001)	Organizational tension in international R&D management: The case of Japanese firms	Research Policy 30(5), pp. 735-757	138
5	Y. Zhang et al. (2007)	R&D intensity and international joint venture performance in an emerging market: Moderating effects of market focus and ownership structure	Journal of International Business Studies 38(6), pp. 944-960	121

Table 1-2 shows again for the 2000 – 2009 period a strong impact of publications from the renowned journal Research Policy. Interestingly the two top publications in the period 2000 – 2019 have received more citations than any publication in the prior 1990 – 1999 period, despite the latter having been published longer and therefore having more time to potentially receive publications. This shows that since the beginning of the millennium, R&D Internationalization has really started to be in the center of academic interest. See also Figure 1-1.

Table 1-3: Top Five Publications by Citations in 2010 - 2019[17]

Rank	Author & Year	Title	Journal	Citations
1	Awate, Larsen, and Mudambi (2015)	Accessing vs sourcing knowledge: A comparative study of R&D internationalization between emerging and advanced economy firms	Journal of International Business Studies 46(1), pp. 63-86	126
2	Hottenrott and Lopes-Bento (2014)	(International) R&D collaboration and SMEs: The effectiveness of targeted public R&D support schemes	Research Policy 43(6), pp. 1055-1066	88
3	Hsu, Lien, and Chen (2015)	R&D internationalization and innovation performance	International Business Review 24(2), pp. 187-195	69
4	Castellani, Jimenez, and Zanfei (2013)	How remote are R&D labs? Distance factors and international innovative activities	Journal of International Business Studies 44(7), pp. 649-675	67
5	Chakrabarty and Wang (2012)	The Long-Term Sustenance of Sustainability Practices in MNCs: A Dynamic Capabilities Perspective of the Role of R&D and Internationalization	Journal of Business Ethics 110(2), pp. 205-217	65

Table 1-3 shows the top publications for the 2010 – 2019 period. With an increasing recency to today's date, we obviously have fewer overall citations. We see from the publication titles and journal names an increasing diversification in topic and target focus, even though a respective Top 5 is certainly just the tip of the iceberg: Whereas in the beginning publications were centered more on general R&D Internationalization, more recent publications have expanded on that knowledge and found a more specific niche.

In fact, today's literature on R&D Internationalization can be grouped into one of the following four distinct streams:

1. Reasons and motives to internationalize R&D.[19] Early research has strived to identify motives and drivers on R&D Internationalization on different levels. I condense and discuss that literature according to my structure presented in Figure 1-2.

[19] Cf. Ambos and Ambos (2009); Gassmann and von Zedtwitz (1998).

2. The patterns and destinations of R&D Internationalization. While some authors have focused their analysis on countries from developed economies,[20] some have focused on one or several emerging economies[21].
3. The interplay and environment of home- and host-country bases of companies. Here, the authors have aimed to analyze the establishment, organization and management of R&D locations and networks.[22]
4. Assessment of the effect of R&D Internationalization on firms' performance.[23] With ambiguous findings, neither the direction nor the shape of relationship between R&D Internationalization and firm performance have been conclusively identified.

Despite the increasing discussion on R&D Internationalization, this topic is not necessarily self-evident in practice, as a recent report, published by the management consultancy McKinsey in November 2020, does not explicitly mention internationalizing a company's R&D, as a key component on building an advanced R&D strategy.[24]

In the following parts I give an overview of the literature on internationalization of R&D in more detail, showing and discussing the drivers of R&D Internationalization on different levels. The practical analysis of R&D data and industries starts from Chapter 3 onward.

I group these factors into my framework of four groups of influencing factors:

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20 Cf. Cantwell and Piscitello (2002).

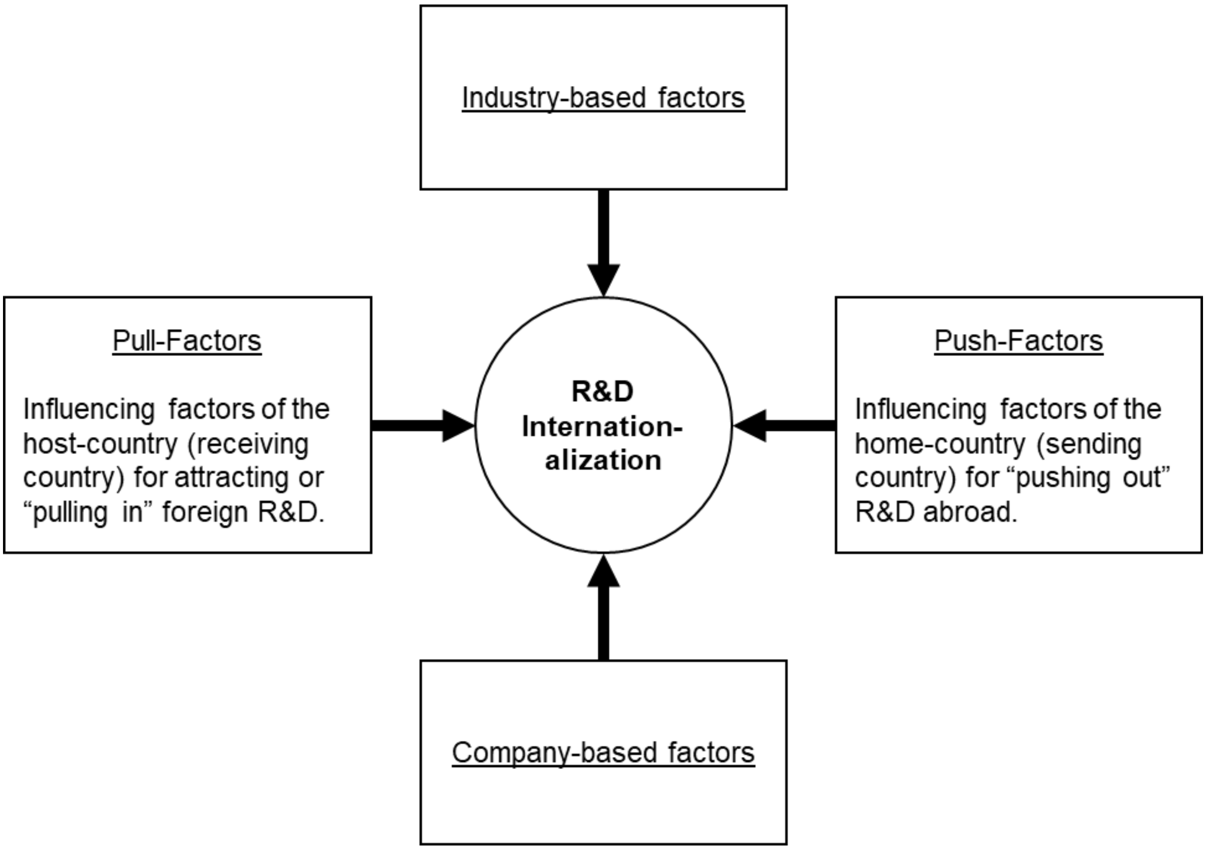
21 Cf. Asakawa and Som (2008); Ayden et al. (2020); Chittoor and Ray (2007); von Zedtwitz and Gassmann (2016).

22 Cf. Gassmann and von Zedtwitz (1998); Westney (1993).

23 Cf. Chen, Huang, and Lin (2012); Hsu, Lien, and Chen (2015); Hurtado-Torres, Aragón-Correa, and Ortiz-de-Mandojana (2017); Nieto and Rodríguez (2011).

24 Cf. Brennan et al. (2020). This can be, however, just indicative that McKinsey does not particularly specialize its strategy consulting on (international) innovation areas, as several competitors, in fact, have been addressing this topic for a longer time. The Boston Consulting Group, for example, gives an annual overview of "The Most Innovative Companies" (BCG, 2020). Arthur D. Little is another firm, whose consultants have written about R&D Internationalization (Roussel, Saad, and Erickson, 1991). Yet another publication addressing researchers and practitioners is the annual ranking and discussion of leading R&D spending firms by the Industrial Research Institute in the years 2000 – 2008 (IRI, 2008).

Figure 1-2: Factors Influencing R&D Internationalization



1.1.1. Pull- & Push-Factors for R&D Internationalization

The framework provided by the respective host-region (or country) in relation to the home-country plays a significant role in the decision process of R&D relocation. Depending on the perspective and constellation a factor can be a pull- or a push-factor. Pull-factors "pull in" foreign R&D because companies expect more stimuli and a higher utility to perform R&D in a particular location, whereas push-factors "push out" domestic R&D internationally. For example, the access to specialized talent can be considered a pull-factor, because the host-country attracts foreign R&D with strong innovation clusters, well-funded universities etc., but also a push-factor if the home-country does not provide such an environment and drives the firm's R&D abroad through its relatively worse standing. Likewise, some governmental regulations can both push-out R&D internationally due to restrictions in the home-country or pull-in foreign R&D due to more liberal legislations.[25]

[25] Cf. EFI (2013, p. 67).

Five main factors can be identified:

First, R&D Internationalization often follows an MNC's general internationalization process of production. Production is likely to be internationalized to regions or countries with a big market size and or a big market and revenue growth potential, as well as existing infrastructure, where R&D would follow.[26] Furthermore a certain degree of industrialization and general development is required for R&D to thrive.[27] The size and or quality of a market can therefore stimulate innovation activities within a specific product line.

Second, R&D highly depends on an educated workforce. MNCs are very likely to locate R&D centers to the proximity of universities and other areas with high concentration of potential employees[28] and there are close linkages between a host-country's innovative performance and educational capabilities. Due to the strategic importance of R&D, qualification of staff is a more relevant driver of R&D Internationalization than lower salary costs for R&D personnel.[29] A growing globalization, i.e. ease of mobility and acceptance of English as a working language[30], has facilitated a growing number of foreign R&D locations. Some studies even attribute the rise of emerging countries mainly to their success in educating large numbers in relevant fields and thereby attracting foreign MNCs.[31]

Third, the selection of a R&D location depends on the local policy and economic environment. Policy makers regularly aim to attract R&D investments through financial incentives and or some kind of preferential treatment of foreign firms.[32] These advantages can include, but are not limited to, lower taxation or special taxation schemes for revenues generated with

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26 Cf. Kuemmerle (1999a); Williams and Vrabie (2018); Odagiri and Yasuda (1996); von Zedtwitz and Gassmann (2002). There is a positive correlation between a country's market size and salary level, meaning that companies usually have little to no salary-cost advantage in countries with big markets. However, the higher revenue in these countries regularly compensates for the higher labor costs. Cf. Le Bas and Sierra (2002).

27 Cf. Reinert (2007), who explains in his book 'How Rich Countries Got Rich and Why Poor Countries Stay Poor' countries success factors on developing or not, based on relevant economic theories.

28 Thursby and Thursby (2006), as well as Kinkel and Maloca (2008) even find the lack of locally qualified R&D staff to be the most important factor for an MNC to relocate its R&D to countries with more qualified personnel.

29 Cf. Huggins, Demirbag, and Ratcheva (2007) or Hegde and Hicks (2008), who analyze overseas U.S. R&D subsidiaries and find that a shift of R&D to Asian countries is mainly attributed to the availability of highly-skilled workforce in the host-country and lack thereof domestically. When deciding between two locations, salary levels only become the deciding factor with other factors being similar (Cincera, Cozza, and Tübke, 2010, p. 17ff).

30 Cf. Miguelez and Fink (2013), who show through patent analyses the relatively higher geographic mobility of high-skilled compared to low-skilled workers.

31 Cf. Grimes and Miozzo (2015); Haakonsson and Ujjual (2015); Lewin, Massini, and Peeters (2009).

32 Especially emerging countries have created special economic zones (SEZ), with own infrastructure and often preferred tax regimes. The benefits of these SEZs for the respective region or country are not always given. Cf. Sosnovskikh (2017).

innovation (e.g. through a patent box[33]) or indirectly, by keeping foreign competition out through tariffs.[34] The literature does observe positive short-term effects for countries employing these policies. However, firms not always create sustainable value when relocating to regions or countries with these incentives and rather benefit by tax shifting and windfall gains. Therefore, several empirical studies do not consider special financial incentives as long-term beneficial for countries.[35] Instead, regions providing reliable infrastructure, improving the education sector, as well as competitive and non-discriminatory tax rates have proven to be successful in attracting and keeping foreign R&D investments. As part of the legal environment, companies will prefer regions or countries with strong appropriability regimes, i.e. systems that efficiently and successfully guarantee that the inventor can also reap the benefits from his inventions. From the side of the policy-makers the optimal level of appropriability can be difficult to determine: on the one hand, a high appropriability encourages R&D but also raises barriers impeding knowledge distribution. On the other hand, a low appropriability will distribute the knowledge more efficiently but discourages R&D, because the inventor might not fully benefit from his invention investments.[36] This appropriability trade-off will be further discussed below.

Fourth, the existence of a lead market. Beise (2004) defines lead markets in innovation, based on the general concept developed by Bartlett and Ghoshal (1990) as markets which induce global innovations through local demand environmental conditions. It is an important concept in explaining the creation and diffusion of innovations. A lead market is not necessarily the market in which an invention took place, as numerous examples in history show the opposite: firms from one country picking up an invention made elsewhere and rolling it out on a large

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[33] A Patent Box offers a significantly lower corporate tax rate for revenue generated through patents or other forms of intellectual property. Cf. Evers, Miller, and Spengel (2013, p. 1). Ireland and France started to establish these tax schemes in the beginning of the 2000s followed by other countries, such as UK, China, Netherlands etc. Some of these respective taxation schemes are considered to be “harmful” by the OECD in terms of a fair and balanced international competition. Cf. OECD (2015a).

[34] Gerybadze (2019), for example, analyzes the Asian countries Japan, South Korea and China based on the thoughts of German economist Friedrich List, arguing that less advanced nations need to protect their nascent entrepreneurial firms from foreign competition, at least initially, through tariffs.

[35] Cf. OECD (2011); Cantwell and Piscitello (2002); Thursby and Thursby (2006); Kinkel and Maloca (2008).

[36] Cf. Malerba and Orsenigo (1995).

scale.[37] It defines and elaborates on a concept brought up in earlier works by Gassmann and von Zedtwitz (1999); Gerybadze and Reger (1999) or Gerybadze (2004a).

The idea of foreign lead markets is, that despite globalization, attitudes, demands, or more generally environments, differ across countries. Often innovations become globally successful after they have reached a critical penetration rate in a lead market, i.e. the high penetration in a lead market stimulates penetration of the lag markets. Apart from the example of the fax machine, outline in footnote 37, one might think of the internet, which was first popularized in the US or several automotive-related inventions, such as the airbag, which were first widely adopted in Germany, before they became industry standard or the photovoltaics industry in China[38]. It is crucial to point that the lead market is not automatically the market which first adopts an invention, but rather the first market to adopt an innovation, which is subsequently adopted by other countries.[39]

Internationalizing R&D is therefore closely connected to the concept of lead markets: firms have to go “where the action is”, i.e. identify and locate lead markets in order to capture and shape nascent technologies.[40] A multitude of analysis has looked at particular cases or industries in detail and confirmed the concept of lead markets as a determining factor of R&D Internationalization.[41] That means that R&D Internationalization does not necessarily imply a broad global distribution of R&D activities, but rather a selected concentration on a few countries or regions, which are technologically advanced and relevant for the particular niche of technology.[42] Therefore, also emerging countries can fill this role and are in fact increasingly relevant as lead markets in certain fields and boosters of R&D Internationalization.[43] With a strategy of exploitation a key approach of R&D Internationalization is rather the fast acquisition of relevant foreign locations and knowledge, instead of building up a foreign location

37 For example, the fax device was popularized in Japan: While the technology was not invented there, the fax machine quickly replaced the existing teleprinters or telex systems: the teleprinter technology allowed for only a restricted size of character set, which limited the practicality with the Japanese ’Kanji’ character system. The fax machine, however, allowed for the transfer all kinds of characters, due to the image processing technology. Japan therefore become the lead market for the fax machine. The US and then Europe adopted the fax machine and within a few years, other systems were pushed to a niche existence.

38 Cf. EFI (2012, p. 106), who outline in detail the case and development of China’s photovoltaics industry as a lead-market.

39 Cf. Beise and Gemünden (2004).

40 Cf. Gerybadze (2020).

41 Cf. for example Klein (2018) for an analysis of the wind energy sector, which identifies particularly Denmark as a lead market or Schaffland (2017) for an analysis of the ICT sector.

42 Cf. Gerybadze and Reger (1999).

43 Cf. Tiwari and Herstatt (2012), who apply the lead market concept to the emerging country of India.

independently from scratch.[44] Such an M&A does not necessarily have to be a singularity, but rather is a sequence of several M&A resulting in an integration and consolidation of existing R&D units.[45]

Accessing lead markets can also benefit firms in a standard-setting process, which plays a relevant role in certain industries and early-stage developments (e.g. technological, IT fields).[46] Performing R&D internationally and at relevant locations can help to be at the forefront of standard-setting, which can give the firm a competitive advantage.[47]

An additional fifth factor, which does not directly affect the decision to internationalize R&D, but rather influences where to the internationalization takes place is the distance of the R&D host- towards the home-location affects costs and benefits. Studies have shown that a geographical and cultural proximity leads to higher cross-regional R&D activities, due to lower coordination and transaction costs.[48] A higher cultural distance implies additional challenges through the lack of tacit knowledge and embeddedness in local informal networks.[49] This "liability of outsidership"[50] decreases over time but can continue to persist.[51] Another factor favoring a close geographic proximity when internationalizing R&D are potential knowledge spillovers: R&D serves not only the purpose to generate new information, but also "enhances the firm's ability to assimilate and exploit existing information"[52]. Direct benefits can be learning about new technologies, materials, methods and processes. Indirect benefits stem from the contact to trade partners and customers.[53] With less distance, there are fewer potential barriers or hindrances for spillovers. As the geographical or cultural proximity is a main

44 Cf. Bertrand and Zuniga (2006); von Zedtwitz and Gassmann (2002). Di Minin, Zhang, and Gammeltoft (2012), for example, outline the relevance of technology exploitation in foreign locations through M&A particularly for fast-moving firms from emerging countries, here China.

45 Cf. Gerybadze (2020).

46 Cf. Dunning and Lundan (2009); Di Minin and Bianchi (2011).

47 Cf. Rysman and Simcoe (2008); Lin (2003).

48 Cf. Guellec and van Pottelsberghe de la Potterie (2004); Luintel and Khan (2017); Carrincazeaux, Lung, and Rallet (2001). Dachs and Pyka (2010) argue that a higher distance between locations implies higher costs through the "decentralization of innovative activity".

49 Cf. Cavusgil, Calantone, and Zhao (2003).

50 Cf. Johanson and Vahlne (2009) who established and developed this term from the "liability of foreignness" by Zaheer (1995, p. 342f). In a follow-up paper Vahlne, Schweizer, and Johanson (2012, p. 229ff) discuss how "experiental knowledge, commitment building and trust" help to overcome this "outsidership".

51 Cf. Fu, Revilla Diez, and Schiller (2013); Ledeneva (2008).

52 Cf. Cohen and Levinthal (1989, p. 569). Aghion and Jaravel (2015, p. 570) build on this concept and explain how companies may conduct basic research less for particular results, than for identification and exploitation of potential knowledge spillovers generated by competitors, universities or public research institutions. They measure R&D spillovers by evaluating the role of new knowledge on R&D intensity of a given industry.

53 Cf. Coe and Helpman (1995); Coe, Helpman, and Hoffmaister (1997).

determinant of the magnitude of positive knowledge spillovers, firms will cluster more in fields with a high degree of spillovers, i.e. R&D activity.[54] A location's attractiveness for R&D investment therefore highly depends on the potential for industry- or cluster-specific spillovers, which in turn to some degree depends on the geographic or cultural distance to the home location.[55]

1.1.2. Industry-based factors for R&D Internationalization

The drivers for R&D Internationalization, differ also on an industrial level, for two reasons: First, R&D has a different strategic importance and outline for different industries. The R&D intensity can indicate the relative importance of R&D[56]. Industries with a high importance of R&D, e.g. pharma, have to follow different strategies than industries with a low relevance, e.g. construction.[57] A higher R&D intensity, however, does not automatically imply a high R&D Internationalization, as, for example, the biotech industry shows a high R&D intensity but is rather concentrated in few countries (e.g. the US).

Second, it is not just the R&D intensity and degree of R&D Internationalization which differs across industries, but also the path of innovation activity. Depending on the respective industry there are substantially different inherent processes towards R&D Internationalization.[58] Partly these differences can be explained with historic differences: IT, for example, is a rather young field, characterized by rapid growth rates in the last decades, whereas classic manufacturing industries such as Aerospace & Defense have lost in relative relevance. The former is generally more internationalized to a higher number of countries than the latter, as the former was "new to everyone" and not based on a historically grown foundation.[59] The detailed

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54 Cf. Breschi and Lissoni (2001); Audretsch and Feldman (1996).

55 Cf. Cantwell and Piscitello (2002); Luintel and Khan (2017).

56 The R&D intensity is defined as the share of a company's expenditure on R&D to its sales (OECD, 2015b). It is comparably high, e.g. in the biotech or pharmaceutical industry, where the R&D intensity is on average well over 10% (European Commission, 2017, p. 12).

57 Cf. Gassmann, Reepmeyer, and von Zedtwitz (2008, p. 48f), who argue that due to the complexity of pharmaceutical substances and technologies, no single company can be successfully innovating alone. Companies aiming to succeed in this competitive market, rather have to "look beyond their own research borders" through international collaborations with universities, research centers and competitors. A high R&D Internationalization in Pharma is furthermore explained by the approval process of drugs: in stage III of the development process, drugs are tested on numerous people in numerous markets, which regularly requires an international presence (FDA, 2018).

58 Cf. Malerba (2002); Castellacci and Zheng (2010). Reddy (2011) & Grimes and Miozzo (2015) explain the unique internationalization pattern in the pharma industry: a long development time of over ten years allows for splitting of the numerous development steps to different locations. The emergence of new technologies in recent years increased the necessity for specialization and thereby for outsourcing parts of the value chains to locations with competences in the respective fields.

59 Cf. Mani, Srikanth, and Bharadwaj (2014) or Nepelski and De Prato (2012) for an overview of R&D Internationalization in the ICT / IT industries.

industry activities will be analyzed in the upcoming chapters. I will also show in the next chapters that R&D Internationalization across industries is not evenly spread on countries, but rather exhibits focused patterns: some countries have created competencies, incentives and other factors which made them attractive for foreign R&D investments in a particular industry.[60]

Four factors can be identified which differently influence the decision to internationalize R&D depending on the industry level.

First, the level of appropriability inherent to the particular industry. As discussed in the previous subchapter, appropriability can strongly differ across regions and countries due to different policies. However, it also differs across industries.[61] In industries, where inventions are harder to codify and thereby harder to protect (e.g. service sector) or where the general complexity of inventions is comparably low and therefore competitors can more easily "invent around" (e.g. clothing, food) knowledge is more likely to spill.[62] In order to reduce this risk, a company in such a sector is more likely to keep its R&D more under its control by remaining centralized and refraining from R&D Internationalization.[63]

Second, the degree of "cumulativeness". Cumulativeness refers to the concept that today's innovation is building on and thereby depends on yesterday's innovation. It describes the degree of serial correlation between subsequent innovations.[64] With a higher complexity of knowledge (see previous point) learning effects, experience and knowledge become relatively more important: technological leaders therefore can be expected to continuously innovate to keep their competitive advantage.[65] Industries with a higher degree of cumulativeness, such as biotech, pharma and IT could be expected to have a more concentrated R&D and thereby less internationalized to achieve a higher degree of specialization and benefit from economies of scope.[66] However, the effect of cumulativeness on an industry level appears to be small, as ample evidence outlines the high degree of R&D Internationalization in the above-mentioned industries with high cumulativeness and studies have found little statistical evidence on the effect of industry to R&D Internationalization with regards to

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60 Cf. Gerybadze (2020).

61 Cf. Levin et al. (1987); Cohen, Nelson, and Walsh (2000), who first reported large-scale evidence about the influence of appropriability regimes on companies' location decisions.

62 Cf. Cohen, Nelson, and Walsh (2000); Hurmelinna-Laukkanen and Puumalainen (2007); Harabi (1995).

63 Cf. Breschi (2000, p. 216).

64 Cf. Malerba and Orsenigo (1996); Breschi (2000, p. 215).

65 Cf. Gambardella and Malerba (1999, p. 74).

66 Cf. Singh (2008), who finds a negative impact of a distributed R&D to the average value of companies' innovations. The exact build of the regression model might distort the findings, as important variables, e.g. a time-variance factor, are omitted.

cumulativeness.[67] One explanation would be that the number of inventors in industries with high cumulativeness is so high, that the benefits of international exchange, i.e. R&D Internationalization outweigh the benefits of knowledge concentration.[68] This relates to the next point:

Third, the relative importance of networks. A high degree of connections to the "outside" fosters R&D Internationalization. On the one hand this can be seen in industries which heavily rely on basic research, such as Pharma or Biotech. Companies in these industries often rely on partners, such as universities or other public research institutions, as well as on competitors through joint-ventures. On the other hand, industries with a highly distributed commodity chain, such as Automotive, depend highly on their networks, as they are tightly connected to their suppliers. Unless the company is already located in a strong lead-market (see Chapter 1.1.1) with a clustered network, a high relative importance of such networks in a given industry will require a company more to put its R&D in proximity to its partners, i.e. to internationalize.[69]

Fourth, tacitness. This term was first used in a modern sense in 1958 by Polanyi and described knowledge which could not be codified and passed on through words.[70] Later, the term tacitness has shifted slightly in meaning and nowadays describes all forms of un-codified personal knowledge without the previous underlying conditions.[71] Therefore, a high degree of tacitness implies that knowledge transfer over a geographical distance becomes expensive. The effects on R&D Internationalization are ambivalent: on the one hand, high tacitness can enable a concentrated R&D, i.e. a low degree of R&D Internationalization, to concentrate the tacit knowledge in one place and avoid the high transaction costs. On the other hand, high tacitness can also enable a high degree of R&D Internationalization: due to the high transaction costs of tacit knowledge a company disperses its R&D, i.e. highly internationalizes it, in order to be present in numerous locations, where the respective local tacit knowledge is clustered.

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67 Cf. Gassmann and von Zedtwitz (1998, p. 148ff), who outline the connection of R&D intensity and R&D Internationalization by analyzing 31 companies from three industries. In several other publications both authors have followed up on this topic: e.g. von Zedtwitz (2005), von Zedtwitz and Gassmann (2016).

68 Cf. Baptista and Swann (1998).

69 Cf. Edquist (1997, p. 67ff), who considers networks as a key element in the innovation process.

70 Cf. Polanyi (1966, p. 4ff; 2005, p. 69ff). In his 1966 work, Polanyi gives the example of recognizing a familiar person's face: while one could recognize it "among a million", one usually could not put in words how exactly to recognize said face.

71 Cf. Cowan, David, and Foray (2000, p. 212).

1.1.3. Company-based factors for R&D Internationalization

Two companies operating on the same regional and industrial level, still can differ in their R&D Internationalization structures, as companies differ with respects to their size, management, product portfolio, cost structure etc. Four factors can be identified influencing the degree of R&D Internationalization on a company level and creating heterogeneity.

First, degree of internationalization in production and distribution. There is a correlation of the degree of production and distribution internationalization, as R&D locations abroad can be intended to support production and distribution: products have to be adapted to local markets and with a geographically close R&D these design, adaptation and development processes can be done in an easier way.[72] Therefore, companies internationalize R&D to "exploit their assets" abroad in a better way.[73] Dunning argues that these assets are exploited through Foreign Direct Investments (FDI), because of ownership, location and integration, i.e. internationalization, advantages. Depending on these factors two otherwise similar companies might follow substantially different R&D Internationalization approaches, due to a self-selection[74].

Second, relevance of creating and gaining new knowledge. Companies internationalize their R&D in order to tap into the globally distributed and increasingly specialized knowledge pool. MNCs are therefore "seeking assets" through specialized and superior knowledge in a certain field.[75] While we have discussed the access to local knowledge already in Chapter 1.1.1, it is also a relevant company-based factor. Depending on the particular firm history, mindset, respective environment a foreign R&D location can function more or less as a "local antenna", meaning that it monitors local trends and transfers information back to the home-base.[76] A main driver for the asset-seeking strategy is the rising complexity of knowledge[77] and technology which requires companies to be present in several locations in order to be at the

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72 Cf. Kafouros et al. (2008). The local adaptation activities can also include following local regulations. For example Kuemmerle (1999a) & Dunning and Narula (1995) point out local environmental laws as a common governmental regulation necessitating local R&D.

73 Cf. Dunning (1973, p. 307ff; Dunning and Lundan (2008, p. 401ff), who call this motive "asset exploitation" . Other researchers call this motive "home-base exploiting" (Kuemmerle, 1999a, p. 2ff) or "market-driven R&D" (Boutellier, Gassmann, and von Zedtwitz, 2008, p. 98ff).

74 Cf. Head and Ries (2003); Helpman, Melitz, and Yeaple (2004). Crescenzi, Gagliardi, and Iammarino (2015), for example, outline market engagement and ownership structure as main effects.

75 Cf. Dunning and Lundan (2008, p. 72ff), who call this motive "asset seeking". Other researchers call this motive "home-base augmenting" (Kuemmerle, 1999a, p. 2ff) or "global R&D strategy" (Boutellier, Gassmann, and von Zedtwitz, 2008, p. 103ff).

76 Cf. Meyer-Krahmer and Reger (1999, p. 769).

77 Some of the knowledge can be tacit, i.e. transferrable only with relative high costs. See discussion in the previous sub-chapter.

technological frontier[78] and located in lead markets.[79] “Asset-seeking” therefore also implies that a company has to collaborate with numerous entities, as substantial knowledge is gained through engagement with local partners, customers and research institutions.[80] Asset exploitation and asset seeking are not mutually exclusive. In fact, several analyses have shown how companies use both strategies, depending on the respective environment and target-country.[81] On top the concept of augmenting vs. exploiting has been discussed and expanded by subsequent research. Gerybadze and Merk (2014) identify three approaches: an increase of number and size of foreign R&D locations, the creation of new products in lead markets and the increasing inclusion of foreign-based inventors in patenting activities. The former two approaches can be subsumed as augmenting and the latter as exploiting.[82]

Third, firm performance and R&D Internationalization. Research has found a connection of the optimal level of R&D Internationalization, in terms of increasing firm performance, and the R&D Internationalization. However, the direction and shape of relationship have not yet been conclusively identified.[83] While the optimal level of R&D Internationalization in terms of the firm size can be hard to determine and appears to be dependent on the respective industry and target countries, however, a connection of R&D, R&D intensity and firm size is undoubted.[84]

Forth, internal company structure. The internal company structure influences the scale and scope of R&D Internationalization both regarding the quantitative cost structure and the qualitative management style. The costs of an internationalized R&D include transaction costs

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78 Cf. Reddy (2011); Grimes and Miozzo (2015).

79 Cf. Gerybadze (2020) and above for an elaboration on “lead markets”.

80 Cf. e.g. Narula and Zanfei (2005) & Florida (1997) & von Zedtwitz and Gassmann (2002). This idea is related to the concept of “Open Innovation”, as discussed by Chesbrough (2006, p. 25ff), who argues that companies increasingly not only use their internal R&D, but also concepts and ideas developed through external parties, including parties located abroad.

81 Cf. Dunning (1993), which first acknowledges the inter-connection of the OLI-framework. Later works expanded on how the components of the OLI-framework are linked over time (Dunning and Narula, 2004, p. 201ff). Studies, e.g. by Ivarsson and Jonsson (2003); Buckley et al. (2016), outline how both strategies are used selectively by MNCs and thereby confirm Dunning.

82 Furthermore, a number of research by Criscuolo, e.g. Criscuolo, Narula, and Verspagen (2005); Criscuolo (2006) expands on the augmenting – exploiting classification.

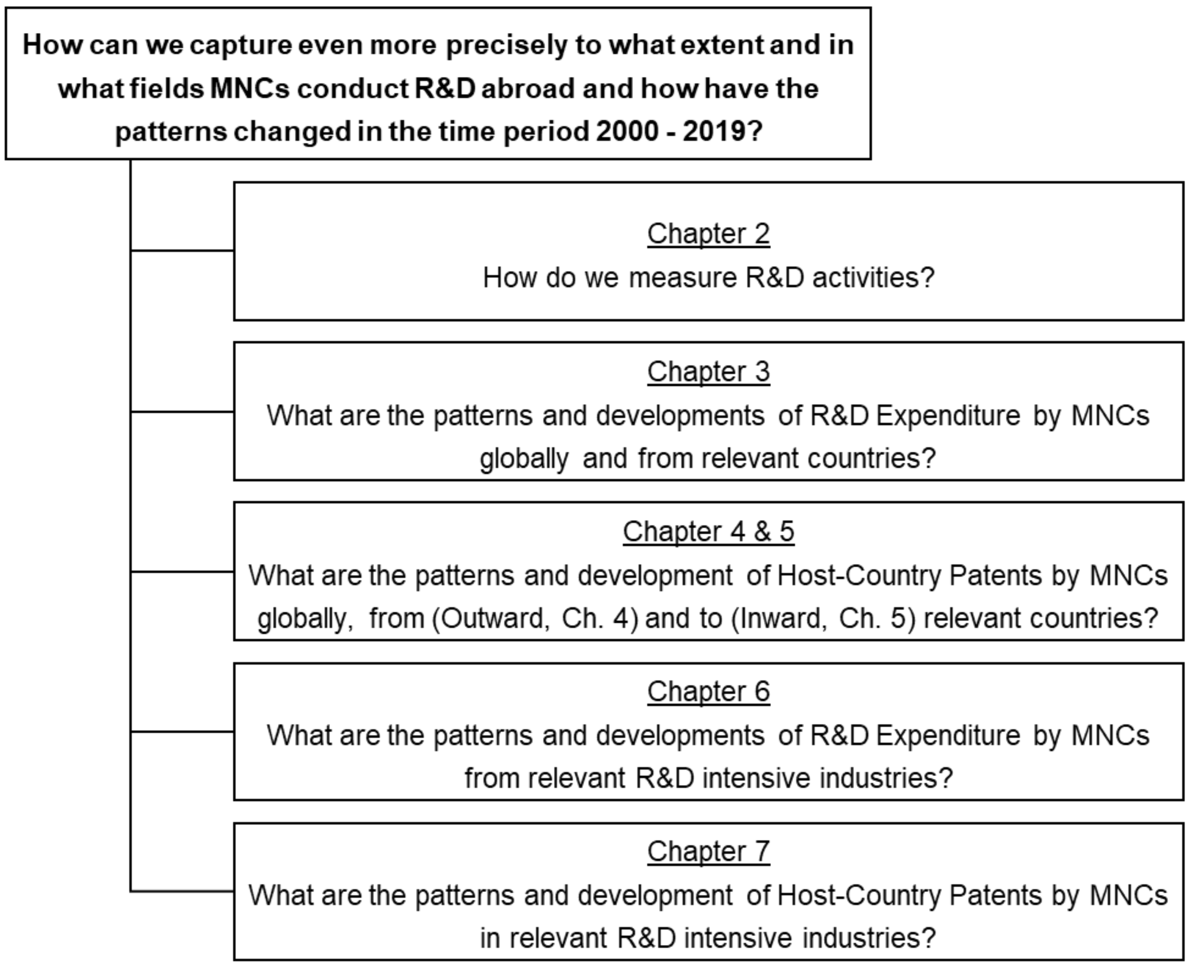
83 Cf. Hsu, Lien, and Chen (2015), who report a curvilinear U-shaped relationship between R&D Internationalization and innovation performance in Taiwanese high-tech firms. The underlying thesis is that only above a certain degree of R&D Internationalization the benefits outweigh the costs and positive impacts on performance can be determined. Hurtado-Torres, Aragón-Correa, and Ortiz-de-Mandojana (2017), on the other hand, find an inverted U-shaped relationship of R&D Internationalization to a firm’s performance in the energy sector, implying that very high levels of R&D internationalization deteriorate innovation performance. However, the finding is contingent upon the positive moderating impact of firm’s international experience embedded into firm’s capability in dealing with the challenges of international expansion.

84 Cf. OECD (2009, p. 148ff).

for the coordination of R&D activities within the firm and opportunity costs for looser control over technologies and a decreasing embeddedness in the national innovation system (NIS) of the home-base, compared to a centralized R&D.[85] A decentralized R&D structure requires an appropriate management structure with an established intrafirm communication[86]: an efficient internal knowledge transfer from the home-base to the foreign location increases the benefits from incoming external spillovers to the home-base. This in turn improves the efficiency of gaining external knowledge and thereby both strengthens and encourages a decentralized R&D structure.[87]

1.2. Research Questions and Structure of Dissertation

Figure 1-3: Research Questions and Structure of Dissertation



85 Cf. von Zedtwitz and Gassmann (2002); Narula (2003).

86 Some authors, e.g. Birkinshaw (2002, p. 257ff), even argue that R&D Internationalization can only made possible with giving a relatively high degree of autonomy to the foreign locations.

87 Cf. Sanna-Randaccio and Veugelers (2007, p. 59); Ramirez and Li (2009, p. 290); Gersbach and Schmutzler (2011, p. 136).

Chapter 2 introduces into the methodology of analyzing R&D Internationalization. I will outline the exact ways and data sources of my analyses, based on relevant prior research. Namely I will outline the methodologies of analyzing R&D Expenditure, Patents, Cultural Distance as a degree of R&D Internationalization, Interviews and Country Classification.

Chapter 3 analyzes structural changes in the R&D Internationalization processes both from a global perspective, as well the four major economies Germany, USA, Japan and China. With quantitative data, i.a. provided by the OECD and national statistic offices, patterns in the R&D Internationalization are determined.

Chapter 4 & 5 analyze Host-Country Patents (HCPs), i.e. patents conducted with inventors located in foreign countries. Patents are regularly used as proxies for R&D Internationalization, due to their standardized nature of publication and disclosure of inventors.[88] I will give a global overview of major home- and host-countries and go into detail for relevant economies. I show Outward HCPs in Chapter 4 and Inward HCPs in Chapter 5. Outward HCPs show in which countries firms from a particular country are basing their R&D. Inward HCPs shows where foreign firms are located, which internationalize R&D into a particular country.

Chapter 6 takes an industry perspective and shows trends and shifts in R&D Expenditure patterns. In this chapter I follow a three-step approach: first, I give an overview over the top R&D expending industries worldwide and their developments. Second, I show the R&D Expenditure of relevant industries per country. Third, I give a country analysis of relevant economies, to outline which country has focused and specialized in what industry.

Chapter 7 gives a methodological patent analysis of relevant R&D intensive industries. I show not only classic indices, such as patent numbers, but also the quality, competitiveness and "internationalization-ness" of patents in major R&D-conducting industries and technological fields.

Chapter 8 summarizes and concludes this dissertation.

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[88] Cf. Laurens et al. (2015).

2. Methodology of Analyzing R&D Internationalization

This chapter breaks down the methodologies of analyzing Research & Development (R&D) and answers the following research questions:

RQ2.1:	With which indices can we measure innovation?
RQ2.2:	How exactly can each index be calculated to give insights into innovation activities?
RQ2.3:	What are the advantages and challenges of the respective indices?

Common methods and standards to measure, analyze and interpret data on innovation is crucial for academics, policy makers and decision makers in businesses in order to make sound analyses and conclusions, as well as to facilitate comparability across geographic regions. The most accepted definitions and standards are jointly published by the OECD and EUROSTAT in their 'Oslo Manual', sometimes called the "bible" for innovation research.[89] The Oslo Manual is regularly updated and now in its 4th version, in order to reflect changes in prevailing opinions what and how innovation can be measured exactly.[90]

Not all innovation measurements are equally relevant for each purpose and approach. Depending on the size and scope of analysis, quantitative or qualitative, broader or more narrow indices can be utilized.

The most common indices, also used in this dissertation are given in the following. One approach is to break down the indices into input and output measures.[91] For precision purposes, I include a third category: intermediary.[92]

1. **Input Measure:** These measures quantify the resources going into the innovative process. They are generally good to measure innovation in the early stages, because input metrics are responsive. The following measurements and a combination thereof are common indices used in the literature. The exact indicators and measurement procedure might differ, as the business environment and ultimate goal of the analysis might be different:
    - R&D Expenditure in absolute terms or as a percentage of sales (R&D intensity).

89 Cf. Finnish Ministry of Education (2009, p. 23).
90 OECD and EUROSTAT (2018).
91 Cf. Criscuolo, Narula, and Verspagen (2005).
92 Cf. Acs, Anselin, and Varga (2002).

    - Number of innovation projects started within a certain time-period.
    - Number of R&D locations or R&D employees: Counting locations or staff can be the "least bad" option, if more precise data is not available. The underlying, yet not necessarily correct, assumption is, that a twice as large R&D location also has around twice as much innovative output.[93]
2. **Intermediary Measure:** A commonly used method of analyzing innovation are patents. Researchers can count the number of patents applied or granted for a very standardized unit of comparison and analysis. However, as a patent stands at the end of a step in the innovation process, it is not an output measure, as product tests and adaption can follow, and not every patent results in some kind of product or process output. A detailed description of patents, as a measurement for innovation, follows.
3. **Output Measure:** These measures quantify the outcomes of the innovation process. Usually, these metrics are easier to collect but less actionable from a business perspective, due to the time-lag of innovative activity and ultimate change in outcome indicator. Commonly used outcome measurements are:
    - Number of new products launched within a certain time period[94]
    - Revenue / Profit from new products
    - Return on Investment (ROI) on innovation activities

When selecting indicators for measuring R&D, the following criteria must be met:

- The indicators must be relevant and meaningful.
- The indicators must be collectible in a reliable way.

In the following the method of analysis for the most relevant measurements, which will be used in this analysis, will be explained. I will show how exactly I measure R&D activities in this dissertation.

[93] Hsu, Lien, and Chen (2015), for example discuss the effect of R&D Internationalization on innovation performance. They measure the degree of companies' R&D Internationalization by counting the respective number of domestic and foreign R&D locations. This approach can be challenged: a company with one R&D location in a certain country employing 10,000 R&D employees would certainly be more innovative and more internationalized in terms of R&D, compared to another company which has three R&D locations in said country, with just 5 R&D employees in each location. Counting only the locations certainly skews the data.

[94] This data is usually collected via surveys, e.g. Geroski (1995). A potential question, as used by the "Business Environment and Enterprise Performance Survey (BEEPS)", is: "How many new or significantly improved products did this establishment introduce in the market over the last three years?" (EBRD and World Bank, 2012)

2.1. R&D Expenditure

Measuring the amount of money spent on Research & Development (R&D Expenditure) is of interest to decision makers, as it shows who conducts R&D to what extent at which places. It can further show the development and shifts in R&D activities and thereby reveal the effectiveness of policy action.[95] R&D Expenditures are an input measurement of innovation activities, so R&D activities through expenditure can be observed with a smaller time lag, than, for example, through patents. Policy makers therefore benefit from timely data.[96]

A certain level of expenditure can be a goal in itself, as the "EUROPE 2020" strategy by the European Commission, published in 2010, set the target that 3% of the EU's GDP should be invested in R&D by 2020.[97]

This "Gross Domestic Expenditure on Research & Development" (GERD) is a commonly used index to show how much money has been spent on R&D within a country during a set period. It helps in comparing countries.

This dissertation focusses on businesses, so I will use the Business Expenditure on R&D (BERD). BERD is a subset of GERD, although the terms GERD and BERD are sometimes used interchangeably. However, it should be clarified, that the GERD refers to all expenditure on R&D, whereas the BERD refers only to expenditures by companies – the focus of analysis in this dissertation. Other, and usually much smaller parts of GERD, are expenditures on R&D by the Government sector (GOVERD), the Higher Education sector (HERD) and the Private Non-Profit sector (PNPRD).[98]

2.1.1. Definition and Terminology

The FRASCATI-manual, defines BERD as "the measure of intramural R&D Expenditures within the Business enterprise sector" OECD (2015b, p. 33). Throughout the dissertation I will use a fixed set of terms. Therefore, I elaborate on the FRASCATI definition and will use the following terms[99]:

95 Cf. OECD (2015b).
96 Cf. Mansfield (1984).
97 Cf. European Commission (2010).
98 Cf. OECD (2015b, p. 145).
99 The FRASCATI-manual breaks down R&D funding flows into performing (intramural, extramural) and funding side (internal, external) (OECD, 2015b, p. 129).

> **Definition:** The BERD of a country is the amount of money spent within that country in a set time period. It is the sum of money spent on R&D within that country by companies ultimately owned by entities from that country (National R&D) and the money spent on R&D coming from foreign companies, i.e. from other countries within that country (Inward R&D). The Outward R&D is the amount of money spent on R&D by companies from that country in other countries. The sum of money spent on R&D by companies from that country domestically and abroad is the Total R&D.

“Ultimately owned” refers to the concept of ’Ultimate Beneficial Owner’ (UBO). It refers to the entity who “ultimately owns or controls” a company.[100] For the classification of R&D, we have to distinguish between domestic and foreign firms, for which the location of the hierarchically highest owner is relevant. Consider the following example: Company A is German; Company B is Norwegian. The Norwegian company B fully owns the German company A. When we analyze the R&D Expenditure of Germany, we would consider R&D Expenditure of company A as foreign (non-German), because it ultimately is owned by a foreign (here Norwegian) entity.

Figure 2-1 illustrates these five sets in a Venn-diagram. The mathematical set notation looks as following:

EQ2-1 $$Inward\ R\&D \subseteq BERD$$

EQ2-2 $$BERD = Inward\ R\&D \cup National\ R\&D$$

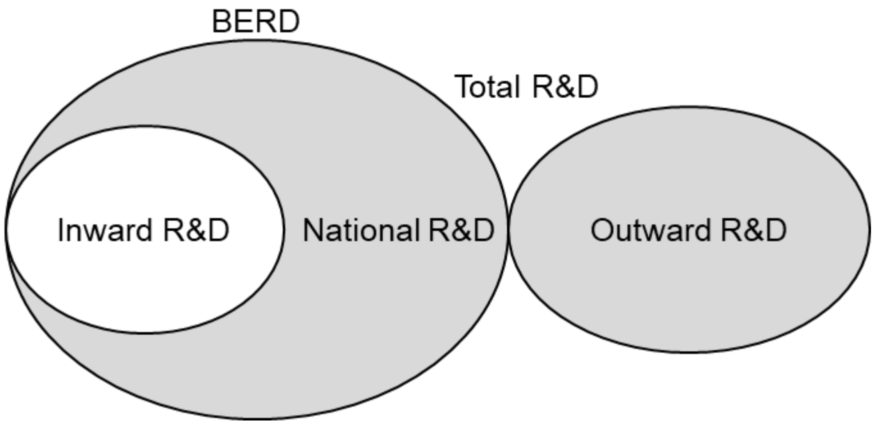
EQ2-3 $$National\ R\&D \cap Inward\ R\&D = \emptyset$$

EQ2-4 $$National\ R\&D \cap Outward\ R\&D = \emptyset$$

EQ2-5 $$Total\ R\&D = National\ R\&D \cup Outward\ R\&D$$

[100] Cf. FATF (2014, p. 8).

Figure 2-1: Terminology of R&D Expenditure Sets



Strategic, political goals, as the earlier mentioned 3% spending goal of the European Union's GDP in R&D are rather broad. First, it considers the GERD, i.e. different categories of R&D Expenditure. Certain political measurements might incentivize businesses to invest, i.e. increase the BERD, while at the same time government activities are reduced, i.e. decrease the GOVERD. Second, the GDP is not a constant variable: in an economic downswing the GERD might, for a short time, remain constant (low elasticity), so that the ratio of GERD to GDP actually increases and potential political goals are being met, with little practical positive impact on innovation. Furthermore, smaller economies with relative strong innovation activities can have a relative high GERD to GDP ratio although their absolute GERD is comparable low. South Korea and Israel, for example, have had a ratio for the last five years of >4%, whereas their absolute GERD can be a fraction of that of bigger economies. Israel's GERD, for example has been consistently <5% of the US'. Therefore, despite having a lower GERD to GDP ratio, the US are, in absolute terms, still a much bigger spender on R&D.[101]

2.1.2. Measurement of R&D Expenditure

Analyzing the measured R&D Expenditure is a standard input measure for innovative activities (see above). As trivial as summing up expenses might sound, the measurement of R&D Expenditure and thereby its analysis, can be challenging and comparability can be limited, despite common definitions through the FRASCATI manual.

Relevant databases to analyze R&D Expenditures are on a country level the OECD's AMNE database (Activity of Multinational Enterprises)[102], the OECD's MSTI database (Main Science

[101] Cf. MSTI database – OECD (2019a).

[102] The AMNE database is an expansion of the historical AFA (Activities of Foreign Affiliates) and FATS (Foreign Affiliates Statistics) databases and uses the industry classifications ISIC Rev. 3 and Rev. 4 United Nations (2008); United Nations (2002); United Nations (1990).

and Technology Indicators)[103] or the National Science Foundation's Science & Engineering Indicators[104]. On a company level the EU's R&D Scoreboard aggregates the top 2500 companies worldwide in terms of their R&D spending[105]. For detailed company level analyses, it can be fruitful to scrutinize a company's annual report, as well as its other publications, such as press releases, news reports etc. outlining the company's R&D activities

Put in a nutshell, R&D Expenditure in light of this dissertation is measured in one of the following dimensions:

- Total Business R&D Expenditure broken down to relevant countries or industries
- R&D investment of domestic firms abroad on a total scale or broken down by target country or industry (Outward R&D)
- R&D investment of foreign affiliates domestically on a total scale or broken down by country of origin or industry (Inward R&D)
- Individual R&D investments by respective companies

2.2. Patent Analysis to Measure R&D Internationalization

"The patent system […]; secured to the inventor, for a limited time, the exclusive use of his invention; and thereby added the fuel of interest to the fire of genius, in the discovery and production of new and useful things" Abraham Lincoln (1859, as cited in Kennedy and Cohen, 2013)

A company is an innovator when it creates new products, technologies or processes, often using substantial resources in the process. An imitator, following the innovator, does not bear its high R&D costs, as it can learn from the innovator's setbacks and follow with similar concepts. Depending on the appropriability regime in the respective country, industry and product segment, it can be easier or harder to take possession of the relevant knowledge.[106]

The innovator strives to maintain exclusivity over its new development. This can be achieved in two ways:

1. **Secrecy:** Keep the innovation secret and thereby protect it from imitation.

[103] Cf. OECD (2019a).
[104] Cf. NSF (2018).
[105] For earlier years, less companies are listed, e.g. the Top 500 EU and Top 500 non-EU firms for 2004 European Commission (2019).
[106] Cf. Teece (1986), who shows a taxonomy of win and lose outcomes from the innovation process for both the innovator and the follower-imitator.

2. **Protection:** Achieve legal exclusivity within the respective jurisdiction.[107]

Successfully implementing the ’secrecy-strategy’ can be challenging, as, in most cases, the innovator wants to bring third parties into contact with his invention: he might require suppliers who need specification, customers or partners who can disassemble the product and aim to reverse-engineer it etc. Technical attacks (hacking) or even such a chatty or disgruntled employee are just a few other possibilities for the ’secrecy-strategy’ to fail and thereby potentially costing a significant potential profit.

Despite the risks, the ’secrecy-strategy’ is regularly applied: either particularly by smaller firms or individuals, who do have other means, such as market power, to fully appropriate their invention[108] or in cases, where inventions are not yet commercializable[109].

2.2.1. Characteristics and Relevance of Patents

Instead of creating and maintaining secrecy, a patent follows a different logic: the innovator describes its innovation in detail and discloses its structure and method to a public institution – the patent office. The disclosure helps the patent office and competitors to check for prior art, i.e. overlaps with other inventions, as well as to disseminate the novel information and thereby advancing the scientific horizon.[110] The patent office checks the application and tests whether it fulfills five criteria. In case of a positive evaluation, the patent office grants the patent. Contrary to popular belief this patent does not grant its holder the right to make, use or sell, it simply grants the right to exclude others from using that technology within the respective legal jurisdiction,[111] for usually 20 years.[112]

The five substantive criteria which have to be fulfilled for patent granting are:[113]

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[107] Cf. Gerybadze (2004b, p. 91ff).
[108] Cf. Arundel (2001); Graham and Hegde (1999).
[109] Cf. Hussinger (2006).
[110] Some academics argue that the economic utility of a patent is rather the dissemination of information, than the rewarding of the R&D costs of the inventor (Kultti, Takalo, and Toikka, 2007).
[111] Cf. Herman v Youngstown Car Manufacturing Co. (1911).
[112] Cf. Merck Co. Inc. v A Kessler (1989). The usual term of a patent worldwide is 20 years, while there are certain exceptions, e.g. in the pharma industry, where extensions can be granted to compensate for delays in market approval.
[113] Cf. EPO (2017); USPTO (2018) for a comprehensive overview.

1. **Eligibility of subject matter:** Even if an invention fulfills all other criteria, certain subject matters can be excluded. Depending on the respective legislation this usually includes intangible objects, e.g. theories, mathematical methods, aesthetic creations.[114] While several European countries usually require a certain degree of "technicity", and thereby exclude patenting of software, the U.S., for example, permits software patents.[115]
2. **Novelty:** An invention cannot be patented if it is already publicly known. The reference point in time is the "priority date", i.e. the date of the first patent filing. The novelty requirement prevents researchers from prior publication: even a simple academic presentation on a conference can destroy the novelty characteristic, as that disclosure on the presentation would be considered "prior art".[116]
3. **No prior use:** The invention furthermore cannot be patented, if it has been used, sold or licensed in the own business.
4. **Inventive:** The new invention must inhibit some degree of inventive activity, i.e. it cannot be obvious to a skilled person.
5. **Usefulness:** The invention must have some concrete utility (U.S. law) or some industrial applicability (EU law). It cannot be merely hypothetical.

In general, the criteria are the same in all relevant markets, although they differ in detail (e.g. technicity) which can lead to disharmonies, i.e. very different results when aiming to patent the same invention across different jurisdictions.[117] Particularly the novelty criterion can be challenging to fulfill, as this prevents researchers from publishing and discussing preliminary results. While the U.S. allows for a grace period of 12 months after the first publication, in which a filed patent still is considered to be "novel", European countries consider the novelty criterion as absolute.

The novelty criterion can also be used strategically as a way of intellectual property protection, called "defensive publication": By publishing an invention on purpose, it becomes public domain and therefore cannot be patented by competitors. This strategy can be advisable for inventors who cannot or do not want to undergo the costly and lengthy process of a patent

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[114] Cf. §52 European Patent Convention, EPO (2016). Other legal forms such as utility models or registered designs may protect such items in certain jurisdictions (WIPO, 2017).

[115] Cf. Bessen and Hunt (2007).

[116] Cf. Franzoni and Scellato (2010). In certain jurisdictions a "grace period" exists: within that period a prior (e.g. academic) publication does not necessarily set a "prior art" and therefore does not conflict with the novelty requirement. In countries such as United States, Canada or South Korea this grace period is 12 months. The EPO and most European countries do not have any grace period.

[117] Cf. Jensen, Palangkaraya, and Webster (2005), who analyze discrepancies between the Trilateral Patent Offices.

filing, while preventing competitors from locking them out of their own invention, by filing the patent themselves.[118]

2.2.2. Patents as Indicator for R&D Activities

Patents are a helpful proxy to determine size and scope of R&D activities.[119] Companies usually do not publish comprehensive quantitative data on the details of their R&D data, whereas the standardized structure of a patent allows for time series analyses, identification of geographical R&D activities[120], as well as comparisons between companies. Patents are public and due to the legal requirement of being published after 18 months, at the latest, patent analyses allow for relatively up-to-date insights. Patent data can therefore help to complement R&D data, as – often but not always – a causality and positive correlation between R&D spending and number of patents has been shown.[121]

It has to be noted that patents and products in industries do not necessarily have a 1:1 connection, i.e. one new product can be based on several patents and one patent can serve as the foundation for several products. One exception is the pharma industry, where there is a tight connection between R&D activity, patent and product.[122] It is therefore not trivial to put a value on one single patent, but at least the criteria for patent filings, as discussed in the previous chapter, ensure a certain degree of technological and economical significance.[123]

2.2.3. Structure and Composition of Patents

Each patent is filed in the same standardized manner. It is crucial to understand this structure in order to develop a stringent model of analysis.[124] In the following the relevant variables of a patent, which are relevant for the upcoming analyses, will be introduced:

1. **Inventor Name and ID:** The inventor(s) listed on the patent are the individuals involved in the invention process. Each inventor gets assigned a unique ID by the patent office.
2. **Inventor Country:** The complete address, including country of the inventor is listed on the patent. It is not to be confused with the country of citizenship or birth of the inventor. The location of the inventor serves as a proxy to determine the location of R&D activity, as it is

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[118] Cf. Adams and Henson-Apollonio (2002); Barrett (2002).

[119] Depending on the industry one inherent error, as mentioned before, is of course that not every R&D activity results in a patent. Cf. Jaffe and Trajtenberg (2002, p. 3f).

[120] Numerous analyses use patent data to determine international R&D flows and discuss the advantages, e.g. Gerybadze and Sommer (2017); Gerybadze and Reger (1999); Criscuolo (2006); Guellec and van Pottelsberghe de la Potterie (2001); Rassenfosse et al. (2013).

[121] Cf. e.g. Pakes and Griliches (1980).

[122] Cf. Brouwer and Kleinknecht (1999).

[123] Cf. Dachs and Pyka (2010).

[124] Cf. Frietsch and Schmoch (2010), for a discussion on the methodology of patent analyses.

assumed that the inventor works and invents close to his residence.[125] If, for example, one patent by a German applicant shows five inventors, of which four reside in China, it can be concluded that a significant portion of the R&D activity was conducted in China. On a micro level patent analysis, the share of inventors is usually partially attributed to the respective countries (partial counting). On a macro level, i.e. country-level patent analysis, patents are usually counted fully, i.e. if at least one inventor comes from a certain country, this country's number of patents are increased by one (full counting).[126]

3. **Applicant Name and ID:** The applicant files for the patent and then owns it. Most patents are held by institutions, i.e. the company which employs the inventor.[127] Analyzing all patents by a company can be challenging and requires attention, as even the applicant ID does not facilitate easy comparisons: The patent office assigns its own application identification number, i.e. there is no common unique identifier such as the International Securities Identification Number (ISIN). However, the same company can receive several different IDs for its patents because the patent examiners do not conduct thorough searches for the company name. Other reasons include, but are not limited to, different notations (e.g. BAYER AG vs. Bayer Aktiengesellschaft[128]) or publications through subsidiaries (e.g. Bayer Intellectual Property GmbH, Bayer Innovation GmbH). In the case of the German pharma and life sciences company 'Bayer' over 100 different IDs for the actual same company can be identified. However, relying on a simple name search can be misleading, as for example the German 'Merck KGaA' is completely independent and separate from the U.S. 'Merck & Co.'. The former operates in North America under the name 'EMD', whereas the latter operates outside North America under 'MSD' (Merck Sharp & Dohme). Properly attributing all relevant subsidiaries to its parent, especially when the subsidiaries are operating under a different name, can be challenging and requires rigor in order to get meaningful results[129]. In addition, some discrepancies arise with spelling, through special characters and different transcriptions, filling words (and / &) and different abbreviations.[130] Recent research underlines the challenges in a proper patent

[125] Cf. Zander (2002). However, a detailed regional analysis of the invention locations can be exacerbated due to the fact, that the general availability of data for the inventor addresses in the patent databases is limited Li et al. (2014).

[126] Cf. Gerybadze and Sommer (2017). For example, if a patent has five inventors, one from Germany and four from China, this patent would count as 0.2 patents for Germany and 0.8 for China. Full counting would simply attribute this patent as one patent for Germany and one for China.

[127] Cf. Degnan and Huskey (2006). Sometimes renowned scientists contractually reserve the right to be named together with their employer as an applicant. The focus of this analysis are MNCs, so patents completely held by individuals will not be regarded.

[128] AG is the abbreviation for 'Aktiengesellschaft', the German legal form of a joint-stock company.

[129] Cf. Bruns and Kalthaus (2020),who outline the complexity of an accurate patent selection.

[130] Cf. Sommer and Bhandari (2018).

selection process.[131] The OECD provides in its HAN (Harmonized Applicant Names)-database a grouping of patent applicant names, expanded with business register data, which reduces the number of unique person IDs by about 30% through automatic matching.[132] This can only be a first step in a thorough analysis as, on the one hand, the OECD outlines itself the possibility of wrong matches and, on the other hand, the algorithms are quite conservative, meaning that for many applicants, there are much more matches or groupings possible and necessary. I expand on the methodology of the HAN-database and use approximate string matching (fuzzy matching) both automatically and manually to account for differences in writing, as well as including additional data, e.g. the applicant's address to help the matching process.[133]

4. **Applicant Country:** The location of the applicant serves as a proxy to determine the source of R&D investment. As mentioned in the previous point companies sometimes file patents under their subsidiaries, which might be located in the host-country. It is crucial to attribute these patents to the ultimate owner, i.e. the parent company in the home-country.[134]
5. **IPC:** Each patent gets assigned at least one category of the "International Patent Classification" (IPC) system designated by a short alphanumerical code. These hierarchically organized categories structure patents for easier search and analysis by other users. From the big eight main sections (e.g. A for Human Necessities or G for Physics) the IPC breaks down into approximately 70,000 subcategories.[135] The IPC categories are built on technical relatedness, not on business relevance, leading to sometimes unevenly distributed numbers of patents within the categories. Therefore, a concordance has to be devised assigning IPCs to the relevant business categories.[136]

   Patents are designed to protect technologies, so they are categorized in one or several categories of the IPC. This classification assigns a letter-number combination to indicate in what technological field(s) the respective patent relates to. For example, the IPC-code "F03D 3/04" is hierarchically organized as following:

[131] Cf. Bruns and Kalthaus (2020).

[132] Cf. HAN database – OECD (2020b).

[133] A company's annual report can be a good source to identify the numerous legal entities belonging to the company at question, even if those names are quite different. For example, German car manufacturer Daimler AG owned the legal entity 'Leonie FSM DVB GmbH'. This, quite different, name does not immediately reveal the connection to the Daimler AG. In September 2020, this entity was terminated and merged into the 'Daimler Mobility AG' Cf. Daimler (2020).

[134] Cf. Picci (2010). Patenting through a host-country subsidiary usually occurs for taxation or legal reasons.

[135] Cf. WIPO (2020b).

[136] Cf. Schmoch (2008), who suggests a concept of technology classification with IPCs.

Table 2-1: Overview IPC Structure with Example[137]

Hierarchy-Label	Example	Description
Section	F	Mechanical Engineering; Lighting; Heating; Weapons; Blasting
Class	F03	Machines or Engines for Liquids; Wind, Spring, or Weight Motors; Producing Mechanical Power or a reactive propulsive thrust, no otherwise provided for
Subclass	F03D	Wind Motors
Main Group	F03D 3	Wind motors with rotation axis substantially perpendicular to the air flow entering the rotor
Subgroup	F03D 3/04	Wind motors with rotation axis substantially perpendicular to the air flow entering the rotor …having stationary wind-guiding means, e.g. with shrouds or channels

We see that the IPC categorization is very thorough and technically specific. Not in all cases a breakdown to the lowest hierarchy level of the sub-group is required: on the one hand, the categories are not symmetric and not equal in size and in some cases the lowest hierarchy level is already the “subclass”. On the other hand, we might want to talk on a higher hierarchy-level on purpose. E.g. when we want to look at all patents relating to “Wind Motors”, we look for patents with the IPC “F03D”, which includes all subordinated main groups and subgroups.

6. **Priority Date:** When first filing for a patent, the date of application gets noted as the priority date on the application. Within 12 months of this application the applicant has the right to file for protection at other patent offices, i.e. other geographic regions, while maintaining the novelty stipulation. This regulation gives the applicant the chance to patent an invention for example in the home-country and then decide within a year whether this invention is worth to be patented internationally.[138] All subsequent patent applications which claim priority belong to the same ’patent family’ and therefore receive the same priority date from the first application.[139] In academia the priority date, and not for example the filing date, is used as a reference point in time, as it is the date closest to the actual inventive activity.[140]

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[137] Cf. WIPO (2020a).
[138] Cf. Heuckeroth (2017).
[139] Cf. §87 European Patent Convention, EPO (2016).
[140] Cf. Hinze and Schmoch (2004).

2.2.4. Measurements of Patent Quality and Patent Links

The advantage of analyzing patents is their standardized nature of publication. Therefore, a minimum level of quality can be assumed for every published patent.[141] Attributing each patent an identical value would be an oversimplification: with the establishment of a new radical technology a company usually aims to hold one or several “core patents” on which the future development and technological expansions are built on. As radical innovations are usually more valuable, said company firms will aim to apply for additional patents in order to exploit the full market and technological potential of the new technology, as well as creating and expanding their patent fence.[142] These patent fences aim to prevent the development of substitute products by competitors, through covering a broad field around the own invention.[143]

Regarding patents not as isolates, but as connected items which build upon each other, does not only help to understand the technological development of technologies, i.e. which invention is building on which, it also helps to determine the quality and thereby the value of an invention.

Several measurements can be used to determine patent linkages and patent quality:

1. **Backward Citations:** Backward citations (sometimes simply called citations) are previous patents on which the filed patent builds on. These citations can help to determine an evolutionary path of a technology by determining which are the basic or foundation patents of an emerging technology and which patents build on them on which point in time and occupy fields of knowledge.
2. **Forward Citations:** In hindsight the forward citations indicate how many and which subsequent patents cite the given patent. Comparable to the academic world, this citation value can be seen as a measure of quality or visibility. However, this value has to be considered in relation to the year and overall citations: a patent published 20 years ago naturally can accumulate more forward citations, than a patent published last year. Alternatively, one might consider only citations which have been, for example, received in the subsequent three years of each patent publication.

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[141] Cf. Harhoff, Scherer, and Vopel (2003).
[142] Cf. Sternitzke (2010), Sorescu, Chandy, and Prabhu (2003).
[143] Cf. Blind et al. (2006).

3. **Revealed Technological Advantage (RTA):** The RTA was initially developed by Soete (1987) and picked up by several academics.[144] It is a proxy for the specialization or "comparative advantage" across technological fields and calculated as following: $RTA_{ij} = \frac{P_{ij}/\sum_i P_{ij}}{\sum_j P_{ij}/\sum_{ij} P_{ij}}$, where P_{ij} gives the number of patents granted to a firm i in the technological field j. The RTA can take any non-negative value: $RTA \in [0; +\infty]$.
   The interpretation of values with no upper bound can be challenging. To facilitate analysis, interpretation and understanding in this dissertation, I normalize the RTA to the $Normalized\ Revealed\ Technological\ Advantage\ (NRTA)$, with the formula: $NRTA = \frac{RTA-1}{RTA+1}$. This $NRTA$ can take a value between -1 and 1: $NRTA \in [-1; +1]$, with positive values indicating a comparative advantage, i.e. that the firm has a higher share in patent numbers in the relevant fields compared to its competitors and negative values indicating a comparative disadvantage, i.e. a lower share.[145]
4. **Composite Patent Quality Index:** The OECD publishes numerous indicators for their patent data, which are added up to form a composite patent quality index. The "Patent Quality Composite Index" used in this dissertation is calculated from the OECD's "Quality Composite Index 6" as published in the OECD PATENT QUALITY Database [146]. It expands on an analysis by Lanjouw and Schankerman (2004) and is a composite of six indices: a granted patent's number of forward citations (up to 5 years after publication), backward citations, grant lag index, patent family size, number of claims and the patent generality index. The time-limit of 5 years for forward citations means that more recent patents do not automatically have a lower citation count, than patents which have been published decades ago and a much larger citation potential. The index can take values between 0 and 1: $Patent\ Quality\ Composite\ Index \in [0; +1]$.

2.2.5. Methodology of Patent Analysis

Patents from different patent authorities cannot be compared, so it is common academic practice to use only patent data from one patent office.[147] Traditionally, the "triadic patent offices" i.e. USPTO, EPO and JPO, which cover the geographic area of the US, Europe and Japan were, by far, the most relevant, due to their size and geographic coverage. With the uprise of other economies in recent decades, such as China and South Korea, their respective

[144] Cf. Patel and Pavitt (1987), Patel and Vega (1999), Cantwell and Iammarino (2000), Le Bas and Sierra (2002).
[145] Cf. Nesta and Patel (2004, p. 537).
[146] Cf. Squicciarini, Dernis, and Criscuolo (2013, p. 59), OECD (2019b).
[147] Cf. Jaffe and Trajtenberg (2002).

patent offices, CNIPA[148] and KIPO, also increased in relevance. These five largest patent offices in the world, connect in the so called 'IP5', a forum to improve and harmonize the examination processes for patents.[149]

When deciding for a patent office, the 'home-advantage effect' has to be considered, i.e. that a company is more likely to patent in its home-country first and patent data therefore can be skewed. EPO data, however, covers more than one country, thereby reducing this effect.[150] Furthermore, the underlying assumption is, that the EPO data sufficiently covers inventions by U.S.-based MNCs as well, as these companies seek for international protection with their relevant patents and therefore patent relevant inventions with the EPO.[151]

Patents do not have to be filed at a singular patent office. Filing a patent under the Patent Cooperation Treaty (PCT) allows the patent applicant to file for protection in any of the treaty member states and designate any number of other member states in which patent protection can be filed for within 12 months of the initial application. The result of the initial patent office gets circulated across the other contracting states allowing for a simplified protection procedure. Each patent office still retains the authority whether to grant patent protection within its jurisdiction or not.[152] Analyzing patents filed under the PCT can be therefore particularly beneficial when focusing on international R&D activities on a country level. When analyzing individual firms, USPTO or EPO data should be analyzed and not PCT data: the PCT is not one singular patent office but rather the aggregate from numerous offices. Data across different patent authorities cannot be reasonably compared on a micro level, as explained above.

In this dissertation I analyze EPO patents on a micro and meso, i.e. company and industry level, and PCT data on a macro, i.e. country level, unless otherwise noted.

EPO patent data is provided by the EPO's PATSTAT database. This biannually published database is provided for a fee and includes additional variables, such as patent abstracts. A simplified dataset free of charge and after some delay is provided by the OECD with its REGPAT database. This REGPAT database can be combined with the OECD's CITATIONS

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[148] In August 2018 the Chinese agency responsible for patents has been renamed from 'State Intellectual Property Office of China' (SIPO) to 'China National Intellectual Property Administration' (CNIPA) (EPO, 2018).

[149] Cf. IP5 Offices (2017).

[150] Cf. Le Bas and Sierra (2002); Criscuolo, Narula, and Verspagen (2005); Dachs and Pyka (2010).

[151] Cf. Criscuolo (2006), who compares patent data from the different patent offices.

[152] Cf. Alcácer, Gittelman, and Sampat (2009). Only few countries worldwide have not undersigned the PCT, such as Argentina or Bolivia (WIPO, 2017).

database. Patent citations can provide additional insights into patents and their quality, comparable to academic journal citations, as discussed in the previous sub-chapter.

In addition, the OECD publishes aggregated, i.e. country-level patent data on its website.[153] This database provides insights into USPTO, EPO and PCT data and is continuously updated.

2.2.6. Overview Patent Number Development

This chapter gives a broad overview over the development of patent filings worldwide. Table 2-2 gives an overview for the years 2000 – 2017 of the patent filing development in the IP5, the world's five biggest patent offices, covering approximately 80% of the worldwide patent applications.[154] The IP5 include the patent offices of the US, Europe, China, South Korea and Japan.

The data is collected and analyzed as published by the IP5. Due to different reporting standards the numbers can slightly differ compared to the publications by the respective patent offices.[155]

Figure 2-2 illustrates the data from Table 2-2 further.

In 2017 over 2.6 Million patents were filed at the IP5, which is an average annual increase (CAGR) compared to 2000 of over 6%. A large share of this growth can be attributed to China, with an CAGR of over 20% and an exponential growth for several years in a row. This underlines the increase in relevance for China in terms of patenting and can be the result of a structured developmental process and uprise of China as a knowledge and innovation center. The Chinese patent office has received more patent applications in 2017, than all other four offices together. Note: Chinese law differentiates between three types of patents: "Creations and Inventions", "Utility Models" and "Designs".[156] Only patent data for "Creations and Inventions" is considered in this analysis.

Japan, in 2000 the patent office with the most applications per year, has, on overage, lost 1.8% of patent applications per year and has fallen behind the US in 2006. The US, South Korea and Europe, on the other hand, have slowly but steadily experienced an increase in patent applications.

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[153] Cf. OECD (2020e).

[154] Cf. IP5 Offices (2017).

[155] The first published year by the IP5 for China is 2008. For previous years, data from the National Bureau of Statistics of China has been used: National Bureau of Statistics of China (2009); National Bureau of Statistics of China (2008); National Bureau of Statistics of China (2005); National Bureau of Statistics of China (2003).

[156] Cf. National Bureau of Statistics of China (2019).

The US patent office (USPTO) had around 600k patent applications in 2017, which makes it the second largest patent office since it was overtaken in 2011 by China.

The South Korean (KIPO) and European patent office (EPO) show a very similar development, both in absolute numbers, as well as in growth, ranging in 2017 at around 200k patent applications.

With the skyrocketing number of patent applications (and patent grants) in China, one certainly may wonder whether and to what degree this number reflects a growth in innovative capability and a shift from imitation to innovation. In fact, a number of researchers and analysts attribute the increase in patent applications to strong subsidies and policies encouraging patent applications.[157]

Research estimates that these subsidies increased patent applications by over 30%.[158] Subsidies are paid out for patent applications (with more money available for successful applications[159]), with the result that a major share of Chinese patents are of lower quality. Several indicators support this claim: first, a majority of patents get discarded after five years, with owners choosing to discontinue paying expensive licensing fees.[160] Second, Chinese firms are reluctant to gain patent protection abroad, with China ranking only fifth worldwide in terms of international patents.[161] Third, subsidies and incentives are paid in a way that it can be financially beneficial for patent examiners at the CNIPA to favorably consider patent applications.[162]

This gives support to the previously discussed statement that patent figures across different patent jurisdictions cannot be reasonably compared, due to differences in evaluation and acceptance standards.

In Table 2-3 the patent applications are broken down to the origin of the (first) applicant. The table shows which percentage of the patents indicated in Table 2-2 have been applied for by an applicant from the respective patent office country or region.[163]

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[157] Cf. Heuckeroth (2017).
[158] Cf. Dang and Motohashi (2015).
[159] Cf. Finnie (2019).
[160] Cf. Bloomberg (2018).
[161] Cf. WIPO (2018).
[162] Cf. Finnie (2019); Yueh (2009); Warner (2014).
[163] The IP5 reports this data as “first named applicant” (IP5 Offices, 2017). Patents which are the result of cooperation projects across countries might skew the data. I.e. if a patent by a German (EPO) and Korean (KIPO) firm would be filed at the EPO, it would count here as a “domestic” patent, if the German applicant is named first, but non-domestic if the Korean applicant would be named first. For the purposes of the overview to be given in this sub-chapter, this error is negligible.

The US are very international with only 55% (in 2000) or 50% (in 2017) of its patents applied for by US firms. Europe is even more international, with a share of European applicants at the EPO of consistently less than 50%. This high rate of international firms justifies the use of EPO data.

Japan, on the other hand, has consistently over 80% of its patents applied for by Japanese firms and therefore appears to be not a particular attractive location for foreign firms to patent.

South Korea is similarly domestically oriented and even increased its share of domestic applicants of around 71% in 2000 to 78% in 2017.

China shows a very interesting development: while in 2000 patent applicants were quite foreign dominated and less than half of the patents applied for by Chinese firms, the domestic share has skyrocketed and has been in 2017 at over 90%. Together with the patent application data from Table 2-2, this may indicate how China has built up its knowledge capabilities and shifted from a small 'innovation outpost' for foreign firms to a patent powerhouse.

Table 2-2: Number and Development of Patents Applied at Major Patent Offices[164]

Country (Patent Office)	**2000**	**2004**	**2008**	**2012**	**2016**	**2017**	**CAGR '00-'17 (%)**
China (CNIPA)	51,747	130,133	289,838	652,777	1,338,503	1,381,594	21.3
US (USPTO)	295,926	356,943	456,321	542,815	605,571	606,956	4.3
Japan (JPO)	436,865	423,081	391,002	342,796	318,381	318,481	-1.8
S. Korea (KIPO)	102,051	140,051	170,632	188,915	208,830	204,775	4.2
Europe (EPO)	100,656	123,859	146,524	149,193	159,085	166,598	3.0
Total	935,498	1,043,934	1,454,317	1,876,496	2,630,370	2,678,404	6.4

[164] Own analysis, based on IP5 Offices (2019).

Figure 2-2: Number and Development of Patents Applied at Major Patent Offices[165]

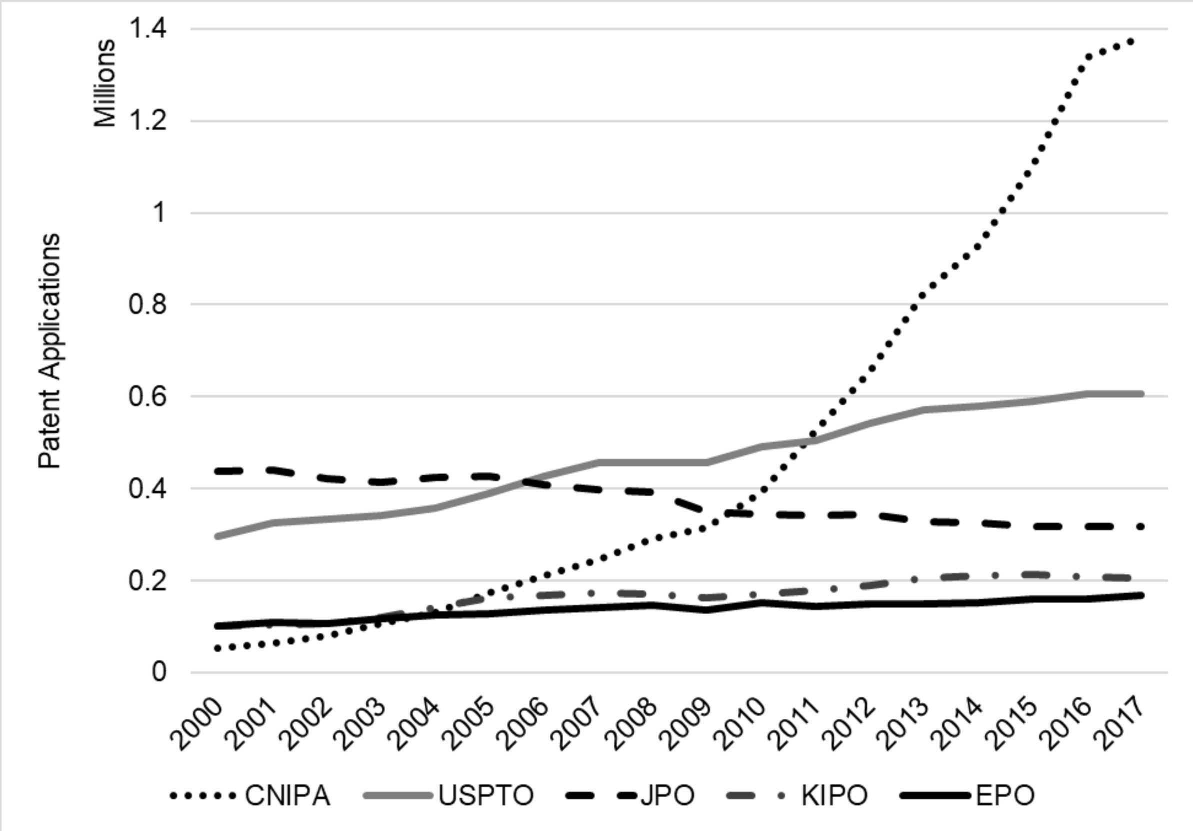

Table 2-3: Share of Home Market Patent Applications in Percent[166]

Country (Patent Office)	2000	2004	2008	2012	2016	2017
China (CNIPA)	49.0	50.6	67.1	82.0	90.0	90.2
US (USPTO)	55.7	52.3	49.5	50.1	50.0	49.9
Japan (JPO)	88.7	87.1	84.4	83.7	81.7	81.7
South Korea (KIPO)	71.4	75.1	74.5	78.4	78.3	77.7
Europe (EPO)	49.9	49.5	49.3	49.1	47.8	47.1

2.2.7. Excursus: Linking R&D Expenditure and Patents

R&D Expenditure is an input, whereas patents are an intermediary measure to quantify innovation, as discussed in this chapter. Both indices by themselves can never explain the full and true innovative activities: on the one hand, not every R&D activity leads to a patent, i.e.

[165] Own analysis, based on IP5 Offices (2019).
[166] Own analysis, based on IP5 Offices (2019).

more R&D Expenditure does not necessarily increase the number of patents by the same factor. On the other hand, not every patent is based on similar levels of inventive activities. See also the discussion on the validity of both indices in the prior parts of this Chapter. However, as both indices measure inventive activities, a connection between both of them can be expected. In this sub-chapter I connect both indices, i.e. R&D Expenditure and patents, for the four major countries USA, Japan, Germany and China, which I also analyze in detail in the upcoming chapters 3.2 & 6.3.

I divide the R&D Expenditure by the number of total patents. I measure the R&D Expenditure in BERD in Million USD PPP current prices, indicating how much money businesses from the respective country spent in total on R&D. I use the complete number of patents, filed under the PCT, with applicants from the respective country, i.e. all patents filed by a MNC from the USA, Germany etc.

In many cases, the R&D Expenditure within one year will not lead to a patent within the same year, as R&D processes take time. I shift the variable three years apart, meaning that the ratio indicated for the year x gives the R&D Expenditure in year $x-3$ divided by the number of patents in year x. This three-year lag is based on feedback in interviews and findings in literature.[167]

Two limitations of this approach should be addressed: First, a lag of three years can easily be contested: several pieces of research have attempted to find a link between R&D Expenditure and patents, with limited results.[168] Second, different propensities to patent across industries might explain differences in ratios across countries. If companies from one country mostly operate in industries with a high propensity to patent, they would be likely to also have a lower ratio of R&D Expenditure to number of patents. This would not necessarily mean that companies from that country would be more efficient in turning their money into patents.[169]

Furthermore, it should be noted, that having a patent does not mean immediate commercial impact. In a study of the pharma industry, an industry with very knowledge intensive and thereby long R&D processes, the time from the first basic patent to commercialization of the drug has been found to be on average eleven years.[170]

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[167] Cf. e.g. Heuckeroth (2017).

[168] Cf. e.g. Hall, Griliches, and Hausman (1984); Griliches (1981); Popp, Juhl, and Johnson (2004). The variance of time-lag can be immense. Some companies decide to patent only after waiting and observing the market for several years, if at all.

[169] Cf. Danguy, de Rassenfosse, and van Pottelsberghe de la Potterie (2009), who analyze the R&D-patent relationship across industries.

[170] Cf. Sternitzke (2010).

Table 2-4 shows the ratio of the BERD, measured in current PPP m$ to the number of patents under the PCT. Therefore, the number indicates the R&D Expenditure per patent. With the included time-lag of three years, we can see this figure very broadly as the cost per patent.

The standard deviation (SD) shows the variation across the years: China shows a stronger change over the years, than Germany or Japan.

Table 2-4: Relationship of R&D Expenditure and Patents under PCT[171]

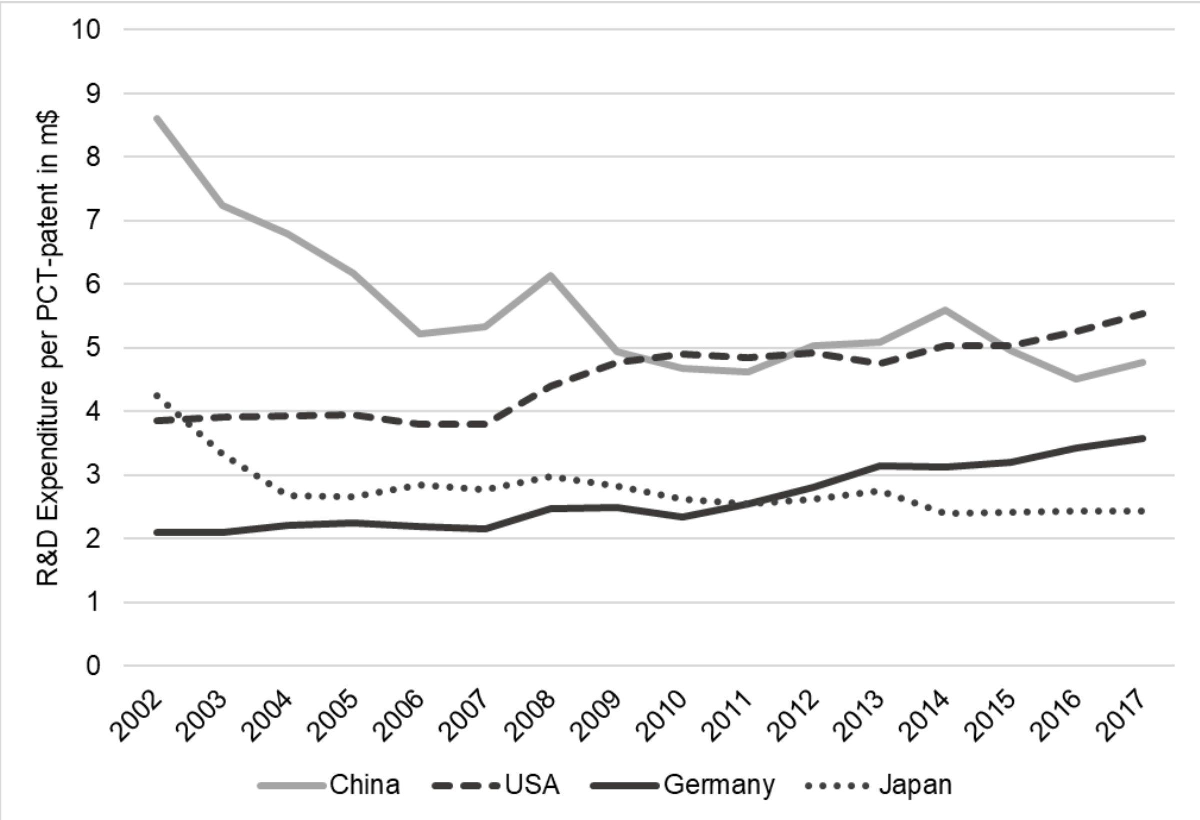
R&D Expenditure in m$ current PPPs, per patent	**2002**	**2005**	**2008**	**2011**	**2014**	**2017**	***SD***
Germany	2.1	2.3	2.5	2.5	3.1	3.6	*0.49*
USA	3.9	3.9	4.4	4.8	5.0	5.5	*0.57*
Japan	4.2	2.7	3.0	2.5	2.4	2.4	*0.44*
China	8.6	6.2	6.1	4.6	5.6	4.8	*1.09*

Note: SD = Standard Deviation of all values from 2002 to 2017 / Outward R&D variable shifted by respective three years.

[171] Own analysis, based on MSTI database – OECD (2020c).

Figure 2-3 illustrates the relationship in a chart.

Figure 2-3: Relationship of Host-Country Patents to Outward R&D[172]



Chinese applications have significantly brought the costs per patent over the years: from almost 9m$ per patent in 2002 to around 5m$ in more recent years – a similar value to the USA.

China's uprise as an economic power coincides in an increase in its patenting activities. In fact, Chinese patent heavily, although most activities are concentrated in few fields and on few companies.[173] China considers patents as a good measure of innovative success: its statistical publications are rather limited on R&D Expenditure data, but very detailed in composition, field and origin of its patents.[174] Furthermore, China sees patents as a signal both domestically and abroad, for its economic capabilities and thereby incentives patenting, particularly patenting abroad.[175]

Japanese firms spent around 2.5m$ in recent years and German firms almost 4m$. Furthermore, the costs per patent have increased in the last years for the USA and Germany.

[172] Own analysis, based on MSTI database – OECD (2020c).
[173] Cf. Kashcheeva, Wunsch-Vincent, and Zhou (2014).
[174] Cf. National Bureau of Statistics of China (2019).
[175] Cf. China Power (2016); Fischer and von Zedtwitz (2004).

This might give support to the argument of the “innovation slowdown”, which posits that less real innovation is conducted due to increasing costs.

For comparability, this analysis shows PCT-patents. It can be argued that not all patents are filed under this treaty, but instead remain on a domestic level. For the USA and Germany, I show the same analysis, but based on the number of patents at the respective domestic patent offices: USPTO and EPO. For Japan (JPO) and China (CNIPA) no equally standardized data is available. Table 2-5 shows the R&D Expenditures per patent from 2002 to 2016, the most recent year with available data.

Table 2-5: Relationship of R&D Expenditure and Patents at Local Patent Offices[176]

R&D Expenditure in m$ current PPPs, per patent	**2002**	**2005**	**2008**	**2011**	**2014**	**2016**	***SD***
Germany (EPO)	1.6	1.7	1.9	2.4	2.9	3.7	0.62
USA (USPTO)	1.3	1.1	1.3	1.6	1.6	2.1	0.27

Note: SD = Standard Deviation of all values from 2002 to 2016 / Outward R&D variable shifted by respective three years

The ratios, i.e. costs per patent are significantly lower, when considering all patents from domestic applicants at the EPO and USPTO and not just those which were filed under the PCT. This comes as little surprise as only particularly promising patents are selected for international protection and thereby filed under the PCT. The number of PCT patents by German or US applicants is therefore lower than those of these applicants at their respective patent office.

However, it again becomes visible how in the last decade the cost per patent has increased, i.e. the ratio of R&D Expenditure per patent has grown.

A detailed breakdown by industry is required and follow in Chapter 6 and 7 to shed more light which industries and companies exactly account for the respective country’s innovative activities.

[176] Own analysis, based on MSTI database – OECD (2020c).

2.3. Cultural Distance to Measure Degree of R&D Internationalization

For most parts in this dissertation, we talk about internationalization as if it was a homogeneous group: a company conducts R&D abroad, i.e. internationally, or not; a patent has foreign, i.e. international, (co-)inventors or not. This simplification is common and necessary, after all, we mostly care about only whether there is a step of going abroad or not. A major argument of why international and non-international R&D, patents, business activities etc. yield different results is the diversity in backgrounds. Certainly, a purely German team could not be as creative or bold in its innovation activities than a mixed global team.[177]

Yet, when analyzing the effects of internationalization, we might want to look closer and differentiate within the group of internationalization: we ask not just whether something is international or not, but “how much international”. Evidently, Germans internationalizing to their southern neighbor country Austria could be considered much less international, then said Germans internationalizing to China. Both cases fall in the category “international”, but the latter much more so than the former. To quantify these different kinds of internationalization, I introduce in this chapter to the concept of cultural distance. Cultural distance is my measurement tool to determine how far the involved countries in the internationalization process are distant from each other, i.e. how big the internationalization step is.

First, I introduce to the concept of culture. Second, I elaborate on how cultures are measured and quantified. Third, I explain how I calculate cultural distances in this analysis. Fourth, I give a literature overview of the connection of culture, innovation and performance as a justification for this chapter. In my patent analyses, conducted in Chapter 7, I will pick up the tool of cultural distance calculation in order to not just look at international vs. non-international patents, but actually find out how much internationalization pays off the most.

2.3.1. Culture as a Relevant Category of Innovation

The term “culture” refers to the collective programming of individuals, shaped by the environments they were brought up in.[178] It is therefore to a degree shared with individuals who live or have lived in the same social environment.[179] The term “culture” has to be differentiated from “human nature” and “personality”. These three terms form the uniqueness of an individual.

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[177] Cf. Adler and Gunderson (2008).
[178] Cf. Eliot (2007).
[179] Cf. Martins and Terblanche (2003).

Table 2-6: Hierarchy of Individuals' Uniqueness[180]

Item	Specificity	Source
Human Nature	Universal	Inherited
Culture	Specific to group or category	Learned
Personality	Specific to individual	Inherited and learned

Human nature includes is traits all mankind share, e.g. the ability to have fear or joy. On the other side of the spectrum, personality is the uniqueness of the individual, i.e. character traits that do not necessarily have to be shared with another individual. Culture is what binds groups together and is the division between “us” and “them”. It can be broken down into different layers of terms such as values or rituals. Even with a changing environment, deeply-rooted values or rituals of a culture do not change quickly.[181]

Classifying cultures through countries is a rather bold assumption: after all country borders can be drawn rather artificially (e.g. in Africa due to Colonialist history) and not all cultures feel like they belong to the dominant culture of the country they are subject to. Recent examples include Chechens in Russia and Basks in Spain. Yet, using countries and classifying cultures through political borders is common practice, simple because collecting comprehensive data on a large scale is only possible this way.[182] I will elaborate on relevant culture-innovation literature in Chapter 2.3.4.

A general criticism remains: there is certainly an inherent error in putting all nationals of a country into one box. Of course, there are traits which make people say, someone is “typically American” or “typically German”. Especially in a globalized world, it might be increasingly hard to equalize country to cultural borders. When analyzing patent inventors, we draw a hard line between inventors based in country X, compared to inventors based in country Y and ignoring migration biographies and other factors. E.g. is a patent inventor located in China necessarily shaped by Chinese culture? However, this limitation is not new, as also the assumption that a China-based inventor implies China-based R&D activity is not necessarily true in all cases.[183] For the purposes of an academic analysis, we are going to accept certain inherent errors.

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[180] Adapted from G. H. Hofstede, Hofstede, and Minkov (2010, p. 6).

[181] Cf. G. H. Hofstede, Hofstede, and Minkov (2010).

[182] Cf. Aycan et al. (2000); Martins and Terblanche (2003); Mueller and Thomas (2001).

[183] For example, in Europe there is quite some significant cross-border commuting, i.e. an inventor might be living in Germany, but actually work in an R&D lab in neighboring Switzerland. The inventor might also be an expat, working far away, but for several reasons might still indicate his old address in the patent application.

Furthermore, in these culture models we are largely neglecting the intra-group variance, i.e. the differences within one culture, and focusing on the inter-group variance, i.e. the differences across cultures.[184] The intra-group can be even larger than the inter-group variance, e.g. the two most distant Germans would be culturally further distant than a particular German and a French.

For this analysis, I measure culture through countries, i.e. I assume all individuals within a country to be sufficiently homogeneous.

2.3.2. Measurement of Cultural Distance

Several attempts have been made to quantify and classify cultures.[185] These studies vary in the cultural categories and exact methodology. Four commonly used country classification studies are by Hofstede, Schwartz, Trompenaars and the GLOBE Project. I have conducted my analysis mainly with the values for Hofstede, so I will focus my explanation on this study. These analyses are generally robust, as I have verified several findings with the values from the Schwartz study.

2.3.2.1. Overview of Cultural Classification Studies

Hofstede has classified countries in six cultural dimensions: power distance, individualism (vs. collectivism), masculinity (vs. feminity), uncertainty avoidance, long-term orientation (vs. short-term) and indulgence (vs. restraint). The study's values are from 2010 and last updated in 2015.[186] I elaborate on these cultural dimensions further below.

Schwartz has raised seven culture value orientations to compare cultural groups: mastery, harmony, hierarchy, egalitarianism, embeddedness, affective autonomy and intellectual autonomy. The cultural values are last updated in 2008[187]

Trompenaars has introduced in 1993 together with Hampden-Turner a model of culture classification, including seven categories: universalism vs. particularism, individualism vs. collectivism, neutral vs. emotional, specific vs. diffuse, achievement vs. ascription, sequential vs. synchronic and internal vs. external control.[188] Trompenaars and colleagues have

[184] Cf. Matsumoto (2007); McCrae (2004); Buss (2001).
[185] As discussed in the previous part, culture and country describe the same sets here.
[186] Cf. G. H. Hofstede (2015).
[187] Cf. Schwartz (2008).
[188] Cf. Trompenaars and Hampden-Turner (1997). This citation refers to the second edition of the book, which was first published in 1993.

analyzed 43 cultures for their studies and published the values in 1996.[189] Hofstede challenges the validity of Trompenaars' analyses.[190]

The GLOBE (Global Leadership and Organizational Behavior Effectiveness) study, founded by Robert House in 1991, has classified countries in nine cultural dimensions: performance orientation, assertiveness, future orientation, humane orientation, institutional collectivism, in-group collectivism, gender egalitarianism, power distance and uncertainty avoidance. The global study's values were raised and last updated in 2004.[191]

Occasionally mentioned is the value orientation theory by Kluckhohn and Strodtbeck (1961), defining five basic value orientations: human nature, man-nature, time, activity and relational orientations.

2.3.2.2. Methodology of Hofstede Classification Study

Hofstede ranks cultures in six categories on a scale between 0 and 100, indicating to what degree the respective category applies to the culture. A higher or lower value does not indicate better or worse but can be simply seen as a degree of applicability. The six categories are[192]:

1. **Power Distance:** This category refers to what degree members of a culture expect and accept a clear hierarchy and an unequal distribution of power. It refers to the question how a culture handles inequalities across people. Countries with a high degree of power distance are Russia or the UAE. Countries with a low degree, i.e. with a more egalitarian and equal attitude, are Sweden or Austria.
2. **Individualism (vs. Collectivism):** A high value refers to an individualistic culture, i.e. where the individuals focusses mostly on themselves and their direct family. Examples include the US or UK. A low value refers to collectivistic cultures, where the community is more important than the individual. Examples include Pakistan or Vietnam. This category refers to the issue "I vs. We".
3. **Masculinity (vs. Feminity):** A high value refers to competitive cultures with a focus and recognition of heroism, assertiveness and material rewards. Examples include Japan. A low-value culture focusses more on consensus and values cooperation and modesty. Examples include Norway or Sweden. This category can also be described as "tough vs. tender".

[189] Cf. Smith, Dugan, and Trompenaars (1996).
[190] Cf. G. Hofstede (1996).
[191] Cf. House et al. (2004).
[192] Cf. G. H. Hofstede, Hofstede, and Minkov (2010).

4. **Uncertainty Avoidance:** Cultures with a high value maintain strong codes of belief and behavioral patterns. Examples include Greece or Portugal. Cultures with a low value are more tolerant towards unorthodox ideas and value more practical results than dogma. Examples include Singapore or UK. This category refers to the question to what degree a culture wants to control the future or rather just lets it happen.
5. **Long-term orientation (vs. short-term orientation):** A high value refers to cultures which have a pragmatic approach and value modesty and education in order to prepare for the future. Examples include South Korea or Japan. A low value refers to cultures valuing traditions and norms, while being rather critical of societal changes. Examples include Colombia or Egypt.
6. **Indulgence (vs. restraint):** Cultures with a high value allow and tolerate easy gratification of basic human needs relating to joie de vivre. Examples include Mexico or Sweden. Culture with a low value regulate and restrict gratification of needs through rigid social norms. Examples include China or Ukraine.

The first four categories were first introduced in 1980.[193] Long-term orientation was added in 1991 and indulgence in 2010.[194]

2.3.3. Methodology of Cultural Distance Calculation

I will use the cultural distance on patent analyses during this dissertation. For that I will be interested in knowing the cultural distance within each patent's inventor team. I calculate the maximum distance for each patent, by determining the maximum distance for each of the six (for Hofstede) categories of the culture involved and adding up the distances, which is possible due to the linearity of the categories. When several cultures are involved are therefore calculate the distance from the most extreme difference, i.e. highest pair of cultural distance for each category.

For patents without any internationalization, the distance is obviously 0. The theoretical maximum distance would be 600, i.e. if the involved cultures in a certain patent had a value of 0 and 100 respectively in all six parameters. In reality, only few patents have a cultural distance >200. Such patents involve international collaborations for example between the US and China. For very few and usually economically less relevant countries no cultural data is available. These patents are filtered out, in order to not distort results.

193 Cf. G. H. Hofstede (2001). This cite is for the second and current version of the book. The first edition was published in 1980.

194 Cf. G. H. Hofstede, Hofstede, and Minkov (2010): Long-term orientation was added in 1991 (first edition of the cited book) and indulgence in 2010 (third and used edition of the cited book).

2.3.4. Cultural Distance and Innovation

Several pieces of research have analyzed the impact of cultural distance on innovation. The overall number of relevant publications in this field is low and the few publications have mostly focused on pairwise cultural combinations. With this regard, the analysis of a large-scale sample with potentially more than two involved cultures in this dissertation is a novelty.

Cultural measurement as outlined before is an established measurement and mostly discussed in the areas of sociology, intercultural management and leadership, as well as negotiations.[195]

This sub-chapter is structured into two parts. First, I will show and discuss relevant literature which discusses the impact of culture and different cultural factors on innovation. Second, I will show and discuss literature which deals with cultural distances, i.e. comparing two or more involved cultures.

2.3.4.1. Impact of Culture on Innovation

Culture is a major determinant in innovation performance: in an older study Feldman (1988) argues that idealism, conformity and selfishness are all characteristics of American culture having both positive and negative effects on business behavior and thereby innovation. He argues that the idealization of product quality leads to a focus on engineering at the expense of marketing. While ideals are generally needed for the innovation process, their effect must be measured in advance so that they do not cannibalize some goals at the expense of other. Feldman posits that innovation requires both a decentralized management structure and decentralized culture. Homogeneous cultures would be conflictive to innovation due to a limitation on sources of creativity to top management. While Feldman talks about organization culture and not explicitly culture in the sense of Hofstede, we can see his arguments as a plea for diversity and internationalization.

Brannen (1991) defines culture as a “historically situated and emergent system of negotiated meanings and practices common to the people in an organization” and thereby endogenous, i.e. developed and shaped over time. She argues that country specific culture, i.e. non-transferable cultural and historical reasons led to the failure of Japanese management techniques in the US.

Some authors, such as Weiss (1984) argue that the success of Japanese firms cannot be explained on different mindsets and attitudes “lower absenteeism, greater corporate loyalty,

[195] Cf. G. H. Hofstede, Hofstede, and Minkov (2010): For managers going abroad intercultural trainings are often an integral part of their preparation program.

and harder working employees". Instead the success is due to a higher share of engineers in the workforce, selective hiring, salary structures which encourage loyalty and a unique capital structure. Ebrahimpour (1985) argues that the success of Japanese firms is therefore not to be explained with culture and country-specific mindsets and attitudes, but rather management practices, which can be adapted and imitated.

Brannen (1991) acknowledges that a detachment of these management techniques from their cultural origin might help to "demystify the Japanese success story" but argues that the inherent cultural differences between the US and Japanese, such as work attitude, are key in the successful implementation of innovations and that generalizable management practices do not necessarily work in different cultures. For example, Bushe (1988) shows that the alleged success practice of Japanese firms of pumping large amounts of money in order to implement technological changes and thereby ensuring success is wrong, as numerous case studies show the failure of this strategy. Brannen (1991) posits that all these failures are at least partially due to cultural barriers to change.

Shane (1993) was one of the first researchers analyzing the different categories of cultural values on innovation, by positing that nations might differ in their rates of innovation due to different cultural values of their citizens. Namely Shane examined the effect of the four Hofstede cultural values of individualism, power distance, uncertainty avoidance and masculinity on national rates of innovation in 33 countries in 1975 and 1980. At this time Hofstede had established the classification of cultures in only these four categories: Long-term orientation and indulgence were added later.[196] Shane found that rates of innovation are most closely associated with a low value in uncertainty avoidance (i.e. a high degree of uncertainty acceptance). Low values in power distance and high in individualism and masculinity also related to high rates of innovations. He includes in his analysis innovation variables, such as patent and trademark statistics and adds countries' economic variables to control for national differences, such as industrial structure and per capita income.

Efrat (2014) expands on Shane and investigated, over twenty years after Shane, the impact of different cultural aspects on countries' motivation both to innovate and to invest in innovation. A main argument and determinant of a country's success in innovation is the presence of a National Innovation System (NIS) as argued by Fagerberg and Srholec (2008): countries with a stable NIS are more innovative and therefore have a higher economic growth. Efrat notes a diminishing relevance of national characteristics in the age of globalization and

[196] Cf. G. H. Hofstede, Hofstede, and Minkov (2010): Long-term orientation was added in 1991 (first edition of the cited book) and indulgence in 2010 (third and used edition of the cited book).

argues that globalization led to the rise of MNCs and therefore to knowledge spillovers, which in turn contributed to a shift from a nation-based to a corporation-based economy. National innovation cultures therefore diminish in relevance, although Efrat acknowledges several cultural factors affecting an innovative national culture both directly and indirectly through a good NIS: openness, an ability to interact with the government and innovate, quality of governance, political system, levels of corruption and civic rights etc. All these indicators interact with the cultural dimensions identified by Hofstede. Efrat concludes that a national culture still significantly affects the performance of R&D units, so MNCs are well advised to identify the relevant cultural factors. The author makes ambivalent findings on the effects of individual cultural factors on innovation and posits that cultural factors are interlinked and connected to other factors.

Tolba and Mourad (2011) strive to combine individual and cultural factors affecting diffusion of innovation. They argue that the diffusion of innovation is greater in high-context, i.e. more implicit, cultures. The authors find that the main cultural factors affecting innovation are individualism and uncertainty avoidance. They argue that one the one hand, a low degree of individualism leads to a higher degree of innovation acceptance in the early stages, where in-groups are highly relevant. On the other hand, innovation diffusion is influenced by the numerous out-groups, meaning that a higher degree of individualism leads to innovation diffusion. A high degree of uncertainty avoidance leads to rather strict rules in a society, implying a slow in both acceptance and diffusion of innovation. The authors furthermore outline the importance of not just the cultural factors, but also the value system of the individual as key to innovation adoption.

Taylor and Wilson (2012) analyze the effects of individualism vs. collectivism on innovation rates. With multi-country datasets, they find on the one hand that generally individualism has a strong positive impact on innovation, even after consideration of a country’s relevant policy measures. On the other hand, certain forms of collectivism, such as strong nationalism, can also lead to innovativeness. Collectivism on a small scale, i.e. “familism” or “localism”, however, harms not only innovativeness and may even have severe negative impacts on a country’s progress in science.

Chua, Roth, and Lemoine (2014) analyze the effect of countries’ culture on creativity, a key factor for innovativeness, also with regards to international collaborations. They argue that cultural tightness is the homogeneity of a culture, i.e. the degree to which strong social norms are prevalent. It generally has a negative effect on creativity, meaning that loose cultures are more likely and more successful in engaging in novel and foreign tasks, even more so as the cultural distance of cultural tightness in a collaboration increases and tight cultures are less receptive to such ideas. The authors also posit that when culturally tight culture works on its own or with culturally close countries, creativity success is pushed. They also point out the challenge of measuring creativity success: in Western cultures novelty and originality tend to be higher rated, compared to usefulness and practicality in Eastern cultures. This, once again, shows the duality of cultural factors. Part of a country's culture can be a dominant religion and ideology, which can affect the culture's innovative capacity (Ruttan, 1988).

Herbig and Dunphy (1998) look at the general links of culture and innovation and conduct a meta-analysis of numerous prior publications. Most of their research analyzed finds that a high degree of individualism in a culture leads to higher innovative capacity or more radical innovations. Collectivist culture, i.e. cultures with a low degree of individualism have less radical, but more process innovations, which can be linked to the close-knit ties between the actors in a collectivist society.

Some research also outlines other cultural factors, such as low hierarchy levels and a high risk-bearing attitude as supportive of innovation. These rather old studies, however, mostly focus on a Western attitude of innovation and innovativeness and have to be taken with a pinch of salt under consideration of today's globalized and complex world.

2.3.4.2. Measuring Cultural Distances

Hofstede and others place numeric values on a few distinct cultural categories for numerous countries. When comparing countries, the question at hand is how to calculate the cultural distance, i.e. how to quantify the difference across cultures.

A classic index to calculate the cultural distance between two countries, in this case the US and another country, has been introduced by Kogut and Singh (1988). They propose the following formula:

Equation 2-1: Kogut-Singh Index

$$KS_j = \frac{1}{4} * \sum_{i=1}^{4} \frac{(I_{ij} - I_{iu})^2}{V_i}$$

Where KS_j is the Kogut-Singh cultural distance of the j. country from the US, I_{ij} the index for the i. dimension (at this time Hofstede had only 4 cultural dimension), V_i the variance of the index of the i. dimension and u indicates the US.

Basically, the Kogut-Singh index takes the distance of each cultural dimension and adds up these distances. Shenkar, Luo, and Yeheskel (2008) call this index for measuring cultural distance a “must have”.

Some criticism of this index deals with the assumption that the distance of each cultural dimension is assumed to be equally important. In response several authors, such as

Barkema and Vermeulen (1997), Brouthers and Brouthers (2001) or Vermeulen and Barkema (2001), operationalize cultural distance through the Euclidian distance. It computes the cultural distance in a four-dimensional space (at this time we are still talking about four Hofstede dimensions) as the square root of the summed up squared differences between each cultural dimension score. As a formula:

Equation 2-2: Euclidian Cultural Distance

$$EC_j = \sqrt{\sum_{i=1}^{4} \frac{(I_{ij} - I_{iu})^2}{V_i}}$$

Where EC_j is the Euclidian cultural distance of the j. country from a base-country (usually the US), I_{ij} the index for the i. dimension, V_i the variance of the index of the i. dimension and u indicates the base-country (here the US).

The Mahalanobis distance by Mahalanobis, Bose, and Roy (1937) and introduced into cultural distance measurement by Berry, Guillén, and Zhou (2010) expands on the Euclidian distance measurements, as it also takes the correlation between the cultural dimensions into account. It considers the full variance – co-variance matrix in calculating cultural distances between two countries. Beugelsdijk, Ambos, and Nell (2018) point out that the Mahalanobis distance particularly pays off for differently scaled indices, whereas the Hofstede cultural distance are similarly scaled, i.e. on a (0;100) scale. For uncorrelated indices, a variance-corrected Euclidian index provides a comparable result (De Maesschalck, Jouan-Rimbaud, and Massart, 2000).

Another approach is to use cultural clustering, e.g. using a dummy variable whether a culture is in the same culture cluster of another culture or not or alternatively a stepwise distance measurement, as done e.g. by Barkema, Bell, and Pennings (1996). For example, Ronen and Shenkar (1985, 2013) condense relevant literature and defined eight cultural clusters: Anglo-Saxon, Germanic, Nordic, Latin European, Latin American, Near East, Far East, Arabic.

Some studies, e.g. Luo (2002), use a rather qualitative approach, by asking managers about the perceived cultural distance. Psychic distance and cultural distance, have to be differentiated, though, as the former term includes the cultural distance, as well as the manager's mindset (Sousa and Bradley, 2006).

The calculation of cultural distance can be complex, with a plethora of methods available. Compared to many other studies, I do not look at only pairwise cultural combination. In fact, patents can involve inventors from numerous countries, requiring a formula which on the one hand is suitable for many countries involved and on the other hand is not too demanding on computational power, with several million observations in the patent data set. I propose and use in this dissertation the following formula:

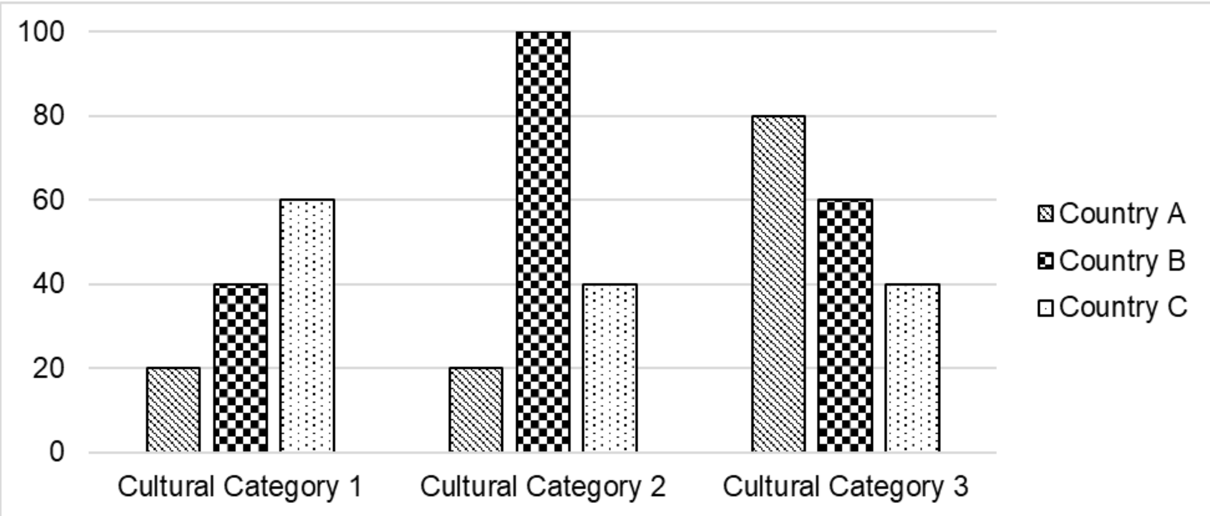
Equation 2-3: Cultural Distance Calculation

$$CD_p = \sum_{i=1}^{6} I_{i,max} - I_{i,min}$$

Where CD_p is the Cultural Distance of the patent p, $I_{i,max}$ the index for the i. dimension from the inventor country with the highest score and $I_{i,min}$ the index for the i. dimension from the inventor country with the lowest score.

Consider the following example of a patent with inventors involved from three cultures / countries, categorized in three cultural categories, for simplification. Figure 2-4 shows the (example) cultural values for each of the three cultures. For example, in cultural category 3, country A has a rather high level of 80 and Country C a rather medium level of 40.

Figure 2-4: Example for Calculating Cultural Distance



As we are interested in the cultural distance, we assume that it is the extreme values, i.e. the cultures with the highest distance who determine the cultural distance in the inventor team. I therefore calculate the cultural distance by adding the maximum distance for each cultural category. In this example in Figure 2-4 (with only three, instead of six cultural categories), we would have a cultural distance CD of $CD = 160 \rightarrow (60 - 20) + (100 - 20) + (80 - 40)$.

With this approach we will have a co-domain $\in (0; 600)$. 0 would be the cultural distance, if there is actually no distance, i.e. if the cultural values are identical in all categories, which means that there is only one culture involved (there are no cultures with identical values in all categories). 600 would be the (theoretical) cultural distance, if in any of the six Hofstede categories we would have at least one culture with the lowest value of 0 and one with the highest value of 100. In reality, this is quite unlikely, and a $CD > 200$ is already quite high. For example, for a US-China collaboration, we calculate a $CD = 237$. The advantage of this formula is, that it is applicable to patent collaborations with many cultures involved.

For the analyses below, I form four groups. The first group are patents with no cultural distance, i.e. $CD = 0$. The remainder of patents are put in 3-quantiles, i.e. terciles, which means the patents are sorted into three equally large groups, depending on their CD: low, medium and large cultural distance and calculate each group's average quality.

We want to check whether the differences in group means are statistically significant, i.e. whether one group really can be considered to have a higher or lower quality of patents, depending on the respective Cultural Distance (CD). As we have more than two groups, respectively, we cannot run a two-sample independent t-test, but instead run a one-way ANOVA with the following hypotheses:

Equation 2-4: Hypotheses One-Way ANOVA

$H_0\colon\ \mu_1 = \cdots = \mu_k$	Where μ_k is the mean patent quality of the k. group of Cultural
$H_1\colon\ \mu_i \neq \mu_j$	Distance (CD) and i and j are any two groups of cultural distance.

A significant F-statistic in our one-way ANOVA would lead us to the rejection of the null hypothesis H_0, i.e. we would infer that there is a significant difference of means in one of the group-pairs of Cultural Distance. In order to identify these groups, we conduct independent t-tests of all pairwise sets. With additional tests we conduct, the chance of a Type-I error, i.e. erroneously rejecting a true null hypothesis, increases, which requires a correction. I use the Bonferroni correction, which sets the significance cut-off for each test at a fraction of the α by the number of tests.[197] The Type-I error will therefore be approximately α. Other potential corrections such as Fisher's least significant difference (LSD), Tukey's range test, Dunnett and Holm are not the focus of this dissertation and not discussed further. For econometrical details refer to Acock (2018); Rawlings, Pantula, and Dickey (1998) or Simonoff (2003).

2.4. Interviews with Relevant R&D personnel

Interviews with relevant R&D personnel, i.e. managers and heads of R&D departments and other institutions linked to R&D activities, can help to shed light on the precise activities and motives of a firm's R&D, thereby complementing quantitative data.

2.4.1. Methodology of Interview

There are two general types of interviews, differing in approach, setting and goals: structured and unstructured interviews. The structured interview has a rigid structure with fixed question

[197] For our four groups, we have six tests, i.e. mathematically possible pairwise combinations: $\frac{n(n-1)}{2}$, with n as the number of groups. The complete test statistics are shown exemplified for Pharmaceutical patents in Appendix-Table 7.

which are asked in a set order. Posing closed questions or rating questions helps to compare the answers across interviews. This type of explicit interview is conducted with a quantitative research question in mind. It uses a strict methodology of interviewing to ensure comparability and minimizing interviewer biases. The interviewer will aim to control and standardize as many factors as possible: from the selection and approach of the interviewee, to the questions to be posed, the setting and tone of the interview, as well as the following analysis and reporting.[198]

An unstructured interview, on the other hand, does not give a strict structure, but rather develops individually during the interviewing process. This type of exploratory interview is conducted with a qualitative research question in mind. While the loose framework can appear appealing, it can challenge the comparability of findings.[199]

Neither one of these interview types are strictly dominant to each other, but rather have to be carefully selected, depending on the research question and goal of analysis.

The methodology of interview used for this dissertation is a combination of both interview types: the semi-structured interview. A set of questions is prepared in advance, some more quantitative and closed to collect "hard numbers" and some more open to explore motives, goals and strategies. The semi-structured interview therefore combines the advantages of the structured and unstructured interview as detailed above and give a suitable complementary data source for the quantitative measurements, as explained in the previous sub-chapters.

The interview guideline used for this dissertation is given below in sub-chapter 2.4.2. The questions are somewhat standardized, yet sufficient room is given for the interviewee to develop and voice his opinion. The formulation and standardization of questions not only helps in not omitting crucial aspects during an interview, it also prevents posing biased or leading questions. A rigorous record of the interview must be kept, in order to differentiate between hard facts and soft opinions given by the interviewee.[200]

2.4.2. Interview Guideline

The methodology of semi-structured interviews requires preparation and a formulated list of questions to be discussed with the respective individual. The general structure of the interviews conducted for this dissertation can be divided into two parts: First, in a quantitative part the interviewee gives hard numbers on the R&D conducted by the respective company, comparable to the figures explained in the previous sub-chapters. This part gains in relevance,

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[198] Cf. Bryman and Bell (2011, p. 202 ff.); Flick (2009); Kvale (1996); Maynard et al. (2002); Myers (2013).

[199] Cf. Bryman and Bell (2011).

[200] Cf. Kvale (2007).

if the company in question does not release in-depth data in its annual report or other publications. These questions are more standardized and can more easily compared across companies and interviews. Second, in a qualitative part, the interview focusses on the motives and structures of R&D in the respective company. These questions are naturally hard to capture in quantitative figures, but are crucial to understand the structure of the respective R&D.

Quantitative Interview Questions

Q-N1. How much do you spend on R&D abroad, both in absolute terms, as well as a fraction of the total R&D spending?
Q-N2. How many employees (full-time equivalents) in R&D do you have abroad and what is their fraction to total R&D employees?
Q-N3. What are your five most relevant foreign R&D locations?
Q-N4. How is your R&D staff distributed on the most relevant foreign R&D locations?

Qualitative Interview Questions

Q-L1. What are your most relevant research locations abroad (as opposed to development) and on what research areas are they focusing?
Q-L2. How are your technology- and development centers distributed on your most relevant foreign locations?
Q-L3. What are or where your key reasons to shift R&D abroad?
Q-L4. How do you rate the performance of your R&D centers abroad?
Q-L5. What key performance indices (KPI) do you use to evaluate your R&D centers and staff?
Q-L6. How is the cooperation and knowledge transfer between your domestic and foreign R&D centers?
Q-L7. How do you consider the future development of R&D Internationalization in your company for the years 2020 – 2025?

2.5. Classification of Countries

For analytical purposes, countries analyzed within this dissertation are classified in one of two categories: developed economies and emerging economies. This classification aids in analysis, as countries with a comparable economic environment are grouped together.

Definition: A developed country within this analysis is a country which has been classified as developed in 1994. All other countries are emerging.

This definition helps particularly in separating the effects of R&D Internationalization as measured on “traditionally developed economies”, i.e. economies which have experience economic strength and innovation capabilities for a longer time, versus “newly developed or developing economies”, i.e. economies which only recently, if even, have increased their capabilities.

There are several definitions and country classification schematics, usually including economic strength and development, as measured through the nation’s gross domestic product (GDP) in both absolute and growth terms. Some countries, particularly those in transition, show attributes which could place them in either of the given categories. China, for example, is classified by the World Bank as an “Upper-Middle-Income Economy”, with its Gross National Income (GNI) per capita in the bracket 3,996 to 12,375 USD.[201] With significant wealth disparities, for example between rich coastal cities like Shanghai and poorer rural areas, the classification of China is not necessarily unequivocal.[202] Some classification schemes, such as provided by the ’International Monetary Fund’ (IMF) are not based on strict numeric criteria.[203]

Over time the classification of a country may change, for example Israel’s classification has shifted from emerging to developing economy around 2010 due to its continuous economic growth.[204]

With heterogeneous evaluation criteria, which are sometimes not even explicitly published, the classification results vary. Greece, for example, is classified by the IMF as a developed country[205], whereas the finance company MSCI considers Greece as an emerging country and therefore includes Greek firms in its “MSCI Emerging Markets Index”.[206]

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201 Cf. World Bank (2019). Status as of 2020. The other country categories are “Low-Income Economies”, “Lower-Middle-Income Economies” and “High-Income Economies”. The income thresholds are regularly calculated and updated with the “Atlas-Method” (World Bank, 1989).

202 Cf. Lampton, Wallace, and Conrad (2016).

203 Cf. IMF (2019).

204 Cf. Solomon (2013).

205 Cf. IMF (2018). Developed economies are labelled “Advanced Economies”. Other countries are grouped as “Emerging and Developing Economies”.

206 Cf. MSCI (2019a). Apart from “Developed” and “Emerging” countries, the MSCI groups countries which are used in the company’s indices in the “Frontier” category.

On top of dividing the world's countries into a set of groups, there is also a plethora of palatable labels for certain groups of countries, which, objectively or subjectively, share common economic characteristics. These labels include "BRIC" (Brazil, Russia, India and China – see below), "Pacific Pumas" (Colombia, Chile, Mexico and Peru)[207], "Asian Tigers" (or "Asian Dragons": Hong Kong, Taiwan, Singapore, South Korea)[208] and its derivative "Tiger Cubs" (Malaysia, Philippines, Thailand, Indonesia, Vietnam)[209] and many more.

BRIC:

The term and acronym BRIC was coined in 2001 for the four countries Brazil, Russia, India and China: these countries were unified by their two-digit annual GDP growth rates and assumed to eventually surpass the established Western economies.[210] The leaders of the BRIC countries regularly meet since 2009, with the addition of South Africa in 2010, thus forming the group known as 'BRICS'[211]. However, as it will be shown further below, the idea of the 'BRICS' or 'BRIC' as the most promising emerging countries, has grown too narrow.

For clarity and purposes of this analysis, I use two mutually exclusive categories, as defined above: all countries which have been developed in 1994, the first year of analysis in this dissertation, are categorized as "developed". All remaining countries are emerging countries. Note: With a general upwards global economic development, there has been no downwards classification over the years across all relevant classification schemes, i.e. there has been no shift in categorization from developed to emerging, only vice versa. The definition in this dissertation of a developed country is therefore comparably strict. The list of countries considered to be "developed" is shown in Table 2-7. The status as a developed country does only indicate its relative economic strength, not its absolute: small countries such as Luxembourg are and have been a developed country for a long time, whereas their international economic relevance is negligible.[212]

[207] Cf. George (2014).
[208] Cf. Young (2000).
[209] Cf. Tani (2017).
[210] Cf. O'Neill (2001).
[211] Cf. The Economist (2013).
[212] In 1994 Luxembourg had an absolute GDP of 27,824m$ (constant prices, constant PPPs, base year 2015), with which it ranged just below Costa Rica (OECD, 2019a).

Table 2-7: List of Developed Countries [213]

Developed Country		
Australia	Germany	Norway
Austria	Ireland	Portugal
Belgium	Italy	Spain
Canada	Japan	Sweden
Denmark	Luxembourg	Switzerland
EU15[214]	Netherlands	United Kingdom
Finland	New Zealand	United States
France		

213 Own classification, based on IMF (2018); MSCI (2019b); World Bank (2019).

214 The EU15 is listed here, as some data is only published as an EU15-aggregate. The EU15 denotes the 15 member-countries of the European Union prior to 1995 and prior to the ascension of ten additional countries. The EU15 includes: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom. Note: Greece is the only country of the EU15, which is not considered a developed country in this analysis. The effect of Greece in the EU15-group is, due to the country's small economic size, negligible.

3. Global Trends and Shifts in R&D Expenditure Patterns

In this chapter I analyze the global trends and developments in R&D Internationalization by relevant home- and host-countries, by scrutinizing and analyzing the Business expenditure on R&D (BERD). The BERD is a significant indicator, capturing R&D and innovation activities of businesses around the world. Analyzing the BERD helps us to understand better the size and location of innovation activities.[215] The detailed methodology has been discussed in the previous chapter.

When enterprises spend money on R&D, not just in their home-country, but abroad (Outward BERD), we can use this information in order to understand where the company conducts foreign R&D activities. Accordingly, we can use the Inward R&D to understand from which country foreign R&D investments are coming.

The following research questions are being answered:

RQ3.1:	What are the structural changes in foreign R&D investment during the period 2000 to 2018?
RQ3.2:	MNCs from which countries invest the most on foreign R&D?
RQ3.3:	What are the major source and target countries for MNCs to invest in R&D internationally?

Data on R&D spending is collected and published on a national level, requiring condensation and consideration of different depths and breadth of data: Some countries, e.g. the United States require companies[216] for detailed information on the type, destination and amount of R&D investments. Other countries, particularly emerging countries, often do not collect or publish this data in a comparable level of detail. This chapter therefore serves to give a condensed and clear overview, based on the research questions posed above.

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[215] As outlined in the methodology part (Chapter 2.1), I will only list and discuss the business expenditure on R&D, i.e. no expenditure by governments or public research institutes. As explained before, certain measures such as tax breaks for innovation or subsidies are not consistently counted in either category across countries: the individual measures vary, despite definitions in the FRASCATI manual (OECD, 2015b).

[216] In Chapter 2.1.1 the concept of Ultimate Beneficial Ownership is discussed: a company, while technically registered locally, might be ultimately owned by a foreign entity, so the company's business figures are to be attributed to that foreign entity.

In the first part I will give a global overview of the R&D Expenditure within a country (BERD), as well as an overview of Inward R&D for major economies in the world. This shows general developments and trends in R&D Internationalization.

In the second part I focus on the four major economies Germany, USA, Japan and China and break down their respective Outward and Inward R&D Expenditures.

In this chapter I show how the R&D expenditures by business around the world have skyrocketed in the last twenty years, particularly driven by rising R&D expenditures from foreign-based firms, i.e. the trans-border R&D flows increase. Furthermore, we will see how more countries have increased in relevance, compared to 2000 where almost all of R&D Expenditures was spent in the US, Japan or certain European countries (e.g. Germany). Since then many more countries have increased in relative relevance as R&D locations, such as Switzerland, Sweden, Netherlands, Canada, but also Austria and Belgium. Most notably, however, we see a rise in relevance of emerging countries, particularly in recent years, such as China, Israel, India and some Eastern European countries, e.g. Poland or Czech Republic. I show how particularly the emerging country China has taken the stage, although precise analyses and interpretations are limited by incomplete data and currency exchange effects.

3.1. Overview Global Development of R&D Expenditure

Table 3-1 gives an overview of the Business Expenditure on R&D within the respective country (BERD). It therefore shows in which countries the most money is spent on R&D. While these figures do not reveal any degree of internationalization, they do show which countries are the largest investors for business R&D.

For example, in the year 2007 280 billion USD have been spent within the United States by businesses to conduct R&D. As discussed earlier, the BERD displays the money spent within a country, but does not differentiate which share of that money comes from national businesses and which from foreign businesses investing in the respective country. A breakdown of the most-relevant host-countries in terms of their Outward (outgoing) R&D investments follows in the following sub-chapter.

The most relevant countries in terms of their BERD are listed, separated into Developed Countries and Emerging Countries[217] and sorted decreasingly by the most recent

[217] For an overview of the grouping and methodology into Developed and Emerging Countries, see Chapter 2.5.

period (2017). I list the respective Top 10 developed and emerging countries, and in addition the group of the EU15-countries.[218]

Missing data for certain years is replaced by data from the most adjacent year and marked accordingly in the table. In order to not having figures distorted through the World Financial Crisis, I include the year 2007, and not 2009 which would be in the middle of 2000 and 2017.

The raw data is collected and supplied by the OECD, through its Main Science and Technology Indicators (MSTI) database. The source data of relevant countries can be found in Appendix-Table 1. Up until the MSTI 2019/1 publication, the OECD collected and published data on Inward R&D as R&D Expenditures of Foreign Affiliates.[219] These publications, covering data up until 2016, aided in giving a comprehensive insight into trans-border R&D activities and have been discussed and condensed, e.g. by Gerybadze (2020).[220] Since then the biannual MSTI publications have been shorted and this data has not been made available, requiring a more fine-grained and dedicated approach to discuss more recent years, as shown in my R&D Matrix in Table 3-2 and Table 3-3.

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[218] See Table 2-7 for a breakdown and discussion of the EU15-countries.

[219] OECD (2019a) – MSTI 2019/1, Table 60; OECD (2018) – MSTI 2018/1; Table 61.

[220] Cf. Gerybadze (2020), Table 3.

Table 3-1: Annual Business R&D Expenditure (BERD) by Country in Mio USD[221]

Country			**2000**	**2007**	**2017**	**CAGR '00-'17 (%)**
OECD-Total			533,000	661,345	846,939	2.8
Business R&D Expenditure (BERD) in	Developed Countries	**United States**	**246,145**	**279,820**	**353,522**	**2.2**
		EU15	*146,348*	*173,986*	*223,664*	*2.5*
		Japan	**86,698**	**119,580**	**122,204**	**2.0**
		Germany	**49,278**	**55,262**	**76,449**	**2.6**
		France	26,976	29,983	36,057	1.7
		United Kingdom	20,348	23,616	29,205	2.1
		Italy	10,129	12,818	17,199	3.2
		Canada	12,709	14,331	12,986	0.1
		Sweden	7,694[222]	9,274	11,016	2.1
		Switzerland	5,951	8,226[223]	10,899	3.6
		Australia	4,913	11,308	10,880[224]	4.8
	Emerging Countries	**China**	**24,465**	**93,206**	**345,076**	**16.8**
		South Korea	15,759	31,211	66,903	8.9
		Taiwan	7,218	13,951	27,550	8.2
		Russia	13,587	20,700	22,903	3.1
		Israel	5,091	7,411	11,055	4.7
		Turkey	1,331	3,451	10,764	13.1
		Poland	1,263	1,230	6,698	10.3
		Singapore	2,306	4,792	5,568	5.3
		Czech Republic	1,416	2,176	3,790	6.0
		Mexico	1,372	3,107	3,077	4.9

Note: Values are given in 2010 million USD, constant prices and PPPs. Countries in bold are analyzed below in Chapter 3.2.

[221] Own analysis, based on OECD (2019a), MSTI database, extracted on 26. Dec. 2019.
[222] Value from 1999.
[223] Value from 2008.
[224] Value from 2015.

The United States are clearly the largest location in terms of R&D Expenditure with an annual Business Expenditure on R&D (BERD) of 354 billion $ per year in the most recent period of 2017. Japan and Germany follow at a significant distance with around 35% and 22% of the US BERD. These three countries have across all periods consistently been the number one, two and three, respectively of all developed countries in terms of their BERD. All developed countries have a CAGR of less than 5%, in the case of Canada even of just 0.1%.

The three biggest BERD countries in Europe are Germany, France and UK, which collectively spend around 63% of the total EU15 BERD. Canada and Australia are two other non-European relevant developed countries.

The Emerging Countries, on the other hand, have undergone a much more dynamic development: with partially much higher annual growth rates, they have consistently increased their BERD. China has undergone the most significant development: with a CAGR of almost 17%, it ranks now directly behind the US of all countries. China has significantly caught up: in 1995, for example China was still on rank 10 of all countries and behind the emerging countries South Korea and Russia. Until 2017, China has consistently reduced the gap in Business Expenditure on R&D to the frontrunner US and only ranks slightly behind it.

Up until here we have analyzed business R&D activities perform within national boundaries.[225] In a next step I focus on trans-border R&D flows, i.e. I investigate how much R&D is spent by businesses in other countries.

Table 3-2 and Table 3-3 show an R&D matrix for 2000 and 2015, respectively, depicting the cross-country inflow of BERD of relevant countries: the column shows the respective declaring country, i.e. the country which reports and in which R&D is invested in (target country). The rows show the investing country or source country, i.e. the country from which the cross-country R&D investment is made from, with a country selection based on Table 3-1. Due to limitations in data availability, the tables are not always completely filled. The emerging countries China and India would be interesting for analysis. However, data on these non-OECD member states is not being presented at this stage, as only rudimentary and comparably imprecise data partly published by these countries is available.

The upcoming tables serve as an overview, showing major R&D Internationalization patterns. In the next sub-chapter, I will show the (international) R&D Expenditures by firms of major countries in more detail.

[225] For a detailed explanation of the nomenclature, refer to Chapter 2.1.1.

Table 3-2: Inward R&D Matrix by Target Country, 2000[226]

	Inward R&D Expenditure 2000 in Mio. USD, by declaring / target country								
Investing Country	**US**	**DE**	**GB**	**JP**	**FR**	**CA**	**NL**	**SE**	**CH**
USA	-		1,846	1,061		1,247	227	1,182	
Germany	5,281	-	180	150		83	33	124	
UK	3,289		-	96		162	80	1,215	
Japan	1,373		212	-		56	26	3	
France	2,205		215	1,709	-	55	100	67	
Canada			61			-	0		
Netherlands			502	182		13	-	148	
Sweden			95				3	-	
Switzerland	2,607		172	37		33	21	210	-
Inward R&D	*20,990*		*4,292*	*3,591*		*1,760*	*642*	*3,083*	
(Total) BERD	*199,961*	*32,881*	*17,414*	*100,776*	*17,870*	*8,345*	*4,117*	*7,208*	*4,672*
Share (%)	*10.5*		*24.6*	*3.6*		*21.1*	*15.6*	*42.8*	

Note: Values for United Kingdom from 1999 / BERD for Sweden as average value from 1999 and 2001.

Table 3-2 shows the Inward R&D Matrix for the year 2000. In the columns we see the inward R&D investment per receiving / declaring / target country. For example, in 2000 German firms have invested 5.3 billion USD in R&D in the US.

The US, the biggest economy and biggest R&D spender (highest BERD) in the world, also has a significant influx of R&D Expenditure by multinational corporations from foreign countries. Around 25% of all Inward R&D is attributed to investments from Germany, for which the US are obviously an important R&D location. Other large investing countries include the UK and Switzerland.

From the investing country side, we can observe that firms from Germany and Japan, both investing rather significantly in the US, invest only smaller R&D sums in other countries. This can be an indication of a rather selective strategy: instead of spreading R&D investments broadly across the globe, these countries focus on a select market, here the US. The US, in turn, invests rather evenly in several other countries, including the UK, Japan, its neighbor

[226] Own analysis, based on OECD (2020e), Dataset: Business Enterprise R&D Expenditure, extracted on 3. Oct. 2020 and converted into USD based on respective exchange rate published by the OECD (2020g).

Canada and Sweden. The UK also invests also quite strongly in Sweden, which can be attributed to mostly market-seeking motives.[227]

Overall, we can observe in 2000 a quite selective international R&D spending pattern. Furthermore, it is noticeable that the data completeness is not optimal: as data is sourced from a respective country's national reporting, usually statistical offices, this simply shows that a thorough analysis on the origins of foreign R&D investments has not been a core concern for many countries.

We have analyzed so far foreign, i.e. Inward R&D, investments for the base year 2000. In a next step, we see how the patterns have changed compared to the year 2015. This is the latest year for which generally reliable data is available.

Table 3-3: Inward R&D Matrix by Target Country, 2015[228]

	Inward R&D Expenditure 2015 in Mio. USD, by declaring / target country								
Investing Country	**US**	**DE**	**GB**	**JP**	**FR**	**CA**	**NL**	**SE**	**CH**
USA	-	4,693	6,421	2,100	1,033	3,231	579	750	
Germany	7,269	-	979		848	161	141		
UK	8,377	778	-		362	272	75		
Japan	7,776		915	-	150	83	262		
France	5,355	830	996		-	340	218		
Canada	906					-			
Netherlands	4,659	2,653			628	80	-		
Sweden	670	218			330		13	-	
Switzerland	10,042	1,495			1,246	114	37		-
Inward R&D	*56,731*	*14,534*	*16,263*	*7,629*	*7,245*	*4,952*			*2,104*
(Total) BERD	*355,821*	*67,627*	*31,908*	*113,064*	*34,542*	*14,040*	*8,509*	*11,331*	*16,272*
Share (%)	*15.9*	*21.5*	*51.0*	*6.7*	*21.0*	*35.3*			*12.9*

Note: Values for France from 2014

Table 3-3 shows the R&D matrix for 2015. As a first major observation we can see the increase of Business Expenditure on R&D in the respective countries, as well as an increase in shares

227 Cf. Braconier, Ekholm, and Knarvik (2001).

228 Own analysis, based on OECD (2020e), Dataset: Business Enterprise R&D Expenditure, extracted on 3. Oct. 2020 and converted into USD based on respective exchange rate published by the OECD (2020g).

of Inward R&D to BERD. In most countries the BERD has significantly increased: for Germany the BERD has more than doubled in the 15 years to a high value of 68 billion USD, outlining the high and increasing relevance of R&D.[229] The US BERD has grown strong as well, yet at a smaller rate and increased by a total of 78%. Japan, despite a rather high BERD, stands out with its comparably small growth rate and increased by a total of 12%. Switzerland stands it in the other direction: the small yet innovation-strong country has increased its BERD of 4.8 billion USD in 2000 to 16 billion USD in 2015, which corresponds to a staggering increase by the factor 3.5.

Once again, we see strong R&D investments into the US, which has remained as one of the largest and most significant target countries for foreign R&D investments. Germany, the leading R&D investing country in 2000, has dropped in the ranking, as countries such as Japan, UK and Switzerland have increased their R&D investments in a much stronger way. The four most relevant countries Germany, USA, Japan and China will be discussed in more detail, i.e. both from an Inward and Outward R&D spending perspective, in the following sub-chapter.

The US still invest strongly in relevant economies, namely Germany, UK, Japan, France and Canada, for all of which the US is the biggest source of Inward R&D. Switzerland, a rather small country with a strong innovation-based economy appears to be quite internationalized with significant R&D investments in several countries.

Germany, in turn, seems to have maintained its rather selective strategy of focusing strongly on the US and with somewhat relevant investments in the UK and France.

Overall, we can make three major observations from the matrices. First, we see how the level of Business Expenditure of R&D has increased at quite different rates across the selection of major economies. Second, we can see that the US is the leading foreign R&D investor in many economies, yet the dominance has decreased until 2015, i.e. the relative distance of the leading investor US to the following second has decreased.

That shows the clearly an increasing interconnectedness of R&D activities, i.e. more firms from more countries are spending increasingly higher amounts and shares to conduct R&D in an increasing broader range of countries.

[229] A doubling of values in 15 years would correspond to a CAGR (Compound Average Growth Rate) of 4.7%.

In Table 3-4 I show the value and share of Inward R&D of the previous nine countries, to show the absolute and relative relevance of the respective country as a target country for foreign R&D investments.

Table 3-4: Overview Inward (Foreign Funded) R&D for Selected Developed Countries[230]

Country	Inward to (Total) BERD (%) 2000	2015	Inward R&D (Mio. $) 2000	2015	CAGR '00-'15 (%)
USA	13.1	15.9	26,180	56,731	5.3
Germany	18.7	21.5	6,881	16,838	6.1
UK	31.3	51.5	5,678	15,522	6.9
Japan	3.6	6.7	2,528	8,927	8.8
France	24.3	20.6	5,002	8,078	3.2
Canada	29.2	35.3	2,944	5,074	3.7
Netherlands	26.1	19.1	1,304	1,808	2.2
Sweden	42.8	42.1	3,083	4,545	2.6
Switzerland	9.4	12.9	403	1,639	9.8
COMPOUND	*14.5*	*17.4*	*54,004*	*119,163*	*5.4*

Note: See Figure 2-1 (p. 25) for terminology of BERD (sub-)sets. / Compound shows calculations based on total for the nine countries shown in the table.

In Table 3-4 I show the total Inward R&D investments, both as an absolute figure and with the corresponding CAGR, as well as in relation to the BERD, i.e. total R&D spending within the country. In Table 3-2 and Table 3-3 I was focusing on a breakdown per country, here we are working with the total aggregates, for which there is better data availability.[231]

We see in the Table 3-4 the total Inward R&D indicated in million USD at current prices and PPPs. The figures, together with the CAGR, show quite different trends and developments across the countries: several European countries have strongly increased their Inward R&D. The US, as one of the biggest economies in the world, can be considered somewhat of a benchmark with a CAGR of 5%. While we have seen before, that US firms invest globally in

[230] Own analysis, based on Table 23 & 60, MSTI 2019/1 – OECD (2019a) and Table 23 & Table 61, MSTI 2014/1 – OECD (2014) and OECD (2020e).

[231] Note: China as a relevant economy would be interesting to include in this sample, however economic data is only available directly through Chinese statistical offices and not standardized through the OECD. Comparing data from such different data-sources leads to compatibility problems, i.e. comparing apples to oranges.

R&D, Table 3-4 shows, how the US have attracted foreign R&D, meaning foreign firms increasingly invest in R&D in the US (Inward R&D).

I give the total for these nine major economies, showing the total Inward R&D in Million USD, as well as the average share of Inward to BERD.

Germany, the UK, Japan and Switzerland stand out with a rather higher CAGR, indicating that they strongly increased the amount of R&D expenditure by foreign firms into their respective countries since 2000. The high CAGR shows how countries have increased their attractiveness.

We can see the relative relevance of R&D Expenditure by foreign firms within a company with the share of Inward R&D to BERD: for example, Japan, a rather un-internationalized country, stands out with low single-digits Inward shares of 4% and 7% respectively, indicating that the overwhelming majority of R&D Expenditure within Japan comes from Japanese firms. On the other side of the spectrum we have the UK, where in 2015 more than half of Business R&D Expenditure in the country came from foreign firms.

We can draw the two major conclusions: First, R&D Internationalization increases as the Inward R&D figures grow mostly at a much stronger rate than the BERD figures. Second, the share of Inward to BERD shows significant differences across countries and thereby reveals structurally different outlines of R&D patterns in each country.

In the next chapter I collect and analyze available Inward and Outward R&D data for the four major economies Germany, USA, Japan and China.

3.2. R&D Expenditure by Country

In this sub-chapter the most relevant countries are analyzed in terms of their Inward- and Outward-oriented R&D Expenditures: Germany, USA, Japan and China. I show how the influx of R&D investments have increased and also diversified, in terms of that increasingly more countries are investing relevant amounts in R&D in a country. Furthermore I also show how the relevance of certain developed countries has shifted and decreased in return to select emerging countries.

The detail, validity and timeliness of the data on Inward R&D are generally higher, compared to Outward R&D, although it highly varies across countries. Countries generally are interested in being attractive investment locations, so measuring the inflows of R&D, can help them to determine which foreign nations are interested in conducting innovative activities within that nation. The Outward R&D, by contrast, may indicate some weakness or deficiencies of the multinational firms' home country.

The raw data is supplied through the respective countries' publications and partly supplemented with OECD data. Depending on the national legislature and reporting standards, data on R&D is either collected through national agencies, e.g. the national statistical office or the Central bank, often on a mandatory reporting basis or through, usually government-mandated, private research institutions which survey relevant companies. The detail, validity and timeliness of the data therefore highly varies across countries.[232]

The most relevant partner countries are shown separated into Developed Countries and Emerging Countries. If available, I show the values for 2000, 2007 (before the financial crisis, to reduce biases) and 2017 (usually most recent available data).

The values are sorted decreasingly by the most recent period 2017. Amounts of money not published in USD or EUR, are converted with the annual average exchange rate into USD.[233]

For the analysis of Inward R&D I calculate the share of Inward R&D to BERD, i.e. the share of money spent within a country on R&D coming from foreign firms.

For the analysis of Outward R&D I calculate two shares: First, the share of Outward R&D to Total R&D, i.e. which percentage of money R&D Expenditure by companies from that country is spent abroad.[234] Second, the share of BERD to GDP. Intuitively, one might argue in putting a measure of R&D Expenditure in relation to the market value of goods and services within an economy. For policy makers this percentage is a meaningful goal. The European Commission, for example, set for its member countries to spend it least 3% of the respective GDP on R&D[235]. Please note, that this calculation includes the GERD, i.e. Inward and National R&D, both by businesses, government and other entities. I chose to remain more specific and continue focusing on the business side, hence the BERD.[236] A high share can indicate that R&D conducted by businesses is important relatively seen to the country's GDP.

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232 It is important to point out that the calculation methods across databases differ: for example what Germany reports as Inward R&D from the US is a different figure than what the US reports as Outward R&D to Germany.

233 Cf. World Bank (2020) – Appendix-Table 6.

234 I call 'Total R&D' the sum of 'National R&D' and 'Outward R&D'. For a recap of terminology: see Chapter 2.1.1.

235 Cf. European Commission (2010).

236 To recap the discussion about these kinds of ratios, please read Chapter 2.1.2: Policy makers usually consider the ratio of GERD to GDP, not BERD. The former ratio naturally is higher, yet its explanatory power is more limited.

Generally speaking, the Outward R&D investments of a country's companies are measured consistently and in detail by only few countries. Table 3-5 shows the data collection institutions and sources for relevant countries.

Table 3-5: Data Collection Agencies for Outward Business R&D

Country	**Agency**	**Title of Publication**
Germany	Stifterverband Wissenschaftsstatistik (*for R&D figures)*	FuE-Erhebung (R&D Survey)
	Deutsche Bundesbank (German Federal Bank) (*for non-R&D figures)*	Foreign Affiliate Statistics (FATS)
USA	Bureau of Economic Analysis (BEA)	Activities of U.S. Multinational Enterprises (MNEs)
Japan	Ministry of Economy, Trade and Industry (METI)	Survey on Overseas Business Activities
China	National Bureau of Statistics of China	China Statistical Yearbook China Statistical Yearbook on Science and Technology (*more detailed R&D figures, available for data from 2009 forward)*

3.2.1. R&D Expenditure: Germany

Germany's business R&D data is collected by the 'Stifterverband Wissenschaftsstatistik'[237] since the 1970s on behalf of the German Federal Ministry of Education and Research with a survey on a biennial basis. Data is only available for uneven years, so instead of data for 2000, I show 2001 instead in Table 3-6.

Inward R&D

The Stifterverband breaks down the source of foreign R&D investments in Germany only for recent years and only for the major markets Europe (EU & non-EU), as well as USA.

[237] Literal translation to English: Science Statistics of the Foundation's Association. It is a part of the 'Stifterverband für die Deutsche Wissenschaft' (Foundation's Association for German Science), or short 'Stifterverband', whose goal is to analyze, consult and support in the areas of education, science and innovation Stifterverband (2019).

Table 3-6: Overview Inward R&D Investments into Germany[238]

Inward R&D Expenditure to Germany in m€	**2001**	**2007**	**2017**	**CAGR ’01-’17 (%)**
R&D Expenditure in Germany (BERD)	36,166	42,759	68,787	4.1
R&D from abroad (Inward R&D)	8,013	11,208	13,701	3.4
Share Inward R&D/BERD (%)	*22.2*	*26.2*	*19.9*	-
From abroad: EU	-	-	6,418	-
From abroad: Europe, non-EU	-	-	1,978	-
From abroad: USA	-	-	3,834	-

Approximately 22% of R&D came from foreign firms in 2001. This share rose to 26%, i.e. more than every fourth R&D Euro came from foreign firms in 2007 and decreased to 20% again in 2017. This shows that the relevance of foreign R&D investors to Germany has increased between 2001 and 2007, but then decreased again until 2017. Compared to previous years the share of Inward R&D to Total R&D (BERD) has decreased, indicating that Germany has become relatively less attractive for foreign R&D investments.

A breakdown for 2017 by origin of the Inward R&D investments reveals that approximately one half of the Inward R&D comes from EU neighbors. Around 28% come from the USA and 15% from European and non-EU countries, which is mostly the southern neighbor Switzerland. The three countries or country-groups, EU, non-EU Europe and USA account for practically all of Germany’s Inward R&D. Other countries or regions, e.g. China, therefore do not significantly contribute to Germany’s Inward R&D.

Outward R&D

The Stifterverband only surveys the amount of R&D spent abroad vs. domestically. It does not ask for destination countries, so the Outward R&D cannot be broken down to target countries. The Stifterverband, however, is aware of that data limitation and strives to elaborate its questioning in future surveys. In this dissertation I use patent analyses, namely the methodology of Host-Country Patents in Chapter 4 to shed more light on the distribution of countries.

[238] Own analysis, based on Stifterverband (2019), Zahlenwerk, Table 6.1, Inward R&D; Stifterverband (2009), FuE-Datenreport, Table 27; OECD (2020e), Dataset: Inward activity of multinationals by industrial sector (manufacturing) - ISIC Rev 3, extracted on 26. Dec. 2019.

Table 3-7: Overview Outward R&D Investments by German Companies[239]

Outward R&D Expenditure by German Companies in m€	**2001**	**2007**	**2017**	**CAGR ’01-’17 (%)**
Total R&D[240]	40,268	38,595	79,089	4.3
Outward R&D	11,949	9,459	30,144	6.0
Share Outward/Total R&D (%)	*29.7*	*24.5*	*38.1*	-

In the 16 years of analysis the R&D spent by German firms (Total R&D) has increased on average at a rate of 4.3% to almost 80 Billion USD in 2017. The part of the Total R&D spent abroad (Outward R&D) has grown at a higher rate of 6.2% per year. The share of Outward to Total R&D has increased from 30% in 2001 to 38% in 2017, indicating that German firms nowadays have a much more internationalized R&D structure: more than every third Euro on R&D gets spent abroad.

Both tables together show us that, while German firms have increasingly internationalized their R&D Expenditure, Germany itself seems to have lost some of its appeal to foreign R&D investing firms in recent years. This analysis, together with other relevant and older studies[241] outlines the following: for Germany the countries of focus are clearly the US, a select number of European neighbors and increasingly China. The upcoming patent analysis in Chapter 4 will shed further light on the international composition and distribution of partner countries.

3.2.2. R&D Expenditure: USA

The U.S. Bureau of Economic Analysis (BEA), an agency of the Department of Commerce, collects statistical data on companies and the economy in the US. It self-describes as “one of the world’s leading statistical agencies”[242]. Filing data for the annual survey is mandatory for all US businesses, which explains the comparably high accuracy and detail of the survey.[243] Furthermore the BEA collects detailed data on Inward R&D investments.

239 Own analysis, based on Stifterverband (2019), Zahlenwerk, Table 6.3, Outward R&D.

240 For years before 2005, calculated based on BERD, provided by OECD (2019a), MSTI database, extracted on 26. Dec. 2019.

241 Cf. German Commission of Experts for Research and Innovation: EFI (2014); EFI (2013) and Gerybadze, Schnitzer, and Czernich (2013)

242 Cf. BEA (2019).

243 US businesses with at least one foreign affiliate file form “BE-10” for the annual survey. Furthermore larger companies are required to file the form “BE-577” for the quarterly survey (BEA, 2004).

Inward R&D

I show the breakdown of Inward R&D investments in Table 3-8, broken down by the most relevant developed and emerging countries by 2017 expenditure. The figures by the BEA are generally higher due to different calculations, than to those by the OECD and reported in Table 3-4. The trends and developments are congruent nonetheless. The recent source data can be found in Appendix-Table 2.

Table 3-8: Overview Inward R&D Investments into USA[244]

		Inward R&D Expenditure to USA in m$	**2000**	**2007**	**2017**	**CAGR ’00-’17 (%)**
		R&D Expenditure in USA (BERD)	246,145	279,820	353,522	2.2
		R&D from abroad (Inward R&D)	29,274	40,967	62,588	4.6
		Share Inward R&D/BERD (%)	*11.9*	*14.6*	*17.7*	
Inward R&D Expenditure from	Developed Countries	Switzerland	3,886	6,395	9,422	5.3
		Japan	3,436	4,416	9,403	6.1
		Germany	5,892	5,893	9,122	2.6
		United Kingdom	4,732	9,470	6,659	2.0
		Netherlands	1,496	1,729	5,571	8.0
		Ireland	369[245]	257	5,262	16.9
		France	2,977	5,589	4,072	1.9
		Canada	3,741	1,574	980	-7.6
		Sweden	386	388	669	3.3
		Denmark	187	368	499	5.9
	Emerging Countries	South Korea	326[246]	215	1,557	9.6
		British West Indies[247]	22	82	1,183	26.4
		China	12	0	1,422	32.4
		Israel	111	149	1,097	14.4
		Hong Kong	5	75[248]	634	33.0
		Singapore	10	69	403	24.3
		India	0	6	213	-
		Taiwan	62	110	87	2.0
		Brazil	0	0	27	-
		Russia	0	0	21	-

[244] Own analysis, based on BEA (2019), Data on activities of multinational enterprises - Foreign Direct Investment in the U.S. - Research and Development Expenditures; OECD (2020e), MSTI database, BERD at constant prices and 2010 PPP m$; extracted on 26. Dec. 2019.

[245] Value for 2002.

[246] Value for 1999.

The Inward R&D has increased both in absolute and relative figures: in 2017 almost 18% of Business R&D Expenditure within the US came from a foreign firm. Most of the biggest R&D investing countries in the US are from Europe: Switzerland, UK, France, Netherlands, Ireland, Sweden and Denmark who collectively invested around 66% of all Inward R&D of the US in 2017. Germany, ranking first in 2000 in terms of Inward R&D investments has dropped to rank three in 2017. Canada in 2000 on rank four with its 3.7 Billion USD R&D investments has dropped in relevance and even experienced a negative CAGR.

The three most relevant emerging countries South Korea, China and Israel stand out with a relatively high CAGR, although their overall contribution to the US Inward R&D is relatively small. The British West Indies can be considered offshore-based US entities and not inherently foreign-based firms. That displays that while the relative importance of the US for Emerging Countries has grown, its absolute relevance is still comparably small.

Outward R&D

Outward R&D investments of US multinational firms are broken down and summarized in Table 3-9. The countries are grouped into developed and emerging countries, as defined in Chapter 2.5 and sorted decreasingly by the most recent value of 2017. Relevant source data can be found in Appendix-Table 3.

[247] The British West Indies (BWI) is a collective term for the British overseas territory in the Caribbean, i.e. geographically close to the US, including Anguilla, the Cayman Islands, Turks and Caicos Islands and several others. The tax regimes is generally company friendly, leading to off-shoring by US firms (PwC, 2019).

[248] Value for 2006.

Table 3-9: Overview Outward R&D Investments by US Companies[249]

		Outward R&D Expenditure by US Companies in m$	**2000**	**2007**	**2017**	**CAGR ’00-’17 (%)**
		Total R&D[250]	224,623	273,299	347,532	2.6
		Outward R&D	20,457	34,446	56,598	6.2
		Share Outward/Total R&D (%)	*9.1*	*12.6*	*16.3*	-
Outward R&D Expenditure in	Developed Countries	*SUBTOTAL Developed C.*	*16,870*	*28,069*	*38,882*	*5.0*
		Germany	3,115	6,403	8,177	5.8
		United Kingdom	4,111	6,000	6,415	2.7
		Switzerland	286	1,162	4,735	18.0
		Canada	2,332	2,712	3,513	2.4
		Ireland	465	1,510	3,350	12.3
		Japan	1,630	1,919	2,875	3.4
		France	1,465	1,557	2,009	1.9
		Netherlands	369	752	1,377	8.1
		Belgium	412	1,191	1,368	7.3
		Australia	349	1,072	940	6.0
	Emerging Countries	*SUBTOTAL Emerging C.*	*2,968*	*6,276*	*17,196*	*10.9*
		China	506	1,173	3,650	12.3
		India	43	382	3,586	29.7
		Israel	630	1,025	2,621	8.7
		Singapore	551	549	1,421	5.7
		South Korea	143	928	1,014	12.2
		Brazil	253	607	886	7.7
		Malaysia	161	390	612	8.2
		Mexico	0	303	504	-
		Taiwan	365	97	441	1.1
		Poland	0	73	371	-

Note: TOTAL of country groups slightly less than Outward R&D, due to rounding and missing values.

249 Own analysis, based on BEA (2019), Data on activities of multinational enterprises, U.S. Direct Investment abroad, R&D Expenditures.

250 Calculated based on BERD, provided by OECD (2019a), MSTI database.

In the 17 years of analysis US companies have increased their annual R&D Expenditure by 3% from 225 billion $ in 2000 to 348 billion $ in 2017. US firms have increasingly internationalized their R&D investments. From 20 billion $ in 2000, or 9% of the Total R&D, they have increased their Outward R&D investments to 57 billion $ or 16% in 2017.

The breakdown of the Outward R&D by country reveals numerous interesting findings.

The biggest target country in terms of received US Business R&D investments is Germany, with over 8 billion $ in 2017. R&D investments in Germany have grown at a rather strong rate of 5.8% per year, which is above the average growth rate for all developed countries of 5.0%.

In 2000 UK ranked first, but dropped behind Germany with a much smaller growth rate of 2.7%. Canada, also a politically close partner to the US, has similarly grown at a small rate and maintained its rank in the Top Five of all developed countries. France, number five in 2000, has dropped to rank seven, of all developed countries and in the last years even received absolutely less US R&D investments.

Switzerland and Ireland, two comparably smaller economies have received two-digit growth rates in US R&D investments. Closer analysis in upcoming chapters will show in what industries exactly these increases have been.

Overall, the share of R&D investments across the developed countries has spread out: in 2000, the Top 3 countries received 57% of the R&D Expenditure of all developed countries, whereas in 2017 the Top 3 countries received only 50%. The emerging countries have experienced a much more dynamic development and grown in relevance: in 2000 only 15% of all foreign investments went to an emerging country, whereas in 2017 this rate grew to 30%.

R&D investments in emerging countries have grown from 3 billion $ in 2000 to 17 billion $ in 2017, with an annual growth rate of 10.9%. The most significant growths of R&D by US firms are observed in China and India, which have received around 3.6 billion $ in R&D investments from the US in 2017. China has grown with a CAGR of 12% and India at a staggering 30%. With these R&D Expenditures China and India are now on the overall rank of 4 and 5 respectively, directly before Canada.

Israel as a close political ally of the US ranks ninth of all target countries with received R&D investments in the amount of 2.6 billion $ in 2017. At a distance, Singapore, South Korea and Brazil follow.

Both the amount of Inward and Outward R&D have continuously increased, and are similar in size and development. The degree of internationalization is smaller compared to smaller countries, e.g. Germany with its Outward R&D ratio of 38%.

Put in a nutshell, we find an increasing internationalization and decentralization of R&D as measured by international R&D Expenditures of US firms in two aspects: on the one hand emerging countries, particularly China and India, have entered the stage and US firms have invested heavily in R&D in these countries. On the other hand, we see very different CAGR-rates across (developed) countries, indicating strong shifts in relevance within the group of developed countries, as well.

3.2.3. R&D Expenditure: Japan

The Japanese Ministry of Economy, Trade and Industry (METI) surveys on an annual basis since 1971 the overseas activities of Japanese businesses. Participation is required and additional interviews may be conducted for clarification.[251] The survey is not as detailed, compared to the US surveys and the country breakdown for Inward and Outward R&D are only surveyed in clusters of few regions.[252]

The most recent data is for 2016, which I will therefore use instead of 2017. The reporting unit of Yen is converted into US Dollar with its respective average annual exchange rate.

Inward R&D

Table 3-10 gives an overview of the Inward R&D investments, i.e. R&D investments from non-Japanese firms into Japan. Relevant source data can be found in Appendix-Table 4.

[251] Cf. METI Japan (2019a).

[252] Older data, i.e. up until 2007, in part, reveals a more detailed breakdown. More current data is, however, limited to the regions being shown.

Table 3-10: Overview Inward R&D Investments into Japan[253]

Inward R&D Expenditure to Japan in m$	**2000**	**2007**	**2016**	**CAGR ’00-’16 (%)**
R&D Expenditure in Japan (BERD)	100,783	117,531	122,755	1.2
R&D from abroad (Inward R&D)	3,591	5,839	6,396	3.7
Share Inward R&D/BERD (%)	*3.6*	*5.0*	*5.2*	-
From abroad: Europe	2,279	5,112	5,177	5.3
From abroad: USA	1,061	637	258	-8.5

Almost all Inward R&D comes from firms located in Europe or the USA, with the latter heavily decreasing their investments. Data available for 2007 shows that around 68% of Europe’s investments can be attributed to France. As mentioned before, no detailed breakdown per country is available since 2008, when the classification and measurement system changed.

The share of Inward R&D to BERD has generally increased over the years, yet is, compared to other countries, at a relatively low rate. Apparently investing in R&D in Japan is not particularly appealing for many foreign companies on an aggregate level. With Japan as the lead-market[254], for example in certain technical fields, we can expect a quite high inter-industry variance. An analysis of Host-Country Patents, as conducted in Chapter 4, can help to shed further light on this assumption.

Between 2015 and 2016 the Inward R&D drops by around 25% explaining the noticeable different values between Table 3-4 (2015) and Table 3-10 (2016).

Outward R&D

Table 3-11 gives an overview of Japanese R&D investments between 2016 and 2000.[255] Relevant source data can be found in Appendix-Table 5.

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[253] Own analysis, based on OECD (2020e), Dataset: Inward activity of multinationals by industrial sector (manufacturing) - ISIC Rev 3 & Rev 4, extracted and last updated on 8. Feb. 2020.

[254] See Chapter 1.1.1 for a discussion.

[255] The reporting unit of Yen is converted into US Dollar with its respective average annual exchange rate.

Table 3-11: Overview Outward R&D Investments by Japanese Companies[256]

Outward R&D Expenditure by Japanese Companies in m$		2000	2007	2016	CAGR '00-'16 (%)
Total R&D		99,962	114,989	123,788	1.3
Outward R&D		2,770	3,297	7,430	6.4
Share Outward/Total R&D (%)		*2.8*	*2.9*	*6.0*	-
Outward R&D in	North America[257]	-	-	3,346	-
	USA	1,900	1,661	-	-
	Asia	-	-	1,971	-
	European Union[258]	629	894	1,960	7.4

Japanese companies have slightly increased their Total R&D Expenditure from 100 billion $ in 2000 to 124 billion $ in 2016, with a compound average growth rate (CAGR) of 1.3%. Investing in R&D abroad has, however, gained in great significance, as the share of Outward to Total R&D increased from 2.8% in 2000 to 6.0% in 2016.

The breakdown per country is, as discussed above, limited to the three major economic regions in 2016: Northern America, Asia (which obviously does not include Japan) and the European Union. The sum of R&D Expenditure in these three regions almost reaches the Outward R&D, indicating that there is only very little R&D Expenditure in countries outside of these three regions.

With limited data sets and several changes in data collection methodology by the METI over the years, further analyses are quite limited. The 'Japan External Trade Organization' (JETRO) aims to incentivize investments in R&D and also somewhat analyzes and incentivizes incoming R&D.[259] International R&D activities by Japanese firms are not thoroughly captured.

[256] Own analysis, based on METI Japan (2019b): Survey of Trends in Business Activities; METI Japan (2018): 48th Basic Survey on Overseas Business Activities and OECD (2019a), MSTI database, Outward activity of multinationals by country of location - ISIC Rev 4, extracted on 26. Dec. 2019.

[257] For 2007 and before the values for United States are shown. Afterwards only an aggregate of North America is available.

[258] "European Union" encompasses until 2007 the EU15, from 2008-2012 the EU27 and since 2013 the EU28. Older data indicates that the majority of R&D investments within the EU is conducted in the old EU-states. Comparability across the years is therefore given.

[259] Cf. JETRO (2020c); JETRO (2020b); JETRO (2020a).

Japan's internationalization rate is growing, yet very low. Taken as a whole and in terms of R&D Expenditure, Japanese companies are neither extremely interested in conducting R&D abroad, nor are foreign firms to conduct R&D in Japan. Host-country patent analyses will show to what extent there are differences in R&D Internationalization across different industries.

3.2.4. R&D Expenditure: China

China's spectacular economic growth in the last decades warrants a detailed analysis with regards to its R&D activities. The National Bureau of Statistics compiles annually detailed economic statistics for the whole country and includes all large and medium-sized businesses in the high-tech industry. We know that most R&D Expenditure indeed comes from the high-tech industry by larger firms, yet the indicated figures generally underestimate the complete BERD. The "China Statistical Yearbook" makes general economic and other statistical figures available, whereas the specialized "China Statistical Yearbook on Science and Technology" gives R&D figures in more detail, but is only available for data from 2009 forward.

The reporting unit of Renminbi is converted into US Dollar with its respective average annual exchange rate.[260]

Inward R&D

Table 3-12 shows the Inward R&D in China. As there is no breakdown by country of origin available, we cannot know from where the Inward R&D Expenditure comes. Relevant data reaches only until the year 2016 and instead of 2007 only data for 2005 is available.

[260] Cf. Appendix-Table 6.

Table 3-12: Overview Inward R&D Investments into China[261]

Inward R&D Expenditure to China in Mio. $ (High-Tech, large- & medium-sized)	**2000**	**2005**	**2016**	**CAGR '00-'16 (%)**
R&D Expenditure in China (BERD)	1,341	4,424	39,143	23.5
R&D from abroad (Inward R&D)	245	1,244	5,635	21.7
Share Inward R&D/BERD (%)	*18.2*	*28.1*	*14.4*	-

Note: The three special regions Hongkong, Macao and Taiwan are considered here as non-foreign and parts of China. R&D Expenditures from these regions are therefore not listed in this Table as "from abroad".

The figures clearly show China's immense growth in R&D Expenditure: over 23% growth on average every year to 309 billion $ in 2016. The Inward R&D has risen as well, although at a smaller rate of 22%. The share of Inward R&D to BERD has increased from 18% in 2000 to 28% and then fallen to 14% in 2016. After the initial growth between 2000 and 2005, foreign R&D investments have grown strongly, albeit at a smaller rate compared to R&D investments from Chinese firms. This shows that while foreign R&D investments are relevant, Chinese firms have grown more in relative relevance.[262]

Two aspects limit the interpretation of this table. First, as outlined, only R&D Expenditure by large- and medium-sized high-tech firms is considered. Second, China's currency, the Renminbi, is comparably volatile impacted by political decision. Using the PPP (purchasing power parity) can help comparability, but also can be limited in a highly dynamic country, such as China.[263] In comparison I list in the following table the Total BERD, as listed by the OECD, both in Renminbi and USD.

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[261] Own analysis, based on National Bureau of Statistics of China (2018), Statistical Yearbook on High Technology Industry, Tables 2-1-3 & 2-1-7 and converted into USD based on the respective exchange rate published by the World Bank (2020) and shown in Appendix-Table 6.

[262] Cf. Nell (2018).

[263] Cf. Prasad (2017); Subramanian (2010).

Table 3-13: Overview BERD China by Currency[264]

Total BERD	**2008**	**2010**	**2013**	**2016**	**2017**
Million Renminbi (National Currency)	338,169	518,547	907,585	1,214,396	1,366,023
Million USD, PPP current prices	106,278	155,755	247,732	304,468	326,502
Million USD, PPP constant prices	106,623	153,291	237,456	309,047	332,924

For the year 2016 we can calculate here an exchange rate of Renminbi to USD of 3.99 (current prices) and 3.93 (constant prices). The official World Bank's exchange rate for that year is 6.64. For the discussion on PPP vs. real exchange-rates, I refer to the relevant economic literature.[265] The main takeaway here is, that a highly dynamic country, such as China can be hardly compared to other countries due to a limitation in data availability and currency exchange effects.

Outward R&D

China does not systematically capture and publish R&D investments by Chinese firms abroad. While the National Bureau of Statistics of China (2019) breaks down in its 'Statistical Yearbook on Science and Technology' R&D Expenditure to 'External Funds', these figures do not describe trans-border R&D activities but rather cross-company business transactions. For Outward R&D activities of Chinese firms we will therefore have to rely on the analyses of Host-Country Patents in Chapter 4.

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[264] Own analysis, based on OECD (2020e) – "Business enterprise R&D expenditure by industry".
[265] Cf. Callen (2007); Choudhry (2005); Froot and Rogoff (1995).

4. Outward Host-Country Patents by Country and Field

In this chapter I list and discuss Host-Country Patents (HCP) of relevant countries from an outwards perspective. Analyzing HCPs, i.e. patents by an applicant from country A and at least one inventor from country B can help to show internationalization activities in R&D. In other words: A Host-Country Patent is every patent where at least one inventor is not located in the country of the applicant(s). The applicant is the multinational corporation (MNC) filing for a patent[266]. Analyzing these patents can help to analyze foreign inventive activities, because we see the location of the inventor as a proxy for the inventive activity. For methodological details, please refer to Chapter 2.2.

Simplified speaking, I look at the patents from all MNCs based in a country, which conducted inventive activities in other countries, hence outward (or "outgoing" patents). For example, for the country of Germany, I show in which other countries German firms such as Siemens, Daimler, Bosch etc. conducted R&D activities.

RQ4.1:	In which countries are the relevant MNCs based, which conduct R&D activities internationally
RQ4.2:	In which foreign countries locate MNCs from relevant economies their inventive activates R&D and what are the structural changes during the period 2000 to 2015?

This sub-chapter is structured in two parts: First, I give a global overview, to justify my selection of nine countries, of which China is the only emerging country. I show from which countries the big MNCs are coming from which conduct R&D on a global scale. In the second part I break down the most relevant countries, to see which the most-relevant target countries for each home-country are. I give a summary together with the Analysis of Inward Host-Country Patents in the next chapter, namely in part 5.4.

All patents analyzed in this chapter are international patent applications, i.e. patents filed under the Patent Cooperation Treaty (PCT), as reported by the OECD[267] and detailed in Chapter 2.

[266] Not all inventors, i.e. individuals involved in the innovation process and named on the patent, are based in the home-country: some inventors are located in a foreign country, i.e. a host-country. Patents with foreign-based inventors are therefore called Host-Country Patents. Cf. Gerybadze and Merk (2014).

[267] Cf. Chapter 2.2.5 for a detailed explanation.

The number of patents from each year is summed up to three-year periods, in order to reduce the effect of potential outlier years. The indicated patent numbers are derived through "full-counting", as explained in Chapter 2.2.3. This also means that the number of "Total Host-Country Patents" can be smaller than the sum of the respective patents across the countries, due to multiple counting.[268]

The most relevant host-countries are listed separately for developed and emerging country, based on the classification discussed in Chapter 2.5. The tables are sorted decreasingly for the most recent time-period (2015-2017). The source data of relevant countries can be found in Appendix-Table 8.

I will show not only how business increasingly patent with inventors based abroad, but also which these target countries are. Specifically, I will show particularly certain emerging countries, such as China or India have gained in relevance as a location for R&D activities by foreign-based firms. The analyses per country shows also the differences across economies, as naturally the internationalization and global distribution of R&D activities is not identical.

4.1. Global Overview of Outward Host-Countries

In this chapter, I show and discuss the global distribution and development of Outward Host-Country Patents (HCPs).

In Table 4-1 we see the total number of patents worldwide, as well as the number of HCPs and the major home-countries of international patents. The table shows the source countries, i.e. the location of companies which file for patents with foreign inventors. This table therefore shows from where the internationalizing companies come from and justifies the selection of countries for the following Outward patent breakdown per country.

[268] For example, if a patent by a German applicant had one German, one French and one Chinese inventor, this one (international) patent would be counted as one patent for each of the three countries, with the latter two being international in this respect.

Table 4-1: Global Development of Host-Country Patents, Source Countries[269]

Global Host-Country Patents, Source Countries			**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	**CAGR ’00-’17 (%)**
Total Patents			316,043	464,548	591,681	685,788	5.0
Total Host-Country Patents			51,411	76,350	88,321	92,350	3.8
Share HCP to Total Patents (%)			*16.3*	*16.4*	*14.9*	*13.5*	-
HCPs with Applicants from	Developed Countries	United States	16,430	22,829	27,554	27,243	2.8
		Germany	7,054	9,815	10,715	10,709	2.8
		Switzerland	5,104	8,227	8,861	8,507	3.4
		France	3,010	5,726	6,846	5,607	4.3
		Japan	1,979	3,000	4,122	5,510	7.2
		Netherlands	4,106	6,523	5,045	5,097	1.7
		Sweden	2,450	3,889	4,359	4,234	2.7
		United Kingdom	3,255	3,186	3,328	3,721	0.5
	Emerging Countr.	China	155	995	2,777	5,143	25.0
		Cayman Islands	245	425	494	2,506	15.3
		South Korea	312	1,015	1,689	1,844	13.7
		Singapore	274	664	1,111	1,013	8.6
		Hong Kong - China	342	528	560	1,007	7.8

Despite strong increases in the numbers of HCPs, HCPs grow at a smaller rate than the number of total patents: the share of HCPs to total patents decreases, which would indicate a decline in relative relevance of HCPs. However, it would be far too premature to conclude that we see a shift in (re-) nationalizing R&D activities: When looking at the country-level data below, we can see that the strong increase in domestic patent numbers can be clearly attributed to the surge of domestic patenting in (mostly) China. Most other economies have increased their share of Host-Country Patents. One explanation for China’s upswing in domestic patents is that domestic patents imply a higher level of control on a political level and are therefore particularly promoted and incentivized. Alternatively, patents without foreign contribution imply lower research activity and complexity compared to their international

[269] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

counterparts. Therefore, national patents would be based on easier and simpler underlying inventions and therefore faster and cheaper to produce. In the detailed patent analysis in Chapter 7, I will therefore introduce indices of patent quality to show whether HCPs, i.e. patents based on international activities are better compared to their national counterparts or not.

The table shows in which countries MNCs are based which conduct R&D activities abroad. For example, the figure “27,243” for “United States” in the period “2015-2017” indicates that over 27,000 patents have been filed by US firms during that period, which have involved inventors from other nations outside the US. The detailed number and breakdown of HCPs by target country for the US and other major economies can be found in the next chapter.

The detailed figures will be discussed in the sub-chapter for the respective countries below. Generally, we can observe strong activities by multinational corporations from the US, Germany, other European countries, as well as from Japan. Nevertheless, emerging countries, led by China, underwent a very dynamic development with strong growth rates. Clearly Emerging Countries are also the home of multinational companies which have increased R&D and inventive activities abroad, even though still at a lower level.

The relatively high values for the Cayman Islands and Hong Kong can be assumed to be a proxy: both regions are known for their tax-friendly regulations, which attract firms.[270] Hong Kong is clearly connected to (Mainland-)China, whereas the Cayman Islands are also home to many Chinese firms. The Chinese car-manufacturer Geely, for example is incorporated in the Cayman Islands with limited liability, although it is headquartered in China.[271] The official explanation for Chinese companies headquartered in the Cayman Islands, such as Internet firms Alibaba and Tencent, is to have access and the ability to be listed on international stock exchanges, which would not be allowed for China-based firms.[272]

So far, we have analyzed the major source or home countries, i.e. the major locations of multinational corporations with significant outward foreign R&D activities.

We now turn to the analysis of relevant host countries for R&D activities, in order to find out where MNCs locate their inventive activities, or more precisely where inventors are located that appear on international patent applications.

[270] Cf. PwC (2019).
[271] Cf. Alvstam, Dolles, and Ström (2014, p. 227).
[272] Cf. Ohlberg (2020).

This chapter's patent analysis uses the methodology of full-patent counting, i.e. if a patent had for example an applicant based in the US and one in Germany (Joint-Venture) we would count it as a respective full patent for either country here. Nevertheless, we can clearly see where the internationalizing companies are located: almost all relevant home-countries, i.e. bases for internationalization are developed countries, with the exception of China. The numbers indicate a high concentration of HCPs across countries. Very broadly speaking, every second HCPs comes from a company based in the Top 3: the US, Germany or Switzerland.[273]

I select a sample of relevant countries which I analyze further in the following sub-chapter. The figure in brackets behind each country gives the country's share to total HCPs in percent for the latest 2015-2017 period and thereby its relative relevance:

US (29.5), Germany (11.6), Switzerland (9.2), France (6.1), Japan (6.0), China (5.6), Netherlands (5.5), Sweden (4.6), UK (4.0).

For example, 29% of all HCPs in 2015-2017 come from an US applicant. Due to full-counting the sum of percentages can obviously be larger than 100%. Despite the limitations of the full-patent counting method, previously discussed, we can see clearly where the companies are internationalizing their R&D activities to.

4.2. Country Breakdown

In this sub-chapter I list and discuss the Outward Host-Country Patents (HCPs) of relevant economies. The overview for each country is comparable to the global overview in the previous sub-chapter: First, I both list the number of total patents with applicants from the respective home-country, as well as the number of Host-Country Patents, i.e. the number of patents with an applicant from the home-country X and at least one inventor not based in that home-country X, i.e. the Outward Host-Country Patents. The growth rates for each host-country can help indicate shifts in relevance of the respective host-country. I give the respectively ten most relevant developing and emerging target countries, in terms of the HCP numbers for the latest 2015-2017 period. Furthermore, I give the share of the respective target country's HCPs in 2015-2017 to all HCPs. This indicates the current relative importance of the respective host-country. Both the absolute HCP numbers, as well as the CAGR is important

[273] We have to be careful when adding up the percentages. For example, it would be imprecise to say that over 50% of the international patents come from the Top 3 countries, i.e. US, Germany or Switzerland. For example, Switzerland might be a (complete) subset of Germany and Germany of the US. That means every patent with a Swiss applicant, also has a German applicant and a US applicant. In that (theoretical) example only 29.5% and not 50% of all HCPs would have a US or German or Swiss applicant. In most cases, though, patents can be attributed to one company from one country (Guellec and van Pottelsberghe de la Potterie, 2000), so with the assumption of rather disjoint sets, we can say that around 50% (29.5+11.6+9.2) HCPs come from a Top 3 country.

to determine the importance of a host-country: for example, a given host-country with a strong CAGR of 24% in the period 2000-2017, might actually not be relevant at all, if this CAGR were based on absolute small number of patents.[274]

Second, I break down the number HCPs by technological field, i.e.by Top-10 IPC classes.[275] Showing which of the 126 IPC classes show the most HCPs for each country indicates which technological fields and potentially industries are particularly interesting for R&D Internationalization.[276] IPC classes can be different in size, so in addition I show a second table with shares: on the one hand I give the share of patents from applicants of the respective country to all patents. This is an indicator for the technology competency of multinational corporations from that country in the respective technological field. For example, a share of 75% in a certain field would indicate that three out four patents in that field have an applicant from the respective country. On the other hand, I give the share of host-country patents to all patents by applicants from the respective country. This share of HCPs shows the internationalization rate, i.e. which percentage of patents by a country and within a field have a foreign inventor.

This shows the relative importance of the analyzed economy in that technological field in a clearer way.

I list the number of total patents and of total Host-Country Patents, whereas the focus of analysis differs: each table shows for a particular country X, the number of patents with (at least) one applicant from country X (Total Patents) and the number of patents with at least applicant inventor from country X and an inventor from outside of country X. The Share of Host-Country Patents therefore indicates here what fraction of patents from a country X have an inventor outside of country X. This share has sometimes been named the XAFI-rate in the literature, which stands for X Applicant of Foreign Inventions.[277] For example, the GAFI-rate (German Applicant of Foreign Inventions) is the share of all patents with a foreign, i.e. non-German inventor and (at least) one German applicant, divided by all patents with (at least) one German applicant. To avoid linguistic contortions (e.g. “NLAFI” would stand

274 For example, 1 patent in the year 2000 and 40 patents in 2017 would result in a CAGR of 24%. With a very small starting base few patents have obviously a strong impact on the CAGR.

275 I break the IPCs down to the class, i.e. the three-character classification and list the classes decreasingly for their latest 2015 value. For example, the Class ’F03’ describes “Machines or Engines for Liquids; Wind, Spring, or Weight Motors; Producing Mechanical Power or a reactive propulsive thrust, no otherwise provided for”. See Table 2-1 for details.

276 See Chapter 1.1 for an overview of motives for R&D Internationalization.

277 Cf. EFI (2013); Gerybadze, Schnitzer, and Czernich (2013).

accordingly for Dutch (Netherland) Applicant of Foreign Inventions and be quite challenging to pronounce) and aid understanding, I stick with 'Share of Host-Country Patents".

The official IPC Class labels can be somewhat lengthy, so I show in the tables a shortened title. The complete names of the IPCs shown in this chapter are displayed in Table 4-2. While this table is lengthy, indicating that for the countries analyzed there are quite different Top-10 fields, in reality there is a big overlap, meaning that a high number of technological fields appears as a patent-intensive field for many countries.

Table 4-2: Overview Relevant IPC Classes for Outward Host-Country Patents

IPC	Official Name
A23	Foods or foodstuffs; their treatment, not covered by other classes
A61	Medical or veterinary science; hygiene
B01	Physical or chemical processes or apparatus in general
B60	Vehicles in general
B65	Conveying; packing; storing; handling thin or filamentary material
C07	Organic chemistry
C08	Organic macromolecular compounds; their preparation or chemical working-up; compositions based thereon
C09	Dyes; paints; polishes; natural resins; adhesives; compositions not otherwise provided for; applications of materials not otherwise provided for
C11	Animal or vegetable oils, fats, fatty substances or waxes; fatty acids therefrom; detergents; candles
C12	Biochemistry; beer; spirits; wine; vinegar; microbiology; enzymology; mutation or genetic engineering
D06	Treatment of textiles or the like; laundering; flexible materials not otherwise provided for
E21	Earth or rock drilling; mining
F01	Machines or engines in general; engine plants in general; steam engines
F02	Combustion engines; hot-gas or combustion-product engine plants
F16	Engineering elements or units; general measures for producing and maintaining effective functioning of machines or installations; thermal insulation in general
F24	Heating; ranges; ventilating
G01	Measuring; testing
G02	Optics
G06	Computing; calculating; counting
H01	Basic electric elements
H02	Generation, conversion, or distribution of electric power
H03	Basic electronic circuitry
H04	Electric communication technique

Source: WIPO (2020b).

It is important to point out that I use different data sets in the respective fourth step: For the country breakdown I rely on aggregated PCT data and for the technological field (IPC) breakdown I analyze individual raw patent data from the EPO.[278] The patent numbers and shares can therefore look quite differently.

[278] See Chapter 2.2 for a methodological elaboration and discussion.

4.2.1. US Outward Host-Country Patents

This part summarizes the outward international patenting activities of US firms. That means we look at patents filed for by multinational firms based in the US and look at host-country patents, i.e. patents with a non-US based inventor. As shown in Table 4-1, the US, as an economic superpower, is the country with the most HCPs in the latest 2015-2017 period (and actually has been in other periods as well for that matter).

Table 4-3: Development of US Outward Host-Country Patents[279]

	Outward Host-Country Patents, USA	2000-2002	2006-2008	2011-2013	2015-2017	*CAGR '00-'17 (%)*	*Share HCPs '15-'17 (%)*
	Total Patents	123,144	149,806	166,926	165,867	*1.6*	-
	Total Host-Country Patents	16,430	22,829	27,554	27,243	*2.8*	-
	Share Host-Country Patents (%)	*13.3*	*15.2*	*16.5*	*16.4*	-	-
HCPs with Inventors in – Developed Countries	Germany	2,332	3,186	3,481	3,595	*2.3*	*13.2*
	United Kingdom	3,197	3,608	3,449	3,189	*-0.2*	*11.7*
	Canada	1,828	2,489	2,540	1,998	*0.0*	*7.3*
	France	1,343	1,786	1,600	1,538	*0.9*	*5.6*
	Japan	1,353	1,770	1,948	1,413	*0.9*	*5.2*
	Spain	230	333	490	877	*7.6*	*3.2*
	Belgium	717	904	920	863	*0.4*	*3.2*
	Switzerland	534	717	901	826	*3.5*	*3.0*
	Netherlands	633	767	670	662	*0.2*	*2.4*
	Italy	547	719	630	590	*0.8*	*2.2*
HCPs with Inventors in – Emerging Countries	China	419	1,329	3,475	3,934	*14.6*	*14.4*
	India	263	927	2,072	2,248	*15.0*	*8.3*
	Israel	945	1,115	1,711	1,490	*1.3*	*5.5*
	Chinese Taipei	160	312	408	820	*13.2*	*3.0*
	Singapore	146	324	485	693	*9.5*	*2.5*
	South Korea	239	423	601	621	*5.7*	*2.3*
	Russia	264	326	575	602	*5.0*	*2.2*
	Brazil	97	164	246	380	*11.3*	*1.4*
	Malaysia	55	93	180	278	*5.4*	*1.0*
	Mexico	72	98	197	246	*6.9*	*0.9*

Firms from the US have overall slightly increased their share of Host-Country Patents (HCPs), from 13.3% to 16.4% in the periods 2000-2002 to 2015-2017. In the period 2015-2017 China has claimed the first place for US HCPs, surpassing Germany. With a distance India and Israel, a close ally of the US, follows.

US firms have increased the number of Host-Country Patents from 16,430 to 27,243 during the three-year periods 2000-2002 and 2015-2017. In these periods, the share of HCPs has been increased from 13.3% to 16.4%.

In most developed countries, except Germany, but including Israel, US firms have somewhat lost interest as the number of HCPs in the 2011-2013 to 2015-2017 period has decreased. The strong increase with Spain can be considered an outlying effect and does not change the overall picture, as HCPs with Spain account for approximately only 3% of all US HCPs.

The table clearly shows the relevance of emerging countries as a host for US inventive activities: China is even the most significant host-country of all for the US, but also India and the strong ally Israel have significant shares.

Emerging countries almost exclusively have the most dynamic upward development as host-countries. China and India not only have the largest absolute numbers in HCPs, but also the highest growth rates from 2000 to 2017. Spain stands out with a surprisingly high CAGR, but that might be, as discussed above, an outlying effect, caused by the activities of only a handful of companies. Switzerland has maintained a rather strong position and, as one of the few developed countries, has grown above average. Other somewhat significant emerging countries follow and even Russia, a historic antagonist to the US has received some attention in Host-Country Patents.

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[279] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

Host-Country Patents by Technological Field

Table 4-4: Host-Country Patent Breakdown for US Applicants by IPC[280]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR ’00-’15 (%)
Total Patents	33,948	34,395	37,100	36,758	0.5
Total Host-Country Patents	6,179	6,894	6,831	6,904	0.7
Share Host-Country Patents (%)	*18.2*	*20.0*	*18.4*	*18.8*	-
A61: Medical	1,405	1,364	1,231	1,415	0.0
G06: Computing	931	638	991	1,059	0.9
H04: Electric Communication	940	955	1,131	1,048	0.7
G01: Measuring	610	455	556	527	-1.0
C07: Chemistry	829	536	497	505	-3.3
H01: Electric Elements	529	481	401	448	-1.1
C08: Organic Compounds	410	383	392	393	-0.3
C12: Biochemistry	568	284	287	248	-5.4
C09: Paints	196	225	243	244	1.5
B01: Processes	258	223	248	242	-0.4

Note: Full-counting leads to some double counting.

The patent numbers generally have increased between 2000 and 2007, including an increase in share of Host-Country Patents, followed by a small decline. Overall the number of patents has only slightly increased over the whole observation period 2000 to 2015. In 2015 the share of HCPs was at around 19%, meaning that almost every fifth patent by a US applicant had a foreign, i.e. non-US based inventor.

[280] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 4-5: Total and Host-Country Patent Shares for US Applicants by IPC[281]

	Share of US Applicants in Worldwide Patents (%)		Share of HCPs to all patents of US Applicants (%)	
IPC Class	**2000**	**2015**	**2000**	**2015**
A61: Medical	43.4	37.2	16.5	17.0
G06: Computing	39.9	36.1	19.9	18.5
H04: Electric Communication	31.8	27.5	18.9	20.3
G01: Measuring	37.9	28.0	14.4	15.2
C07: Chemistry	42.0	35.1	17.8	18.7
H01: Electric Elements	27.2	20.6	16.1	19.1
C08: Organic Compounds	31.1	23.7	23.6	29.9
C12: Biochemistry	48.2	39.6	16.0	12.3
C09: Paints	33.6	25.4	17.5	28.2
B01: Processes	33.1	27.9	15.6	19.5

Medical, Chemistry, Organic Compounds and Biochemistry are relevant IPC classes, although the number of HCPs has decreased over the years, as well as the worldwide share of HCPs in their respective technological field.

Technical categories, such as Computing, Electric Communication, Electric Elements are the second big group of technological fields. Here, we can partly see an increase between 2000 and 2015 in HCPs, i.e. a positive CAGR, although, again, the share of worldwide HCPs decreases between 2000 and 2015.

Measuring is a rather broad field in the section G (Physics) and also characterized by decreased in HCPs and shares.

Overall, we can observe that the HCP-numbers in the major technological fields have decreased between 2000 and 2015 and furthermore the worldwide shares of HCP in the respective fields have decreased. That means, for these major fields other firms based in countries have increased their number of patents, whereas the dominant economy USA has somewhat lost in relative relevance. The internationalization rate, i.e. the share of host-country

[281] Source: Own analysis, based on REGPAT database by the OECD (2020h).

patents to all patents by US applicants across technological fields has generally not changed much, indicating that there has not been drastic new internationalization effects.

4.2.2. Germany Outward Host-Country Patents

This part summarizes the outward international patenting activities of German firms. We look at patents filed for by multinational firms based in Germany and look at host-country patents, i.e. patents with a non-Germany based inventor. As shown in Table 4-1, Germany, a major European economy, is the country with the second most HCPs in the latest 2015-2017 period.

Table 4-6: Development of German Outward Host-Country Patents[282]

Outward Host-Country Patents, Germany		**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	***CAGR ’00-’17 (%)***	***Share HCPs ’15-’17 (%)***
Total Patents		41,776	53,606	55,164	56,092	*2.0*	-
Total Host-Country Patents		7,054	9,815	10,715	10,709	*2.8*	-
Share Host-Country Patents (%)		*16.9*	*18.3*	*19.4*	*19.1*	-	-
HCPs with Inventors in: Developed Countries	United States	2,328	2,366	3,021	3,157	*1.3*	*29.5*
	France	729	899	1,103	1,101	*2.8*	*10.3*
	Austria	817	879	772	931	*0.9*	*8.7*
	Switzerland	580	904	778	806	*1.5*	*7.5*
	United Kingdom	522	678	828	668	*1.8*	*6.2*
	Japan	317	332	341	432	*3.5*	*4*
	Italy	192	283	314	380	*3.1*	*3.5*
	Netherlands	433	1387	918	358	*-0.4*	*3.3*
	Spain	181	318	229	300	*2.9*	*2.8*
	Belgium	311	371	372	277	*-0.1*	*2.6*
HCPs with Inventors in: Emerging Countries	China	63	377	844	890	*18.0*	*8.3*
	India	42	96	239	242	*10.7*	*2.3*
	Hungary	42	77	109	215	*9.3*	*2*
	Malaysia	20	44	54	139	*12.5*	*1.3*
	Czech Republic	34	77	89	129	*10.2*	*1.2*
	Brazil	29	98	150	125	*13.2*	*1.2*
	Singapore	86	125	138	107	*4.2*	*1*
	South Korea	15	58	82	101	*15.9*	*0.9*
	Romania	5	15	60	95	*19.9*	*0.9*
	Russia	102	96	155	91	*0.4*	*0.8*

German firms overall have increased their rate of HCPs to 19.1%, from 16.9% in the 2000-2002 period. That means, almost every fifth patent in the latest 2015-2017 period having an international (co-)inventor. The number of HCPs has increased from 7,054 to 10,709 from the 2000-2002 to 2015-2017 period.

[282] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

German firms are heavily patenting with inventors based in the US: almost one third of all HCPs in the 2015-2017 period are achieved there. France follows with 10%, Germany's close neighbor and political ally, and other European countries. 8% of all HCPs have a (co-)inventor based in China.

China and other emerging countries, such as India, Hungary or Malaysia, have gained strongly as a partner for German HCPs. China is the strongest growth country for Germany, but accounts for only 8% of all German HCPs in the 2015-2017 period. Several European neighbors, as well as Japan have also increased the number of HCPs above average, but only slightly above the average of 2.8%.[283]

[283] The CAGR of Total HCPs is 2.76%, and of France 2.83%. France therefore has grown above average, even though rounding to one digit equals both figures.

Host-Country Patents by Technological Field

Table 4-7: Host-Country Patent Breakdown for German Applicants by IPC[284]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	22,036	24,259	22,799	21,837	-0.1
Total Host-Country Patents	3,104	4,185	4,316	3,909	1.5
Share Host-Country Patents (%)	*14.1*	*17.3*	*18.9*	*17.9*	-
A61: Medical	587	665	561	488	-1.2
G01: Measuring	377	352	423	355	-0.4
H01: Electric Elements	367	327	485	336	-0.6
C07: Chemistry	457	375	317	288	-3.0
B60: Vehicles	233	325	224	250	0.5
G06: Computing	164	275	225	250	2.9
F16: Engineering Elements	119	274	259	234	4.6
C08: Organic Compounds	207	248	280	231	0.7
H04: Electric Communication	238	231	163	193	-1.4
C09: Paints	168	155	227	187	0.7

Note: Full-counting leads to some double counting.

The number of HCPs by German applicants has grown between 2000 and 2012 and then slightly dropped until 2015. In many technological fields we see a peak in patent numbers until 2007, followed by (slight) drops. The Host-Country Patent share is 18% in 2018, meaning that almost every fifth patent by a German firm (applicant) has at least one non-Germany based inventor. Among the leading technological fields in terms of HCPs are Medical, Chemistry and Organic Compounds, which, except for the latter, have decreased in HCP-number over the years and also lost in share of worldwide HCPs.

284 Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 4-8: Total and Host-Country Patent Shares for German Applicants by IPC[285]

	Share of DE Applicants in Worldwide Patents (%)		Share of HCPs to all patents of DE Applicants (%)	
IPC Class	**2000**	**2015**	**2000**	**2015**
A61: Medical	12.0	9.7	25.1	22.5
G01: Measuring	18.8	16.1	17.9	17.8
H01: Electric Elements	17.2	14.1	17.7	20.9
C07: Chemistry	14.9	11.7	27.6	31.9
B60: Vehicles	34.4	24.5	12.5	14.5
G06: Computing	8.5	6.9	16.6	22.8
F16: Engineering Elements	28.2	25.0	8.0	14.2
C08: Organic Compounds	20.4	14.2	18.2	29.4
H04: Electric Communication	9.9	4.8	15.4	21.3
C09: Paints	22.1	17.2	22.7	32.0

Vehicles, a technological field closely connected to one of Germany's leading industries, is one of the few fields with a positive CAGR, although the former dominance in worldwide HCP share of 34% in 2000 has dropped to 25% in 2015. This figure is nevertheless strong and indicates that around every fourth patent in the Vehicles field comes from a German applicant. Engineering Elements is another strong field, which has even increased over the years with a strong CAGR of 4.6% and strong, yet decreasing worldwide share from 28% in 2000 to 25% in 2015. This field can be partly linked to the German Automotive Industry, but also other industries. As outlined before, please note, that there a technological field (IPC class) and industry can only be indirectly linked.

Computing is another field with a positive CAGR, although the worldwide share nevertheless still slightly decreases to 7% in 2015. For many technological fields we can observe strong increases in the share of host-country patents to all patents, meaning that the share of international patents has increased. The most internationalized technological fields are Chemistry with 32% and Organic Compounds with 29% in 2015. That means that almost every third patent by a German multinational corporation (applicant), has a non-Germany based inventor listed on the patent. Medical, an already rather internationalized field shows a slight decrease. Once again, it shall be noted that a decrease in internationalization share only

[285] Source: Own analysis, based on REGPAT database by the OECD (2020h).

shows the relative decrease. It could be possible that the number of national patents simply grows at a higher rate than the rate of international or host-country patents, as extensively discussed with the case of China. In this situation, however, we see with the decrease in absolute numbers in Table 4-7, that Medical is indeed a shrinking field in terms of patent numbers for German applicants.

4.2.3. Switzerland Outward Host-Country Patents

This part summarizes the outward international patenting activities of Swiss firms. We look at patents filed for by multinational firms based in Switzerland and look at host-country patents, i.e. patents with a non-Switzerland based inventor. As shown in Table 4-1, Switzerland, the small innovation-driven country in the Alps, is the country with the third most HCPs in the latest 2015-2017 period and a substantial HCP-share.

Table 4-9: Development of Switzerland Outward Host-Country Patents[286]

		Outward Host-Country Patents, Switzerland	2000-2002	2006-2008	2011-2013	2015-2017	*CAGR '00-'17 (%)*	*Share HCPs '15-'17 (%)*
Total Patents			8,355	12,491	13,647	13,645	*3.3*	-
Total Host-Country Patents			5,104	8,227	8,861	8,507	*3.4*	-
Share Host-Country Patents (%)			*61.1*	*65.9*	*64.9*	*62.3*	-	-
HCPs with Inventors in	Developed Countries	United States	1,812	2,607	2,542	2,327	*2.0*	*27.4*
		Germany	1,391	2,301	2,231	2,221	*3.5*	*26.1*
		France	971	1,434	1,645	1,021	*-0.4*	*12*
		Sweden	260	503	652	722	*5.0*	*8.5*
		United Kingdom	369	547	602	687	*5.7*	*8.1*
		Italy	205	345	362	473	*4.5*	*5.6*
		Austria	160	334	305	274	*3.5*	*3.2*
		Netherlands	97	148	169	175	*2.1*	*2.1*
		Canada	79	153	148	161	*6.1*	*1.9*
		Japan	138	127	147	132	*-0.9*	*1.6*
	Emerging Countries	China	31	144	326	440	*27.0*	*5.2*
		India	11	104	220	244	*20.8*	*2.9*
		Russia	22	38	60	75	*2.0*	*0.9*
		Singapore	14	33	69	62	*10.7*	*0.7*
		Czech Republic	11	26	42	59	*12.1*	*0.7*
		Poland	11	25	88	57	*9.9*	*0.7*
		Brazil	14	25	46	44	*11.1*	*0.5*
		Israel	21	103	45	44	*7.8*	*0.5*
		Liechtenstein	12	31	26	26	*15.7*	*0.3*
		Chinese Taipei	7	7	15	23	*5.3*	*0.3*

The small country of Switzerland has a highly internationalized patent portfolio with almost two thirds of the patents having at least one international (co-)inventor. The very international Swiss firms conduct R&D globally and have over 50% of their patents with at least one US or

286 Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

German (co-)inventor. China and India are the drivers for the emerging countries, whereas their absolute HCP number does not (yet) play a major role.

Swiss firms focus their R&D Internationalization on very few countries: around 50% of all HCPs have a US and / or German (co-)inventor. Emerging countries, such as China or India do not play a major role in the 2015-2017 period, as both countries have a rather small share of all HCPs.

Germany, Switzerland's second-biggest host-country, has grown slightly above average, underlining the strong ties between the two neighboring countries. The emerging countries China and India, while still accounting for a relatively small share of Swiss HCPs, have grown particularly strong with a two-digit CAGR. Other uprising host-countries are mostly in Europe. The strong growth in UK might be attributable to activities by Swiss pharmaceutical companies. Outside of Europe, Canada has gained in attractiveness with a CAGR of 6%. To some degree Canada might be a substitute for activities in the US, as Canada's southern neighbor has grown with a meager 2% CAGR.

Host-Country Patents by Technological Field

Table 4-10: Host-Country Patent Breakdown for Swiss Applicants by IPC[287]

IPC Class	Number of HCPs per Priority Year				CAGR '00-'15 (%)
	2000	2007	2012	2015	
Total Patents	4,020	5,570	5,679	5,667	2.3
Total Host-Country Patents	2,029	3,371	3,407	3,242	3.2
Share Host-Country Patents (%)	*50.5*	*60.5*	*60.0*	*57.2*	-
A61: Medical	669	1,231	760	672	0.0
G01: Measuring	228	382	432	362	3.1
C07: Chemistry	415	508	443	333	-1.5
H02: Electric Power	61	100	218	279	10.7
B65: Packing	127	160	176	209	3.4
H01: Electric Elements	80	167	237	208	6.6
G06: Computing	72	194	162	172	6.0
C12: Biochemistry	200	224	176	159	-1.5
B01: Processes	98	118	171	139	2.4
H04: Electric Communication	58	99	175	127	5.4

Note: Full-counting leads to some double counting.

The small country of Switzerland has naturally a comparably high share of HCPs, which increased until 2007 and fallen since to the rate of 57% in 2015. That means that more than every second patent by a Swiss applicant or firm has a non-Switzerland based inventor. With strong internationalization activities, Swiss firms have increased their shares in worldwide HCPs in almost all leading technological fields listed above between 2000 and 2015.

[287] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 4-11: Total and Host-Country Patent Shares for Swiss Applicants by IPC[288]

	Share of CH Applicants in Worldwide Patents (%)		Share of HCPs to all patents of CH Applicants (%)	
IPC Class	**2000**	**2015**	**2000**	**2015**
A61: Medical	4.8	4.7	70.9	64.3
G01: Measuring	3.8	4.9	53.4	59.2
C07: Chemistry	4.7	6.2	80.0	69.4
H02: Electric Power	3.9	7.4	53.0	71.7
B65: Packing	6.2	7.9	47.0	63.0
H01: Electric Elements	2.0	3.0	32.9	60.5
G06: Computing	1.8	1.7	34.4	65.2
C12: Biochemistry	3.3	4.1	81.0	76.8
B01: Processes	3.4	4.7	57.6	66.8
H04: Electric Communication	1.3	1.2	28.4	57.7

The usually quite internationalized fields of Medical, Chemistry and Biochemistry show a comparably small dynamic: these fields have been more or less continuously strong. The very high rate of host-country patents to total patents, i.e. the patent internationalization rate, has decreased until 2015, yet remains at high levels. For these fields we also observe a small decrease in absolute HCP numbers. Other classes in the technological field show a more dynamic development, namely Electric Power, Electric Elements and Computing with significant increases, both in terms of HCP-numbers, as well as worldwide shares. Packing is a rather unusual leading field, related and linked to logistics activities.

The internationalization rate is unsurprisingly high for the small country of Switzerland in many fields. In the technical fields of Electric Elements and Computing this rate almost doubles from 33% and 34% respectively in 2000 to 60% and 65% in 2015, indicating a high dynamic in internationalization. In Electric Communication we see an increase from 28% to 58%.

4.2.4. France Outward Host-Country Patents

This part summarizes the outward international patenting activities of French firms. We look at patents filed for by multinational firms based in France and look at host-country patents, i.e. patents with a non-France based inventor. As shown in Table 4-1, France, next to Germany,

[288] Source: Own analysis, based on REGPAT database by the OECD (2020h).

another major European economy, is the country with the fourth most HCPs in the latest 2015-2017 period.

Table 4-12: Development of France Outward Host-Country Patents[289]

Outward Host-Country Patents, France			**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	***CAGR '00-'17 (%)***	***Share HCPs '15-'17 (%)***
Total Patents			14,752	21,820	26,011	24,599	*3.0*	-
Total Host-Country Patents			3,010	5,726	6,846	5,607	*4.3*	-
Share Host-Country Patents (%)			*20.4*	*26.2*	*26.3*	*22.8*	*-*	-
HCPs with Inventors in	Developed Countries	United States	1,482	2,536	2,896	2,167	*3.2*	*38.6*
		Germany	432	888	883	792	*4.2*	*14.1*
		United Kingdom	248	525	665	440	*1.6*	*7.8*
		Japan	111	209	310	411	*10.0*	*7.3*
		Belgium	143	347	416	291	*3.0*	*5.2*
		Italy	197	182	163	204	*0.1*	*3.6*
		Switzerland	99	167	191	191	*5.6*	*3.4*
		Canada	83	274	253	154	*3.8*	*2.7*
		Spain	71	128	154	114	*4.2*	*2*
		Netherlands	65	118	146	78	*-2.9*	*1.4*
	Emerging Countries	China	26	405	734	588	*19.5*	*10.5*
		India	18	56	134	123	*19.9*	*2.2*
		Singapore	21	40	64	91	*7.0*	*1.6*
		Brazil	16	25	86	87	*12.1*	*1.6*
		Russia	22	115	98	71	*13.0*	*1.3*
		Poland	10	14	27	45	*11.6*	*0.8*
		Korea	6	19	40	45	*12.6*	*0.8*
		Saudi Arabia	2	9	34	33	*13.7*	*0.6*
		Hong Kong - China	4	13	26	31	*11.1*	*0.6*
		Israel	9	19	25	26	*7.9*	*0.5*

France's patents are relatively internationalized with a share of HCPs of over 20%. The rate has increased from 20% to 23% in the time periods 2000-2002 to 2015-2017. The absolute

289 Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

number of HCPs in the same periods has increased from 3,010 to 5,607. By far the biggest partner is the US, followed by France's close European neighbors Germany and the UK.

French firms are strongly focusing their international patents on the US: Almost 40% of all HCPs have a (co-)inventor based in the US, followed by France's neighbor Germany with 14%. China and India are the two relevant emerging countries in which French firms have patent inventors located. Other countries include select European neighbors, Japan and Canada.

Unsurprisingly, the emerging countries have strongly gained in relative importance, once again particularly through China and India, whose CAGR is respectively at almost 20%. Brazil and Russia are two other emerging countries which have increased strongly in relative importance, although their absolute share in HCPs is rather small.

Host-Country Patents by Technological Field

Table 4-13: Host-Country Patent Breakdown for French Applicants by IPC[290]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	7,387	9,047	9,673	9,738	1.9
Total Host-Country Patents	1,556	2,172	2,418	1,959	1.5
Share Host-Country Patents (%)	*21.1*	*24.0*	*25.0*	*20.1*	-
H04: Electric Communication	402	605	665	355	-0.8
A61: Medical	230	275	245	277	1.2
G06: Computing	127	141	254	215	3.6
G01: Measuring	87	159	175	155	3.9
B60: Vehicles	121	149	179	148	1.4
H01: Electric Elements	185	153	201	131	-2.3
C07: Chemistry	147	190	135	122	-1.2
E21: Mining	23	115	105	83	8.9
F16: Engineering Elements	56	58	59	75	2.0
C08: Organic Compounds	104	82	118	74	-2.2

Note: Full-counting leads to some double counting.

The share of France's Host-Country Patents has increased between 2000 and 2012 to 25% and then dropped to 20% in 2015. In fact, for many technological fields we can observe drops in HCP-numbers between 2012 and 2015. About every fifth patent, a figure comparable to that of the US and Germany, of a French applicant or firm has at least one foreign-based inventor. Medical and Chemistry have undergone only smaller changes in HCP-numbers, but the share of worldwide HCPs has increased between 2000 and 2015.

[290] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 4-14: Total and Host-Country Patent Shares for French Applicants by IPC[291]

IPC Class	Share of FR Applicants in Worldwide Patents (%)		Share of HCPs to all patents of FR Applicants (%)	
	2000	2015	2000	2015
H04: Electric Communication	6.9	6.5	37.5	29.3
A61: Medical	5.6	5.1	21.0	24.3
G06: Computing	4.7	6.5	23.3	20.8
G01: Measuring	5.0	7.1	15.6	17.6
B60: Vehicles	8.9	12.7	24.9	16.6
H01: Electric Elements	5.5	6.6	28.0	17.5
C07: Chemistry	4.5	5.2	29.2	30.2
E21: Mining	7.3	10.9	48.9	65.4
F16: Engineering Elements	6.4	7.2	16.6	15.8
C08: Organic Compounds	5.9	5.8	31.3	22.9

Vehicles, a field of a strong French industry has lost in share of worldwide HCPs, whereas Mining, another less common technological field is one of the uprising fields and with a worldwide share of HCPs of 29% in 2015 clearly dominated by French applicants or firms. For the technological fields we see a mixed picture, the strongest field Electric Communication has dropped in numbers and share, as well as the related Electric Elements, whereas Computing has gained in HCPs, despite the 2012 to 2015 drop, and share in worldwide HCPs.

[291] Source: Own analysis, based on REGPAT database by the OECD (2020h).

4.2.5. Japan Outward Host-Country Patents

This part summarizes the outward international patenting activities of Japanese firms. We look at patents filed for by multinational firms based in Japan and look at host-country patents, i.e. patents with a non-Japan based inventor. As shown in Table 4-1, Japan, is the country with the fifth most HCPs in the latest 2015-2017 period.

Table 4-15: Development of Japanese Outward Host-Country Patents[292]

Outward Host-Country Patents, Japan			**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	***CAGR ’00-’17 (%)***	***Share HCPs ’15-’17 (%)***
Total Patents			37,929	84,218	128,058	139,258	*9.2*	-
Total Host-Country Patents			1,979	3,000	4,122	5,510	*7.2*	-
Share Host-Country Patents (%)			*5.2*	*3.6*	*3.2*	*4.0*	-	-
HCPs with Inventors in	Developed Countries	United States	1,213	1,616	1,636	1,782	*2.8*	*32.3*
		United Kingdom	134	262	466	518	*7.9*	*9.4*
		Germany	193	305	383	438	*8.7*	*7.9*
		Sweden	27	32	110	309	*8.8*	*5.6*
		France	57	140	168	281	*10.0*	*5.1*
		Italy	17	33	75	88	*11.8*	*1.6*
		Switzerland	19	35	31	85	*11.9*	*1.5*
		Netherlands	47	21	45	75	*6.2*	*1.4*
		Belgium	22	36	84	69	*8.5*	*1.3*
		Australia	24	44	66	57	*4.7*	*1*
	Emerging Countries	China	50	119	638	1,231	*23.1*	*22.3*
		South Korea	52	124	155	199	*13.9*	*3.6*
		Thailand	4	34	66	109	*21.4*	*2*
		Singapore	49	95	102	108	*19.6*	*2*
		Chinese Taipei	26	17	34	98	*10.5*	*1.8*
		India	3	7	32	76	*21.4*	*1.4*
		Malaysia	1	7	12	21	*17.3*	*0.4*
		Turkey	0	3	4	16	-	*0.3*
		Hong Kong - China	1	6	15	10	*9.9*	*0.2*
		Poland	17	2	12	10	*0.0*	*0.2*

Japanese MNC have increased the number of PCT patents with foreign inventors from 1,979 to 5,510 between the period 2000-2002 to 2015-2017.

Japanese firms patent very little with international activities: only 4% of the sizeable amount of 139,258 patents in the 2015-2017 period had an international (co-)inventor. This share has decreased from 5.2% in the 2000-2002 period. In the periods in between, we can observe a major decline in the share of HCPs: in the period 2006-2008 the share was 3.6%, and in 2011-2013 it was 3.2%. Therefore, in the last period, we actually observe an increase in share of foreign inventorship.

Over half of these international HCPs can be attributed to either the US or, since recently, China. Other countries follow at a large distance and include select European countries and Asian neighbors.

The largest relative increase in HCPs can be observed for (co-)inventors from China and Singapore with a CAGR of around 20%. South Korea follows at 14%. European developed countries follow at a distance, although we also here can observe relatively high growth rates, namely France, Sweden, Germany and UK.

[292] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

Host-Country Patents by Technological Field

Table 4-16: Host-Country Patent Breakdown for Japanese Applicants by IPC[293]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	22,275	22,096	21,995	20,774	-0.5
Total Host-Country Patents	904	1,252	1,104	1,255	2.2
Share Host-Country Patents (%)	*4.1*	*5.7*	*5.0*	*6.0*	-
H04: Electric Communication	198	457	396	478	6.1
G06: Computing	174	182	153	194	0.7
A61: Medical	144	142	107	125	-0.9
H01: Electric Elements	151	113	70	91	-3.3
G01: Measuring	67	94	77	86	1.7
C08: Organic Compounds	83	68	91	74	-0.8
C07: Chemistry	138	101	68	69	-4.5
D06: Textile Treatment	2	1	0	54	24.6
C09: Paints	46	41	38	46	0.0
F16: Engineering Elements	33	26	28	41	1.5

Note: Full-counting leads to some double counting.

Japanese firms have increased their numbers of HCPs, despite a drop, both in total number and in many technological fields, between 2012 and 2015. The share of HCPs, while still comparably low has increased to 6% in 2015, meaning that only relatively few patents by Japanese applicants have a foreign (co-)inventor.

[293] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 4-17: Total and Host-Country Patent Shares for Japanese Applicants by IPC[294]

	Share of JP Applicants in Worldwide Patents (%)		Share of HCPs to all patents of JP Applicants (%)	
IPC Class	**2000**	**2015**	**2000**	**2015**
H04: Electric Communication	23.6	13.9	5.4	18.3
G06: Computing	24.2	13.1	6.2	9.3
A61: Medical	9.9	10.3	7.4	5.4
H01: Electric Elements	33.2	24.4	3.8	3.3
G01: Measuring	15.1	15.0	4.0	4.6
C08: Organic Compounds	23.8	28.9	6.3	4.6
C07: Chemistry	12.6	9.9	9.8	9.0
D06: Textile Treatment	12.0	13.8	1.5	37.5
C09: Paints	24.8	27.1	5.5	5.0
F16: Engineering Elements	22.1	17.8	2.8	3.5

The clearly leading technological field is Electric Communication, with a strong CAGR of 6% and a big gap to the second-biggest technological field. The international share of Japanese applicants in this field, however, drops from 24% in 2000 to 14% in 2015. The somewhat related fields of Electric Elements and Computing have developed rather modestly with a similar decrease in worldwide share between 2000 and 2015.

Medical, Chemistry and Organic Compounds do not play a major role in terms of HCPs for Japanese firms, with a negative CAGR between 2000 and 2015. The share of Japanese applicants in this fields, however, increased partially: in 2015 29% of all patents in Organic Compounds came from a Japanese applicant. In the related field of paints, that share was 27%. This means that more than every fourth patent in these fields comes from a Japanese firm.

Measuring is a rather broad field in the section G for Physics. The strong increase of Textile Treatment particularly between 2012 and 2015 leads to the assumption that this effect is attributable to a small number of firms.

294 Source: Own analysis, based on REGPAT database by the OECD (2020h).

4.2.6. China Outward Host-Country Patents

This part summarizes the outward international patenting activities of Chinese firms. As shown in Table 4-1, China is the country with the sixth most HCPs in the latest 2015-2017 period and the only emerging country in this overview. As shown repeatedly in this dissertation, China has a special status of all emerging countries, as it has transformed and overtaken many developed economies in several aspects.[295]

[295] Cf. Zhou and Leydesdorff (2006).

Table 4-18: Development of Chinese Outward Host-Country Patents[296]

Outward Host-Country Patents, China		**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	***CAGR '00-'17 (%)***	***Share HCPs '15-'17 (%)***
Total Patents		2,980	15,795	54,913	119,874	*23.2*	-
Total Host-Country Patents		155	995	2,777	5,143	*25.0*	-
Share Host-Country Patents (%)		*5.2*	*6.3*	*5.1*	*4.3*	-	-
HCPs with Inventors in: Developed Countries	United States	62	536	1,385	1,761	*23.0*	*34.2*
	Canada	6	28	269	913	*33.3*	*17.8*
	Germany	2	38	227	726	*34.2*	*14.1*
	Japan	14	63	121	381	*24.0*	*7.4*
	Sweden	7	53	133	372	*29.5*	*7.2*
	United Kingdom	9	40	57	97	*24.9*	*1.9*
	Australia	2	28	45	84	*18.1*	*1.6*
	France	8	21	61	65	*11.7*	*1.3*
	Italy	2	11	26	33	*10.5*	*0.6*
	Austria	0	4	2	28	-	*0.5*
HCPs with Inventors in: Emerging Countries	Hong Kong - China	15	55	174	300	*18.0*	*5.8*
	Chinese Taipei	3	61	184	262	*32.7*	*5.1*
	India	0	9	25	59	-	*1.1*
	Singapore	4	6	34	52	*17.3*	*1*
	South Korea	18	43	56	47	*16.3*	*0.9*
	Russia	2	0	8	20	*13.8*	*0.4*
	Israel	0	6	6	17	-	*0.3*
	Malaysia	0	4	6	7	-	*0.1*
	Poland	0	0	12	6	-	*0.1*
	United Arab Emirates	0	1	0	4	-	*0.1*

As an emerging country, China has strongly grown its patent numbers in the last decades. Overall the share of HCPs is quite low and has decreased.[297] As China has recently only

[296] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

[297] The CAGR of HCPs is higher than that of Total Patents, as the CAGRs are calculated in single years, i.e. from 2000 to 2017 and are therefore more subject to outlying years. The "Share Host-Country Patents (%)" is calculated on the shown three-year aggregates.

gained competencies and capabilities and is a very large economy, it comes as little surprise that outward innovation strategies are not particularly visible on the aggregate level. Certain companies, particularly well-known industry-leaders can have a different strategy and patent strongly with foreign research activities.

Overall the strongest partner for China is the US, with around 34% of all HCPs in the period 2015-2017. Canada, the neighbor of the US, Germany and Japan, which are other strong economies, follow. Hong Kong and Taipei are somewhat connected to China, but are listed as separate entities by OECD standard. We can see that Chinese internationalization is very selective in a small number of developed countries.

While the US is the by far most relevant host-country for China, other countries have particularly grown, most notably Germany with a CAGR of 34%. Canada follows with 33%. This increase can be particularly attributed to growth in the last years and might indicate a slight shift in focus away from the US, and towards its northern neighbor Canada.

Host-Country Patents by Technological Field

Table 4-19: Host-Country Patent Breakdown for Chinese Applicants by IPC[298]

IPC Class	Number of HCPs per Priority Year				CAGR '00-'15 (%)
	2000	2007	2012	2015	
Total Patents	140	1,892	5,225	7,591	30.5
Total Host-Country Patents	36	208	558	935	24.3
Share Host-Country Patents (%)	*25.7*	*11.0*	*10.7*	*12.3*	-
H04: Electric Communication	4	103	267	395	35.8
G06: Computing	2	19	44	146	33.1
A61: Medical	9	15	43	95	17.0
H01: Electric Elements	12	10	56	87	14.1
D06: Textile Treatment	0	4	1	58	-
H03: Electronic Circuitry	0	2	17	51	-
C07: Chemistry	3	11	36	47	20.1
G02: Optics	1	5	19	29	25.2
B60: Vehicles	0	2	9	23	-
C12: Biochemistry	2	3	7	23	17.2

Note: Full-counting leads to some double counting.

China, an emerging economy which has grown in the last years to become an economic power itself, has undergone highly dynamic developments in its Patent and Host-Country Patent (HCP) numbers. It not only is a destination for foreign R&D and patenting activities, but also patents strongly itself. Both the numbers of total patents and HCPs have grown strongly with a two-digit CAGR, but since domestic activities have grown even stronger, the share of HCPs has decreased, although only until 2012 and then increased to 12% in 2015.

[298] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 4-20: Total and Host-Country Patent Shares for Chinese Applicants by IPC[299]

	Share of CN Applicants in Worldwide Patents (%)		Share of HCPs to all patents of CN Applicants (%)	
IPC Class	**2000**	**2015**	**2000**	**2015**
H04: Electric Communication	0.2	15.3	11.1	13.8
G06: Computing	0.1	8.5	25.0	10.8
A61: Medical	0.2	3.5	25.7	12.1
H01: Electric Elements	0.2	6.0	63.2	12.8
D06: Textile Treatment	0.0	18.0	-	30.9
H03: Electronic Circuitry	0.3	8.4	0.0	40.8
C07: Chemistry	0.2	5.3	15.0	11.5
G02: Optics	0.0	7.7	100	9.3
B60: Vehicles	0.0	1.9	0.0	17.2
C12: Biochemistry	0.2	3.4	16.7	13.1

The, by far, leading technological field in terms of HCP is Electric Communication, which accounts in 2015 for 15% of worldwide patents. Related fields such as Computing, Electric Elements and Electronic Circuitry also rank highly. The usual Medical and Chemistry have significant HCP-numbers in 2015, although their share of worldwide patents is at 4% and 5% respectively. Other and less common fields include Textile Treatment, with a particular strong increase in HCPs between 2012 and 2015 and a high global share in patents and Optics.

We can see how Chinese firms internationalize their R&D, particularly in the technological fields, with significant numbers of HCPs and noticeable shares of worldwide patents.

4.2.7. Netherlands Outward Host-Country Patents

This part summarizes the outward international patenting activities of Dutch firms. We look at patents filed for by multinational firms based in the Netherlands and look at host-country patents, i.e. patents with a non-Netherlands based inventor. As shown in Table 4-1, the Netherlands, a smaller, but international European economy, is the country with the seventh most HCPs in the latest 2015-2017 period.

[299] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 4-21: Development of Dutch Outward Host-Country Patents[300]

Outward Host-Country Patents, Netherlands			2000-2002	2006-2008	2011-2013	2015-2017	*CAGR '00-'17 (%)*	*Share HCPs '15-'17 (%)*
Total Patents			12,320	15,247	13,813	14,088	*0.9*	-
Total Host-Country Patents			4,106	6,523	5,045	5,097	*1.7*	-
Share Host-Country Patents (%)			*33.3*	*42.8*	*36.5*	*36.2*	-	-
HCPs with Inventors in	Developed Countries	United States	1,565	2,847	2,149	2,086	*1.5*	*40.9*
		United Kingdom	882	1,319	887	710	*-2.2*	*13.9*
		Germany	653	751	524	603	*1.2*	*11.8*
		Switzerland	97	223	255	218	*8.8*	*4.3*
		France	371	484	366	189	*-4.3*	*3.7*
		Belgium	179	212	163	122	*-2.7*	*2.4*
		Italy	101	137	117	104	*-3.6*	*2*
		Spain	36	56	92	99	*4.4*	*1.9*
		Norway	19	142	78	87	*7.5*	*1.7*
		Sweden	106	94	123	86	*-1.7*	*1.7*
	Emerging Countries	India	84	207	285	372	*13.3*	*7.3*
		Saudi Arabia	2	10	51	343	*34.2*	*6.7*
		Israel	49	38	92	261	*9.6*	*5.1*
		China	41	223	279	260	*23.5*	*5.1*
		Russia	25	138	94	73	*6.7*	*1.4*
		Singapore	5	44	34	51	*13.8*	*1*
		South Korea	4	8	14	46	*5.9*	*0.9*
		Malaysia	4	35	34	23	*8.5*	*0.5*
		Ukraine	7	7	5	23	*7.8*	*0.5*
		Brazil	25	29	49	20	*-1.3*	*0.4*

Dutch companies have increased their share of patents with international (co-)inventors from 33% to 36% from the period 2000-2002 to 2015-2017. In this time periods the number of HCPs has increased from 4,106 to 5,067. In 2006-2008 the share of HCPs was even higher at 43%.

[300] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

Dutch firms are clearly targeting the US as a location for R&D: 41% of all international patents have at least one US-based (co-)inventor. Furthermore, the UK and Germany are two developed countries with significant shares in Dutch HCPs. From the emerging countries we see certain differences compared to HCP internationalization patterns of other countries: India has a higher share in HCPs than China, but also Saudi Arabia and Israel play a major role.

Overall the number of HCPs has grown at rather small rate. For several target countries, the number of HCPs has even decreased, resulting in a negative CAGR. Since the overall number of HCPs has changed only little, we can therefore argue for a shift away from several developed European countries towards emerging countries. Particularly Saudi Arabia has significantly increased in relative importance with a CAGR larger than 30%, now ranking fifth in the number of HCPs for the Netherlands. China and India follow with two-digit CAGRs as well. Other emerging countries such as Israel and Russia have strongly increased in relevance as well. However, we also see strong growth rates for certain European developed countries, such as Switzerland or Norway.

Host-Country Patents by Technological Field

Table 4-22: Host-Country Patent Breakdown for Dutch Applicants by IPC[301]

IPC Class	Number of HCPs per Priority Year				CAGR ’00-’15 (%)
	2000	**2007**	**2012**	**2015**	
Total Patents	4,225	4,497	4,340	4,732	0.8
Total Host-Country Patents	1,413	2,045	1,664	1,692	1.2
Share Host-Country Patents (%)	*33.4*	*45.5*	*38.3*	*35.8*	-
A61: Medical	245	311	243	203	-1.2
G01: Measuring	128	308	244	188	2.6
C08: Organic Compounds	108	137	151	174	3.2
C07: Chemistry	122	125	107	155	1.6
H01: Electric Elements	169	171	135	122	-2.1
H04: Electric Communication	194	201	119	120	-3.2
G06: Computing	111	168	141	103	-0.5
A23: Foods	89	127	118	95	0.4
B01: Processes	51	61	66	94	4.2
E21: Mining	42	110	114	85	4.8

Note: Full-counting leads to some double counting.

Between 2000 and 2015 we can generally observe only small changes in patent numbers, as the CAGR, both for the totals, as well as the respective technological fields, is rather low. In more detail, we can see that the patent numbers mostly strongly increase between 2000 and 2007 and then drop until 2015. This includes the share of Host-Country Patents which drops after an initial increase to 45% in 2007 to 36% in 2015. Therefore, approximately every third patent by a Dutch applicant or firm has a non-Dutch inventor in 2015.

301 Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 4-23: Total and Host-Country Patent Shares for Dutch Applicants by IPC[302]

IPC Class	Share of NL Applicants in Worldwide Patents (%)		Share of HCPs to all patents of NL Applicants (%)	
	2000	**2015**	**2000**	**2015**
A61: Medical	2.9	3.9	43.8	23.2
G01: Measuring	3.2	4.2	35.4	36.5
C08: Organic Compounds	3.7	5.4	52.7	58.0
C07: Chemistry	2.5	3.4	43.1	58.5
H01: Electric Elements	4.0	2.1	35.3	49.8
H04: Electric Communication	5.6	1.8	22.3	36.3
G06: Computing	4.5	2.8	21.1	23.6
A23: Foods	10.6	10.9	54.3	55.9
B01: Processes	3.1	4.1	32.9	52.2
E21: Mining	9.9	10.1	65.6	72.6

While Medical and Organic Compounds have decreased in HCP numbers, both fields, together with the related Chemistry have increased their worldwide share of patents.

The technological fields Electric Elements, Electric Communication and Computing have lost in absolute and relative relevance for HCPs, approximately halving the share in worldwide patents. Foods, a less common field is comparably relevant in terms of patent numbers, as it is one of the few fields with a double-digit share in worldwide patents for Dutch applicants. The Netherlands, comparable to the similarly small Switzerland, has quite high internationalization rates, i.e. the share of host-country to total patents is high and increasing for all technological fields. Mining (and the somewhat related Petroleum field not listed in the tables) is the most internationalized field with 73% of all patents, i.e. almost three out of four, by a Dutch firm having a non-Netherlands based inventor.

4.2.8. Sweden Outward Host-Country Patents

This part summarizes the outward international patenting activities of Swedish firms. We look at patents filed for by multinational firms based in Sweden and look at host-country patents, i.e. patents with a non-Sweden based inventor. As shown in Table 4-1, Sweden, a relevant

[302] Source: Own analysis, based on REGPAT database by the OECD (2020h).

economy from the Nordics, is the country with the eighth most HCPs in the latest 2015-2017 period.

Table 4-24: Development of Sweden Outward Host-Country Patents[303]

Outward Host-Country Patents, Sweden			2000-2002	2006-2008	2011-2013	2015-2017	*CAGR '00-'17 (%)*	*Share HCPs '15-'17 (%)*
Total Patents			8,766	10,912	11,132	11,262	*0.6*	-
Total Host-Country Patents			2,450	3,889	4,359	4,234	*2.7*	-
Share Host-Country Patents (%)			*27.9*	*35.6*	*39.2*	*37.6*	-	-
HCPs with Inventors in	Developed Countries	United States	571	1,090	924	956	*1.8*	*22.6*
		Germany	395	552	631	645	*3.2*	*15.2*
		Canada	136	215	384	389	*3.1*	*9.2*
		Finland	175	255	172	379	*4.8*	*9*
		Italy	101	197	339	294	*7.2*	*6.9*
		United Kingdom	471	442	264	213	*-4.9*	*5*
		France	126	221	254	195	*2.8*	*4.6*
		Spain	46	118	124	131	*9.1*	*3.1*
		Denmark	69	69	71	108	*0.6*	*2.6*
		Japan	49	123	147	104	*0.4*	*2.5*
	Emerging Countries	China	6	165	532	541	*39.5*	*12.8*
		India	9	19	101	164	*17.4*	*3.9*
		South Korea	6	2	204	115	*9.0*	*2.7*
		Hungary	30	126	132	104	*7.3*	*2.5*
		Brazil	4	17	44	37	*10.3*	*0.9*
		Poland	10	13	9	22	*3.3*	*0.5*
		Czech Republic	3	5	17	17	*11.1*	*0.4*
		Turkey	0	0	0	14	-	*0.3*
		Greece	5	3	8	11	*4.2*	*0.3*
		Liechtenstein	0	0	0	11	-	*0.3*

The relatively small country of Sweden has a very internationalized patent portfolio with more than every third patent having at least one international (co-)inventor. The rate of HCPs

[303] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

increased from 28% to 38% in the periods 2000-2002 to 2015-2017. In the same time the absolute number of HCPs increased from 2,450 to 4,234. The US are the biggest partner for Swedish HCPs, followed by Germany, Canada and Finland, a close neighbor to Sweden. China has particularly gained between the periods 2006-2008 and 2011-2013 and is far ahead of all other emerging countries.

The US has clearly the highest share of HCPs of all host countries for Sweden, although for the following countries, the distribution is relatively even. Other relevant developed countries include Germany and other European countries, as well as Canada. For the emerging countries, China accounts for 13% of all Swedish HCPs, and India for 4%.

The biggest increase in relative importance can be observed for the emerging countries China and India, with respectively two-digit growth rates. South Korea and Hungary, with absolutely smaller HCP numbers have grown with high shares, as well. For the developed countries the South-European countries Spain and Italy stand out, whereas other European countries, such as Germany, France or Finland, as well as Canada have grown slightly above average. With a CAGR of 1.8% HCPs in the US have clearly grown below average, indicating a shift away from the US, towards mostly European and some Asian emerging economies.

Host-Country Patents by Technological Field

Table 4-25: Host-Country Patent Breakdown for Swedish Applicants by IPC[304]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	2,658	3,346	3,886	3,446	1.7
Total Host-Country Patents	784	1,170	1,529	1,308	3.5
Share Host-Country Patents (%)	*29.5*	*35.0*	*39.3*	*38.0*	-
H04: Electric Communication	286	545	831	674	5.9
G06: Computing	53	77	100	94	3.9
B60: Vehicles	30	62	89	78	6.6
F16: Engineering Elements	26	68	160	75	7.3
A61: Medical	223	216	95	70	-7.4
D06: Textile Treatment	4	7	4	47	17.9
F24: Heating	5	8	11	43	15.4
G01: Measuring	57	50	95	37	-2.8
F02: Combustion Engines	6	6	16	27	10.5
F01: Machines	3	5	15	27	15.8

Note: Full-counting leads to some double counting.

For Sweden we can overall observe an increase in patent numbers until 2012, followed by a slight drop. The share of Host-Country Patents has developed in a similar pattern and increased from 29% in 2000 to 39% in 2012 and then decreased to 38% in 2015. That means that more than every third patent by a Swedish applicant has an inventor located abroad.

304 Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 4-26: Total and Host-Country Patent Shares for Swedish Applicants by IPC[305]

	Share of SE Applicants in Worldwide Patents (%)		Share of HCPs to all patents of SE Applicants (%)	
IPC Class	**2000**	**2015**	**2000**	**2015**
H04: Electric Communication	4.2	7.1	43.9	50.4
G06: Computing	1.8	1.6	24.9	37.5
B60: Vehicles	2.1	3.7	26.8	29.8
F16: Engineering Elements	2.7	3.2	18.2	35.2
A61: Medical	2.7	1.4	42.6	22.9
D06: Textile Treatment	0.7	5.4	50.0	83.9
F24: Heating	4.1	4.8	15.2	51.8
G01: Measuring	2.0	1.7	25.7	17.6
F02: Combustion Engines	1.6	2.7	12.5	35.1
F01: Machines	1.7	2.4	9.4	35.1

The usually quite strong fields of Medical and Chemistry are not particularly relevant for Swedish applicants. The former shows a particular negative CAGR and decrease in worldwide share in HCPs and while the latter is not shown here in this table, the pattern of development is quite similar. Instead other fields are more relevant for Swedish R&D Internationalization, most notably Electric Communication which always has been the technological field with the most HCPs across all periods and has a particular lead to the second-highest field. Furthermore, the Swedish share of worldwide patents has increased from 4% to 7% in 2015. The somewhat related technological field Computing ranks highly as well. Vehicles and the related field Engineering Elements have both grown with a strong CAGR and have increasing their respective share in worldwide patents. Textile Treatment and Heating are two additional and less common fields which rank highly for Swedish HCPs, including a comparably high share of host-country to total patents (internationalization rate), although the generally small number of HCPs decreases the robustness of such an analysis.

4.2.9. UK Outward Host-Country Patents

This part summarizes the outward international patenting activities of UK firms. We look at patents filed for by multinational firms based in the UK and look at host-country patents, i.e.

[305] Source: Own analysis, based on REGPAT database by the OECD (2020h).

patents with a non-UK based inventor. As shown in Table 4-1, the UK, a former member of the European Union, is the country with the ninth most HCPs in the latest 2015-2017 period.

Table 4-27: Development of UK Outward Host-Country Patents[306]

Outward Host-Country Patents, UK			**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	***CAGR '00-'17 (%)***	***Share HCPs '15-'17 (%)***
Total Patents			16,031	16,063	15,394	17,014	*0.0*	-
Total Host-Country Patents			3,255	3,186	3,328	3,721	*0.5*	-
Share Host-Country Patents (%)			*20.3*	*19.8*	*21.6*	*21.9*	-	-
HCPs with Inventors in	Developed Countries	United States	1,185	1,006	1,212	1,592	*0.6*	*42.8*
		Germany	261	289	281	378	*4.9*	*10.2*
		Netherlands	368	265	235	192	*-4.8*	*5.2*
		France	280	216	179	166	*-2.3*	*4.5*
		Italy	160	161	125	128	*-0.5*	*3.4*
		Switzerland	115	145	124	111	*0.3*	*3*
		Canada	88	113	137	103	*-4.0*	*2.8*
		Spain	54	90	72	94	*3.8*	*2.5*
		Sweden	90	108	65	84	*-1.5*	*2.3*
		Japan	69	60	65	76	*-0.3*	*2*
	Emerging Countries	India	79	190	216	261	*10.1*	*7*
		China	34	98	194	221	*15.2*	*5.9*
		Israel	78	75	65	52	*-2.2*	*1.4*
		Russia	45	32	43	41	*-2.4*	*1.1*
		South Africa	55	34	20	39	*-3.3*	*1*
		Hungary	5	7	14	35	*4.2*	*0.9*
		Saudi Arabia	2	2	9	27	*16.8*	*0.7*
		Singapore	15	33	35	26	*3.3*	*0.7*
		United Arab Emirates	2	12	28	19	*4.2*	*0.5*
		Brazil	22	26	20	18	*0.0*	*0.5*

[306] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

The number of UK total and Host-Country Patents has changed only slightly over the years, with a respective CAGR close to 0%. The share of HCPs has increased from 20% to 22% in the periods 2000-2002 to 2015-2017.

The most relevant country for UK HCPs is by far the US, with 43% of all UK HCPs having at least one US-based inventor. Other European countries and Canada follow. The only two somewhat relevant emerging countries are India and China. It is noteworthy, that unlike for most other countries, China is not the emerging country with the most HCPs, but the second-biggest. India, a country with a strong historical connection to UK has had more HCPs than China in every period.

For many countries we can observe a decrease in HCPs, i.e. we have a negative CAGR. Only few countries have relative patent numbers and a CAGR above average, i.e. larger than 0.5%. Most notably, we can see the two emerging countries China and India, with a respectively two-digit CAGR. From the developed countries Germany stands out with 5%, followed by Spain and the US, which only grew slightly above average.

Host-Country Patents by Technological Field

Table 4-28: Host-Country Patent Breakdown for UK Applicants by IPC[307]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR ’00-’15 (%)
Total Patents	5,085	4,743	4,448	5,001	-0.1
Total Host-Country Patents	1,164	1,075	1,022	1,226	0.3
Share Host-Country Patents (%)	*22.9*	*22.7*	*23.0*	*24.5*	-
A61: Medical	389	299	250	311	-1.5
C07: Chemistry	248	187	113	166	-2.6
H04: Electric Communication	110	97	93	117	0.4
G01: Measuring	114	81	83	103	-0.7
G06: Computing	82	88	65	87	0.4
H01: Electric Elements	57	36	67	71	1.5
C11: Oils	114	48	55	62	-4.0
A23: Foods	61	80	57	59	-0.2
B01: Processes	52	50	46	53	0.1
H02: Electric Power	8	14	25	44	12.0

Note: Full-counting leads to some double counting.

UK Patents and Host-Country Patents are characterized by a quite static development as very few CAGRs are even larger than 2%. With the UK we can observe a development diametral to what we have seen with several other countries: here the patent numbers mostly decrease between 2000 and 2012, only to increase slightly again for 2015. The share of HCPs has moved around a bit and increased to 25% in 2015, meaning that around every fourth patent by a UK applicant has a foreign-based inventor.

[307] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 4-29: Total and Host-Country Patent Shares for UK Applicants by IPC[308]

	Share of GB Applicants in Worldwide Patents (%)		**Share of HCPs to all patents of GB Applicants (%)**	
IPC Class	**2000**	**2015**	**2000**	**2015**
A61: Medical	5.9	4.1	33.5	33.6
C07: Chemistry	6.0	5.1	37.2	42.3
H04: Electric Communication	3.8	2.3	18.5	27.5
G01: Measuring	5.2	4.3	19.7	19.4
G06: Computing	4.4	2.9	16.0	19.1
H01: Electric Elements	2.5	2.4	18.8	26.0
C11: Oils	13.3	9.5	84.4	84.9
A23: Foods	6.4	5.3	61.6	71.1
B01: Processes	4.7	4.3	22.0	27.5
H02: Electric Power	2.1	3.7	13.1	22.7

The two leading technological fields Medical and Chemistry have decreased both in terms of absolute HCP-numbers through the negative CAGR, as well as in relative relevance through the decrease in share of worldwide patents in the respective fields.

The technical fields, i.e. Electric Communication, Computing and Electric Elements have lost comparably less.

The two less common fields Oils and Foods have decreased the number of HCPs and their worldwide share, although both fields remain comparably relevant internationally being the only two technological fields with a two-digit share in worldwide HCPs in 2015.

The internationalization rate, i.e. share of host-country to total patents by UK applicants is rather high and has increased between 2000 to 2016. Particularly internationalized are the fields Oils and Foods.

Overall the relevance of UK multinational firms seems to have dropped, as the only technological field with an increase in worldwide share is Electric Power, with an increase from 2% in 2000 to 4% in 2015.

[308] Source: Own analysis, based on REGPAT database by the OECD (2020h).

5. Inward Host-Country Patents by Country and Field

In this chapter I list and discuss Host-Country Patents (HCP) of relevant countries from an inwards perspective. As opposed to the previous chapter, now I look at the target countries, i.e. the countries in which R&D is conducted by foreign multinational corporations. I therefore analyze from where the foreign MNCs are coming from, which conduct R&D in the country.[309]

Simplified speaking, I look at the international patents created with inventors within a country and list where the foreign MNCs are coming from, hence inward (or “incoming”) HCPs. For example, for inventive activities conducted within the country of Germany, I show how much of the foreign firms doing these activities are coming from the US, Japan, China, France etc. That means I show for Germany how much R&D non-German firms such as GE, Toyota, Huawei, Saint-Gobain etc. conduct in Germany.

RQ5.1:	Which are the countries in which foreign MNCs conduct the most R&D activities?
RQ5.2:	In which foreign countries are the MNCs based in, which conduct R&D activities in relevant economies and what are the structural changes during the period 2000 to 2015?

This sub-chapter is again structured in four parts: First, I give a global overview, to justify my selection of six developed and six emerging countries. I show in which foreign countries the big MNCs are particularly conducting R&D in on a global scale. In the second and third part I break down the most relevant developed and emerging countries, respectively, to see which the most-relevant home countries for each host-country is. Fourth, I summarize the findings from this chapter.

All patents analyzed in this chapter are international patent applications, i.e. patents filed under the Patent Cooperation Treaty (PCT), as reported by the OECD[310] and detailed in Chapter 2.

The number of patents from each year is summed up to three-year periods, in order to reduce the effect of potential outlier years. The indicated patent numbers are derived through

309 For methodological details, please refer to Chapter 2.2.
310 Cf. Chapter 2.2.5 for a detailed explanation.

“full-counting”, as explained in Chapter 2.2.3. This also means that the number of “Total Host-Country Patents” can be smaller than the sum of the respective patents across the countries, due to multiple counting.[311]

The most relevant host-countries are listed separately for developed and emerging country, based on the classification discussed in Chapter 2.5. The tables are sorted decreasingly for the most recent time-period (2015-2017). The source data of relevant countries can be found in Appendix-Table 9.

In this chapter I show which the most relevant countries to conduct R&D in for foreign-based companies are. It comes as little surprise, that the country with the most inwards HCPs is consistently the USA. However, in the breakdown over time, we can see how particularly emerging countries, such as China or India have strongly increased and attracted R&D activities by foreign-based firms in the last years.

5.1. Global Overview of Inward Host-Countries

In this chapter, I show and discuss the global distribution and development of Inward Host-Country Patents (HCPs).

In Table 5-1 the major host-countries of international patents are shown. The table shows the target countries, i.e. depicts in which countries inventors reside who contribute significantly to international patenting activities. Therefore, the table gives us an insight into which countries companies internationalize R&D activities. This table justifies the selection of countries for the following Inward patent breakdown per country.

[311] For example, if a patent by a German applicant had one German, one French and one Chinese inventor, this one (international) patent would be counted as one patent for each of the three countries, with the latter two being international in this respect.

Table 5-1: Global Development of Host-Country Patents, Target Countries[312]

Global Host-Country Patents, Target Countries			**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	**CAGR ’00-’17 (%)**
Total Patents			316,043	464,548	591,681	685,788	5.0
Total Host-Country Patents			51,411	76,350	88,321	92,350	3.8
Share HCP to Total Patents (%)			*16.3*	*16.4*	*14.9*	*13.5*	-
HCPs with Inventors in	Developed Countries	United States	14,132	19,678	21,627	22,252	3.1
		Germany	6,763	10,775	11,318	11,745	4.0
		United Kingdom	6,814	8,663	8,700	8,112	1.3
		France	4,479	6,195	6,471	5,906	1.9
		Canada	2,737	3,997	4,479	4,464	2.2
		Japan	2,438	3,318	3,970	3,788	3.1
		Switzerland	1,970	3,085	3,022	2,906	2.8
		Italy	1,715	2,532	2,784	2,710	2.3
		Sweden	1,432	2,089	2,266	2,601	2.8
		Belgium	1,671	2,299	2,493	2,180	1.4
	Emerging Countries	China	906	3,658	8,884	11,957	18.1
		India	487	1,782	3,678	4,270	15.5
		Israel	1,299	1,621	2,224	2,193	2.3
		Chinese Taipei	242	561	879	1,438	14.1
		South Korea	376	805	1,328	1,321	8.4
		Singapore	395	782	1,089	1,280	9.0
		Russia	735	938	1,260	1,146	2.2
		Brazil	212	410	695	793	11.3
		Hong Kong – China	195	423	550	635	7.1
		Poland	167	264	520	614	9.9

This table shows where inventors are located if the R&D-conducting firm is foreign. This is used as a proxy for significant foreign R&D activity. For example, the figure “22,252” for “United States” in the period “2015-2017” indicates that over 22,000 patents have been filed

312 Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

by foreign applicants, i.e. by non-US firms for which at least one US-based inventor is listed in the patent document in that period. The detailed number and breakdown of HCPs by target country for the US and other major economies can be found in the next sub-chapter.

Between 2000 and 2008 the major inventor locations were in the US, Germany, UK, France, Canada and Japan. Only more recently, i.e. since 2011, inventors from emerging nations are becoming more prominent. Here we can see a strong growth of HCPs in China, India, Taiwan, Singapore and South Korea.

For the most recent 2015-2017 period, China has overtaken Germany in numbers of HCPs and has achieved a second position on a global scale only behind the US.

It comes as little surprise that the major economy US is leading in terms of HCPs, with almost double the numbers of its followers China and Germany.

I select a sample of twelve countries which I analyze further in the following sub-chapters. The figure in brackets behind each country gives the country's share to total HCPs in percent for the latest 2015-2017 period and thereby its relative relevance.

Developed Countries: US (24.1), Germany (12.7), UK (8.8), France (6.4), Canada (4.8), Japan (4.1).

Emerging Countries: China (12.9), India (4.6), Israel (2.4), South Korea (1.4), Singapore (1.4), Russia (1.2).

For example, 24% of all HCPs in 2015-2017 had a US-based inventor. Due to full-counting the sum of percentages can obviously be larger than 100%. Despite the limitations of the full-patent counting method, as previously discussed, we can see clearly where the companies are internationalizing their R&D activities to: almost every fourth international patent listed at least one US-based inventor. One the one hand, we can still see a strong dominance of developed countries attracting foreign R&D, such as the US, Germany or UK. On the other hand, we have a smaller concentration than with the applicant countries and see how important emerging countries as a host for foreign R&D activities have become.[313]

In the next two parts, I list and discuss the Inward Host-Country Patents (HCP) of relevant economies. Again, I list the number of total patents and of total HCPs, whereas the focus of

[313] Once again, we have to be careful when simply adding up percentages, due to the methodology of "full counting". For example, it would be imprecise to say almost 20% (12.9+4.6+2.4) of the HCPs have an inventor in a Top 3 emerging country, i.e. every fifth HCP has an inventor based in China, India and / or Israel. In most cases patents, especially HCPs will have several inventors, even though in many cases they will be in one host-country and the home-country. For the justification, please refer to footnote 273.

analysis differs: in each section I focus on one country X. I take all patents where at least one inventor is registered in that country X and where an applicant is based outside of country X. Foreign applicant is used here as an indicator of a foreign multinational corporation. The Share of Host-Country Patents therefore indicates here what fraction of patents with an inventor from country X has an applicant from outside of country X (Inward Host-Country Patent rate). This share has sometimes been named the FAXI-rate in the literature, which stands for 'Foreign Applicant of X Inventions.[314] For example, the FAGI-rate (Foreign Applicant of German Inventions) is the share of all patents with a foreign, i.e. non-German, applicant and (at least) one German inventor, divided by all patents with (at least) one German inventor. Once again, to avoid linguistic contortions (e.g. “FAJPI” would stand accordingly for Foreign Applicant of Japanese Inventions and be confusing to read and challenging to pronounce) and aid understanding, I stick with “Share of Host-Country Patents”.

Each economy is analyzed in two steps. First, I show and discuss the patents by country. This country breakdown indicates to what degree and for which countries the country is relevant to conduct R&D for foreign MNCs. Second, I break down once again the number of HCPs by technological field, i.e.by IPC classes.[315] Showing which of the 126 IPC classes show the most HCPs in each country indicates which technological fields and potentially industries are particularly interesting in conducting R&D in the respective host-country. The IPC classes are not necessarily equally large: some classes are rather broad and some are more specific. In addition to the absolute number of HCPs for selected years and the corresponding CAGR, I therefore also show the share of HCPs with the particular economy and IPC class in relation to all (Inward) Host-Country Patents (HCP) in that IPC class. This shows the relative importance or attractiveness of the analyzed economy in that technological field in a clearer way.

The official IPC Class categories are somewhat lengthy, so I use a shortened title in the tables. The complete names of the IPCs shown in this chapter are displayed in Table 5-2.

[314] Cf. EFI (2013); Gerybadze, Schnitzer, and Czernich (2013).

[315] I break the IPCs down to the class, i.e. the three-character classification and list the classes decreasingly for their latest 2015 value. For example, the Class 'F03' describes “Machines or Engines for Liquids; Wind, Spring, or Weight Motors; Producing Mechanical Power or a reactive propulsive thrust, no otherwise provided for”. See Table 2-1 for details.

Table 5-2: Overview Relevant IPC Classes for Inward Host-Country Patents

IPC	Official Name
A01	Agriculture; forestry; animal husbandry; hunting; trapping; fishing
A61	Medical or veterinary science; hygiene
B01	Physical or chemical processes or apparatus in general
B41	Printing; lining machines; typewriters; stamps
B60	Vehicles in general
B64	Aircraft; aviation; cosmonautics
B65	Conveying; packing; storing; handling thin or filamentary material
C07	Organic chemistry
C08	Organic macromolecular compounds; their preparation or chemical working-up; compositions based thereon
C09	Dyes; paints; polishes; natural resins; adhesives; compositions not otherwise provided for; applications of materials not otherwise provided for
C11	Animal or vegetable oils, fats, fatty substances or waxes; fatty acids therefrom; detergents; candles
C12	Biochemistry; beer; spirits; wine; vinegar; microbiology; enzymology; mutation or genetic engineering
D06	Treatment of textiles or the like; laundering; flexible materials not otherwise provided for
E21	Earth or rock drilling; mining
F01	Machines or engines in general; engine plants in general; steam engines
F16	Engineering elements or units; general measures for producing and maintaining effective functioning of machines or installations; thermal insulation in general
G01	Measuring; testing
G02	Optics
G03	Photography; cinematography; analogous techniques using waves other than optical waves; electrography; holography
G06	Computing; calculating; counting
H01	Basic electric elements
H02	Generation, conversion, or distribution of electric power
H04	Electric communication technique

Source: WIPO (2020b).

It is important to point out that I use different data sets in the respective two steps. For the country breakdown I rely on aggregated PCT data and for the technological field (IPC) breakdown I analyze individual raw patent data from the EPO.[316] The patent numbers can therefore look quite differently.

[316] See Chapter 2.2 for a methodological elaboration and discussion.

5.2. Developed Countries

In this part I show and discuss the six most relevant developed countries as a location for R&D activities by foreign multinational corporations. These six countries are the US, Germany, UK, France, Canada and Japan and have been selected based on their global HCP numbers outlined in Table 5-1. That means we look at patents filed for by multinational firms based outside the US, Germany etc. respectively and look at host-country patents, i.e. patents with a US- / German- etc. based inventor.

5.2.1. US Inward Host-Country Patents

This part summarizes the inward international patenting activities of foreign firms in the US. As shown in Table 5-1, the US, as an economic superpower, is the country with the most inward HCPs in the latest 2015-2017 period (and actually has been in other periods as well for that matter).

Table 5-3: Development of US Inward Host-Country Patents[317]

		Inward Host-Country Patents, USA	**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	***CAGR '00-'17 (%)***	***Share HCPs '15-'17 (%)***
Total Patents			127,210	155,378	171,358	171,621	*1.6*	-
Total Host-Country Patents			14,132	19,678	21,627	22,252	*3.1*	-
Share Host-Country Patents (%)			*11.1*	*12.7*	*12.6*	*13.0*	-	-
HCPs with Applicants from	Developed Countries	Germany	2,328	2,366	3,021	3,157	*1.3*	*14.2*
		Switzerland	1,812	2,607	2,542	2,327	*2.0*	*10.5*
		France	1,482	2,536	2,896	2,167	*3.2*	*9.7*
		Netherlands	1,565	2,847	2,149	2,086	*1.5*	*9.4*
		Japan	1,213	1,616	1,636	1,782	*2.8*	*8.0*
		United Kingdom	1,185	1,006	1,212	1,592	*0.6*	*7.2*
		Sweden	571	1,090	924	956	*1.8*	*4.3*
		Canada	1,004	1,242	1,278	918	*-0.8*	*4.1*
		Ireland	211	285	360	589	*7.4*	*2.6*
		Finland	471	369	601	486	*2.7*	*2.2*
	Emerging Countries	China	62	536	1,385	1,761	*23.0*	*7.9*
		South Korea	149	456	645	728	*11.9*	*3.3*
		Puerto Rico	7	49	140	603	*39.3*	*2.7*
		Singapore	99	214	349	365	*8.6*	*1.6*
		Chinese Taipei	87	171	217	357	*14.3*	*1.6*
		Israel	249	257	292	307	*1.4*	*1.4*
		Hong Kong - China	77	99	179	216	*7.4*	*1.0*
		Cayman Islands	152	220	149	213	*3.1*	*1.0*
		India	50	65	150	182	*10.2*	*0.8*
		Saudi Arabia	5	27	124	146	*23.5*	*0.7*

The United States are the largest target country for Inward R&D and Host-Country Patents (HCPs) by foreign MNCs. The total number of foreign HCPs with at least one US (co-)inventor has increased from 14,132 to 22,252 in the periods 2000-2002 to 2015-2017. The share of HCPs increased from 11% to 13% in the same period. That share is relatively low, but increases indicating that the US is an interesting location for incoming R&D activities.

[317] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

Furthermore, that share is somewhat lower than the share of R&D investments by foreign firms in the US of around 16% (see Chapter 3.2.2 for details). Two theories can support this discrepancy: First, the discussion of an innovation slowdown, i.e. the observation that increasing R&D expenditures does not transform into an accordingly increasing innovation output. Second, with relatively high labor and commodity costs in the US R&D investments can be expected to be generally higher than the resulting patents.

A lot of different countries are conducting R&D with US inventor participation, as both the high numbers of respective HCPs and the relatively even distribution indicates. Germany, Switzerland and other European countries are leading.

Firms from emerging countries have strongly grown, with China accounting now for a significant 8% share of Inward HCPs. Puerto Rico, an unincorporated territory of the US, is the third biggest emerging country, but can be attributed somewhat to the US, and a proxy for US firms registering there for tax reasons.[318] France and Belgium are countries from which the Inward HCPs have grown (slightly) above average. To some degree, Ireland might be a proxy of US firms, as well: due to same language and business-friendly taxation, the country is host to many US firms.[319]

[318] Cf. Deloitte (2019b).
[319] Cf. McDonald (2015).

Host-Country Patents by Technological Field

Table 5-4: Host-Country Patent Breakdown for US Inventors by IPC[320]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	34,152	35,963	39,157	38,542	0.8
Total Host-Country Patents	6,383	8,462	8,888	8,688	2.1
Share Host-Country Patents (%)	*18.7*	*23.5*	*22.7*	*22.5*	-
A61: Medical	1,966	2,163	1,926	2,169	0.7
H04: Electric Communication	817	1,455	1,852	1,440	3.9
G06: Computing	674	833	1,033	1,163	3.7
C07: Chemistry	1,232	967	933	962	-1.6
G01: Measuring	726	613	671	669	-0.5
C08: Organic Compounds	443	468	532	500	0.8
H01: Electric Elements	653	445	554	490	-1.9
C12: Biochemistry	828	427	494	457	-3.9
B01: Processes	295	284	400	326	0.7
A01: Agriculture	223	310	260	297	1.9

Note: Full-counting leads to some double counting.

The share of Host-Country Patents (HCP) with US inventors has increased between 2000 and 2007 and then slightly decreased again to 23% in 2015. That means that almost every fourth patent with (at least) one US-based inventor has a foreign-based applicant. In other words: almost every fourth patent (partly) created with US inventive activity gets filed by a foreign firm. We can see that the number of Host-Country Patents has grown at a higher rate than the number of all patents with an US-based inventor, i.e. including domestic applicants. This shows the increasing internationalization of patent activities over the years, despite the small decline since 2007.

[320] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 5-5: Total and Host-Country Patent Shares for US Inventors by IPC[321]

	Share of US Inventors in Worldwide Patents (%)		Share of HCPs to all patents of US Inventors (%)	
IPC Class	**2000**	**2015**	**2000**	**2015**
A61: Medical	46.3	40.5	21.7	23.9
H04: Electric Communication	31.0	29.6	16.8	26.0
G06: Computing	37.7	36.8	15.3	19.9
C07: Chemistry	45.6	41.0	24.3	30.4
G01: Measuring	38.9	29.2	16.7	18.5
C08: Organic Compounds	31.7	25.6	25.0	35.2
H01: Electric Elements	28.2	20.9	19.2	20.5
C12: Biochemistry	51.7	43.7	21.7	20.6
B01: Processes	33.8	29.8	17.4	24.6
A01: Agriculture	33.6	30.7	23.9	30.5

The technological fields with the most patents show a clear focus on either Pharma, Biotech, Chemistry, or a technical field. For the two technical IPCs “Measuring” and “Electric Elements” not only the number of HCPs has decreased, but also, quite significantly, the share of US HCPs: while in the year 2000 39% or 28% of patents by foreign applicants had one US-based inventor in the fields “Measuring” and “Electric Elements”, that share has fallen to 29% and 21% respectively. This can be an indicator for a decreasing relevance, both absolutely and relatively, likely due to the uprise of other countries, although foreign firms still value the US as a base for R&D activities. The Pharma, Biotech and Chemistry fields all show a high, yet decreasing share of around 40% in 2015, or in other words almost every second patent in these fields have (partly) built on inventive activities in the US.

Interestingly enough almost all of the over 100 IPC classes show a share of >20% in 2015, meaning that at least every fifth patent in any given technological field has at least one US-based inventor. This shows clearly the remarkable relevance of the US for foreign MNCs to conduct R&D in, in many fields.

[321] Source: Own analysis, based on REGPAT database by the OECD (2020h).

For all technological fields shown here, we observe an increase in internationalization. That means in 2015 a patent in any given field with a US-based inventor is more likely to be a host-country patent (international patent), compared to 2000.

5.2.2. Germany Inward Host-Country Patents

This part summarizes the inward international patenting activities of foreign firms in Germany. As shown in Table 5-1, Germany, a major European power, has been displaced to the third rank in terms of number of inward HCPs by China in the latest period.

Table 5-6: Development of German Inward Host-Country Patents[322]

Inward Host-Country Patents, Germany		2000-2002	2006-2008	2011-2013	2015-2017	*CAGR '00-'17 (%)*	*Share HCPs '15-'17 (%)*
Total Patents		44,320	58,310	59,249	60,837	*2.1*	-
Total Host-Country Patents		6,763	10,775	11,318	11,745	*4.0*	-
Share Host-Country Patents (%)		*15.3*	*18.5*	*19.1*	*19.3*	-	-
HCPs with Applicants from – Developed Countries	United States	2,332	3,186	3,481	3,595	*2.3*	*30.6*
	Switzerland	1,391	2,301	2,231	2,221	*3.5*	*18.9*
	France	432	888	883	792	*4.2*	*6.7*
	Sweden	395	552	631	645	*3.2*	*5.5*
	Netherlands	653	751	524	603	*1.2*	*5.1*
	Austria	312	388	459	464	*2.2*	*4.0*
	Japan	193	305	383	438	*8.7*	*3.7*
	Finland	193	450	454	385	*7.2*	*3.3*
	United Kingdom	261	289	281	378	*4.9*	*3.2*
	Liechtenstein	37	348	236	353	*11.8*	*3.0*
HCPs with Applicants from – Emerging Countries	China	2	38	227	726	*34.2*	*6.2*
	Singapore	20	73	68	83	*22.8*	*0.7*
	Israel	32	27	34	39	*4.9*	*0.3*
	Korea	13	26	242	38	*13.8*	*0.3*
	India	4	12	20	26	*12.1*	*0.2*
	Czech Republic	5	7	25	23	*8.5*	*0.2*
	Poland	7	3	18	21	*9.0*	*0.2*
	Hong Kong – China	2	21	14	17	*8.5*	*0.1*
	Brazil	8	4	19	14	*3.3*	*0.1*
	Russia	27	14	22	13	*-3.4*	*0.1*

The share of HCPs is increasing, whereas the country distribution is quite concentrated: almost 50% of HCPs in Germany comes from either a US or Swiss applicant. The share of Inward HCPs has increased from 15% to 19% in the periods 2000-2002 to 2015-2017. That means that in the last period almost every fifth patent with a German inventor was filed by a

[322] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

non-German company. That might come insofar as a surprise, as the share of foreign R&D to BERD, i.e. the share of R&D Expenditure by foreign MNCs compared to all R&D Expenditure spent in Germany has decreased over the years, as outlined in Chapter 3.2. With a complex relationship between R&D Expenditure and patent numbers a multitude of factors can explain this phenomenon. Ultimately this underlines the requirement of looking not just at one variable in order to analyze and explain R&D Internationalization.

Further relevant countries of origin are Germany's European neighbors, particularly Germany's close ally France, and Japan. For the emerging countries, China stands out, accounting for 6% of all incoming HCPs.

The by far strongest growth can be observed for China, with a CAGR of 34%. Over the time periods analyzed, the number of HCPs has skyrocketed and increased more than 100-fold. Other strong growth can be observed for Liechtenstein. The tiny German-speaking nation south of Germany hosts many firms due to a business-friendly taxation regime.[323] Japanese HCPs have also increased: Germany is one of the few countries Japan somewhat internationalize R&D to. Other above-average growth countries are European neighboring countries of Germany.

[323] Cf. Deloitte (2019a).

Host-Country Patents by Technological Field

Table 5-7: Host-Country Patent Breakdown for German Inventors by IPC[324]

IPC Class	Number of HCPs per Priority Year				CAGR '00-'15 (%)
	2000	2007	2012	2015	
Total Patents	23,600	26,544	24,246	23,699	0.0
Total Host-Country Patents	4,668	6,470	5,763	5,771	1.4
Share Host-Country Patents (%)	*19.8*	*24.4*	*23.8*	*24.4*	-
A61: Medical	810	1279	853	849	0.3
H04: Electric Communication	584	812	626	619	0.4
G01: Measuring	417	483	439	429	0.2
H01: Electric Elements	493	447	506	398	-1.4
C07: Chemistry	598	674	478	394	-2.7
G06: Computing	288	283	279	363	1.6
B60: Vehicles	251	329	306	330	1.8
C08: Organic Compounds	357	371	369	284	-1.5
F16: Engineering Elements	194	269	311	283	2.5
B01: Processes	251	215	261	225	-0.7

Note: Full-counting leads to some double counting.

While the number of patents with a German inventor has only slightly fluctuated between 2000 and 2015, the number of Host-Country Patents has increased. Overall, we see an increase of patent numbers between 2000 and 2007, followed by a decrease, both for the total patent numbers, as well as the patent number across most technological fields.

[324] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 5-8: Total and Host-Country Patent Shares for German Inventors by IPC[325]

IPC Class	Share of DE Inventors in Worldwide Patents (%)		Share of HCPs to all patents of DE Inventors (%)	
	2000	**2015**	**2000**	**2015**
A61: Medical	13.1	11.3	31.6	33.5
H04: Electric Communication	12.1	7.1	30.8	46.4
G01: Measuring	19.2	16.7	19.5	20.7
H01: Electric Elements	18.2	14.6	22.4	23.8
C07: Chemistry	16.2	13.1	33.2	39.0
G06: Computing	9.5	7.6	25.9	30.0
B60: Vehicles	34.8	25.7	13.3	18.3
C08: Organic Compounds	23.1	15.1	27.7	33.8
F16: Engineering Elements	29.6	25.7	12.4	16.7
B01: Processes	23.2	18.0	21.6	28.1

The share of HCPs with a German inventor is in the two-digits for almost all technological fields, even the ones not shown in the Table 5-8, which is comparable to the observation for the US in Table 5-5: clearly Germany is a relevant location for R&D in many fields, even though these shares have mostly decreased between 2000 and 2015. We can also see the high shares of HCPs to all patents with a Germany-based inventor (international patent), indicating the relevance of foreign MNCs for Germany as an innovation location.

The leading industry in terms of patent numbers, i.e. patents conducted with at least one Germany-based inventor, is once again Medical with related fields such as Chemistry or Organic Compounds in the list as well. Technical relevant technological fields are Electric Communication, Electric Elements and Computing. Measuring is a field attributable rather to natural sciences and Vehicles, together with Engineering Elements is a field which is unsurprisingly quite strong for Germany. This can be indicative that not only German Automotive firms are strong, but the German competence in this area attracts also foreign firms to conduct R&D with German inventors.[326]

[325] Source: Own analysis, based on REGPAT database by the OECD (2020h).
[326] See also the Chapter 1.1 on the concept of Lead Markets.

5.2.3. UK Inward Host-Country Patents

This part summarizes the inward international patenting activities of foreign firms in the UK. As shown in Table 5-1, the UK, a former EU member and relevant European economy, has received the fourth-highest number of inward HCPs in the 2015-2017 period.

Table 5-9: Development of UK Inward Host-Country Patents[327]

Inward Host-Country Patents, UK			**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	***CAGR ’00-’17 (%)***	***Share HCPs ’15-’17 (%)***
Total Patents			20,197	22,070	21,194	21,747	*0.3*	-
Total Host-Country Patents			6,814	8,663	8,700	8,112	*1.3*	-
Share Host-Country Patents (%)			*33.7*	*39.3*	*41.0*	*37.3*	-	-
HCPs with Applicants from	Developed Countries	United States	3,197	3,608	3,449	3,189	*-0.2*	*39.3*
		Netherlands	882	1,319	887	710	*-2.2*	*8.8*
		Switzerland	369	547	602	687	*5.7*	*8.5*
		Germany	522	678	828	668	*1.8*	*8.2*
		Japan	134	262	466	518	*7.9*	*6.4*
		France	248	525	665	440	*1.6*	*5.4*
		Sweden	471	442	264	213	*-4.9*	*2.6*
		Finland	123	257	146	186	*0.9*	*2.3*
		Belgium	129	151	143	186	*1.3*	*2.3*
		Ireland	121	180	191	172	*4.1*	*2.1*
	Emerging Countries	China	9	40	57	97	*24.9*	*1.2*
		South Korea	8	63	129	69	*15.1*	*0.9*
		Singapore	21	55	69	51	*7.2*	*0.6*
		Hong Kong – China	33	40	31	50	*5.1*	*0.6*
		India	13	20	23	38	*5.3*	*0.5*
		Saudi Arabia	2	2	21	34	*18.5*	*0.4*
		Mexico	1	16	17	31	*13.0*	*0.4*
		Thailand	0	1	4	28	-	*0.3*
		Israel	15	30	17	27	*7.6*	*0.3*
		South Africa	26	16	9	17	*0.0*	*0.2*

[327] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

The UK has a rather high share of HCPs, which has decreased in the latest 2015-2017 period. Parts of this downward trend might be attributed to uncertainties related to Brexit activities and the times around the 2016 United Kingdom European Union membership referendum. For several countries, including the, by far, biggest investing country US, the number of HCPs even decreases, i.e. we have a negative CAGR, despite an increase in the 2006-2008 period.

The share of HCPs is rather high: after continuously increasing from 34% in the period 2000-2002 to 41% in 2011-2013, it has slightly decreased now to 37% in 2015-2017. Nevertheless, this rate is comparably high, indicating that a major share of patents with a UK-based inventor is filed by a foreign firm. These shares are generally smaller than the share of foreign R&D Expenditure within the UK, which was around 51% for 2015[328].

The by far biggest country conducting R&D activities in the UK is the USA, a close political and historical ally of the US, despite a general downwards trend and negative CAGR. Other countries, mostly European, follow at a distance, whereas firms from emerging countries do not play a relevant role. Netherlands is the second-biggest investing country in the UK and home to several major MNCs. Japan accounts for 6% of the Inward HCPs.

Switzerland and Japan are one of the few developed countries which have developed rather positively in a general stagnating or downwards trend. We can see in Table 5-9 that emerging countries have grown with a strong CAGR, however their absolute number of HCPs is negligible. Apart from Switzerland and Japan, other European countries, including UK's neighbor Ireland follow with a smaller CAGR.

[328] Cf. MSTI – OECD (2020d).

Host-Country Patents by Technological Field

Table 5-10: Host-Country Patent Breakdown for UK Inventors by IPC[329]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	6,928	6,707	6,545	6,842	-0.1
Total Host-Country Patents	3,007	3,039	3,119	3,067	0.1
Share Host-Country Patents (%)	*43.4*	*45.3*	*47.7*	*44.8*	-
A61: Medical	777	641	544	579	-1.9
H04: Electric Communication	537	495	542	415	-1.7
G06: Computing	416	271	320	382	-0.6
C07: Chemistry	537	380	254	265	-4.6
G01: Measuring	266	260	331	246	-0.5
H01: Electric Elements	208	152	214	238	0.9
C11: Oils	139	59	76	131	-0.4
H02: Electric Power	41	38	99	121	7.5
B65: Packing	128	92	91	105	-1.3
C09: Paints	80	92	104	99	1.4

Note: Full-counting leads to some double counting.

The UK is an economy with quite stagnating patent numbers overall and decreases in major technological fields. Overall a quite high share of between 43% and 48% of patents with an UK-inventor are Host-Country Patents, i.e. patents from a non-UK applicant.

329 Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 5-11: Total and Host-Country Patent Shares for UK Inventors by IPC[330]

	Share of GB Inventors in Worldwide Patents (%)		Share of HCPs to all patents of GB Inventors (%)	
IPC Class	**2000**	**2015**	**2000**	**2015**
A61: Medical	7.9	5.3	50.2	48.5
H04: Electric Communication	6.5	3.9	52.6	57.4
G06: Computing	7.2	4.7	49.2	50.9
C07: Chemistry	8.6	6.4	56.2	54.0
G01: Measuring	6.5	5.4	36.4	36.4
H01: Electric Elements	3.8	3.9	45.8	54.1
C11: Oils	15.8	18.5	86.9	92.3
H02: Electric Power	3.2	5.1	43.6	44.6
B65: Packing	7.4	5.5	40.0	45.7
C09: Paints	4.8	4.2	50.3	68.8

The only relevant technological field with a strong increase between 2000 and 2015 is Electric Power, a class of the section H (Electricity), with the related field of Electric Elements showing a small positive CAGR. For Oils, the quite high global share has even increased from 16% in 2000 to 19% in 2015, despite an overall decrease in patent numbers.

For the internationally growing and highly relevant technological fields, including Medical & Chemistry, as well as IT (Electric Communication, Computing) we can observe drops in shares, indicating the UK has lost in relative relevance for foreign firms as a location to conduct R&D in such fields.

The share of HCPs to total patents with a UK-based inventor is generally quite high, meaning that foreign MNCs play a strong role in comparison to UK MNCs.

5.2.4. France Inward Host-Country Patents

This part summarizes the inward international patenting activities of foreign firms in France. As shown in Table 5-1, France, next to Germany another major European power, ranked fourth in number of inward HCPs in the 2015-2017 period.

[330] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 5-12: Development of French Inward Host-Country Patents[331]

	Inward Host-Country Patents, France	**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	***CAGR ’00-’17 (%)***	***Share HCPs ’15-’17 (%)***
	Total Patents	16,682	23,039	26,419	25,735	*2.5*	-
	Total Host-Country Patents	4,479	6,195	6,471	5,906	*1.9*	-
	Share Host-Country Patents (%)	*26.8*	*26.9*	*24.5*	*22.9*	-	-
HCPs with Applicants from – Developed Countries	United States	1,343	1,786	1,600	1,538	*0.9*	*26.0*
	Germany	729	899	1,103	1,101	*2.8*	*18.6*
	Switzerland	971	1,434	1,645	1,021	*-0.4*	*17.3*
	Luxembourg	77	162	252	412	*11.4*	*7.0*
	Belgium	167	319	280	322	*2.6*	*5.5*
	Japan	57	140	168	281	*10.0*	*4.8*
	Sweden	126	221	254	195	*2.8*	*3.3*
	Netherlands	371	484	366	189	*-4.3*	*3.2*
	United Kingdom	280	216	179	166	*-2.3*	*2.8*
	Italy	60	83	83	115	*2.4*	*1.9*
HCPs with Applicants from – Emerging Countries	China	8	21	61	65	*11.7*	*1.1*
	Singapore	4	7	26	25	*11.4*	*0.4*
	South Korea	3	100	33	25	*13.8*	*0.4*
	Israel	18	14	11	17	*0.0*	*0.3*
	Monaco	16	11	16	16	*2.0*	*0.3*
	Hong Kong – China	9	13	9	15	*6.7*	*0.3*
	Poland	2	8	8	8	*8.5*	*0.1*
	Morocco	1	6	6	7	*11.1*	*0.1*
	Saudi Arabia	0	1	5	6	-	*0.1*
	Russia	7	4	1	5	*-2.4*	*0.1*

The share of HCPs in France is relatively high but has decreased slightly over the years from 29% in 2000-2002 to around 23% in 2015-2017. The leading countries US, Germany and Switzerland, have held their positions with a rather constant CAGR. Other countries follow at

[331] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

a distance and emerging countries do not play a significant role, with HCP numbers well in the two-digits.

Most of the HCPs, around 61% of the HCPs can be attributed to an applicant from the US, Germany or Switzerland. Other countries, mostly European, follow at a distance.

The strongest growth with a relevant number of HCPs comes from Liechtenstein, a micro-country known for its business-friendly taxation.[332] Japan is also one of the uprising partners, with a CAGR of 10%. Other countries growing above average are France's second-biggest partner Germany, Belgium, as well as Sweden.

Host-Country Patents by Technological Field

Table 5-13: Host-Country Patent Breakdown for French Inventors by IPC[333]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	8,036	9,744	9,974	10,535	1.8
Total Host-Country Patents	2,205	2,869	2,719	2,756	1.5
Share Host-Country Patents (%)	*27.4*	*29.4*	*27.3*	*26.2*	-
A61: Medical	529	578	433	439	-1.2
G01: Measuring	160	217	234	221	2.2
H04: Electric Communication	302	265	268	218	-2.1
G06: Computing	234	159	159	208	-0.8
C07: Chemistry	375	395	241	195	-4.3
H01: Electric Elements	135	149	175	166	1.4
F16: Engineering Elements	106	110	154	146	2.2
B60: Vehicles	212	227	206	143	-2.6
C08: Organic Compounds	169	184	151	126	-1.9
C09: Paints	72	85	99	91	1.6

Note: Full-counting leads to some double counting.

[332] Cf. Deloitte (2019a).
[333] Source: Own analysis, based on REGPAT database by the OECD (2020h).

We can observe an increase in host-country patent numbers between 2000 and 2007, followed by a slight decrease. The share of Host-Country Patents increases as well from 27% to 29% from 2000 to 2007 und then decreases to 26% until 2015. Overall the CAGR both on a total and on a technological field level are quite small, indicated relatively little movement.

Table 5-14: Total and Host-Country Patent Shares for French Inventors by IPC[334]

	Share of FR Inventors in Worldwide Patents (%)		**Share of HCPs to all patents of FR Inventors (%)**	
IPC Class	**2000**	**2015**	**2000**	**2015**
A61: Medical	7.1	5.8	37.9	33.7
G01: Measuring	5.6	7.7	25.4	23.3
H04: Electric Communication	6.2	5.7	31.0	20.3
G06: Computing	5.6	6.5	35.9	20.3
C07: Chemistry	6.6	6.2	51.3	40.9
H01: Electric Elements	5.1	6.9	22.1	21.2
F16: Engineering Elements	7.4	8.3	27.4	26.8
B60: Vehicles	10.6	12.6	36.8	16.2
C08: Organic Compounds	7.1	6.7	42.6	33.6
C09: Paints	4.4	6.3	49.3	42.3

For several fields we have a negative CAGR and also a decrease on share of worldwide HCPs, indicating a drop both in absolute and relative relevance of France as a location for R&D activities. This includes Medical & Chemistry, as well as some technical fields (Electric Communication). For Engineering Elements, Electric Elements and the natural science field Measuring, however, we have both a positive CAGR and an increase in worldwide share. Measuring, as outlined in Chapter 5.2.2, is a rather broad class in the section G (Physics).

The share of HCPs to all patents with a France-based inventor has generally decreased, meaning that the relative relevance of foreign MNCs conducting R&D in France has decreased in practically all technological fields.

[334] Source: Own analysis, based on REGPAT database by the OECD (2020h).

5.2.5. Canada Inward Host-Country Patents

This part summarizes the inward international patenting activities of foreign firms in Canada. As shown in Table 5-1, Canada, the US's northern neighbor, ranked sixth in number of inward HCPs in the 2015-2017 period.

Table 5-15: Development of Canadian Inward Host-Country Patents[335]

Inward Host-Country Patents, Canada			**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	***CAGR '00-'17 (%)***	***Share HCPs '15-'17 (%)***
Total Patents			8,211	10,383	11,211	10,678	*1.4*	-
Total Host-Country Patents			2,737	3,997	4,479	4,464	*2.2*	-
Share Host-Country Patents (%)			*33.3*	*38.5*	*40.0*	*41.8*	-	-
HCPs with Applicants from	Developed Countries	United States	1,828	2,489	2,540	1,998	*0.0*	*44.8*
		Sweden	136	215	384	389	*3.1*	*8.7*
		Germany	111	162	149	164	*3.1*	*3.7*
		Switzerland	79	153	148	161	*6.1*	*3.6*
		France	83	274	253	154	*3.8*	*3.4*
		United Kingdom	88	113	137	103	*-4.0*	*2.3*
		Netherlands	31	142	139	59	*2.2*	*1.3*
		Ireland	75	37	19	52	*-1.8*	*1.2*
		Japan	47	40	61	52	*2.6*	*1.2*
		Luxembourg	14	49	39	37	*3.3*	*0.8*
	Emerging Countries	China	6	28	269	913	*33.3*	*20.5*
		Singapore	14	37	101	77	*9.3*	*1.7*
		India	3	5	10	25	*8.5*	*0.6*
		Hong Kong – China	30	12	11	24	*-4.7*	*0.5*
		Israel	18	19	22	22	*4.2*	*0.5*
		Korea	9	23	15	13	*2.8*	*0.3*
		United Arab Emirates	0	1	1	13	-	*0.3*
		Saudi Arabia	0	0	11	9	-	*0.2*
		Brazil	1	3	8	8	*9.9*	*0.2*
		Russia	0	0	3	8	-	*0.2*

[335] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

It comes as little surprise, that Canada, the US's northern neighbor, receives a significant number of Inward HCPs from just south the border. The share of Inward HCPs is rather high and has increased from 33% in 2000-2002 to 42% in 2015-2017.

US firms account for a staggering 45% of all HCPs in Canada, followed by China with 21%. China has grown to be a strong investor in Canada, presumably due to the cultural and geographic proximity to the US. Sweden follows with 9%, where the next ranks are filled by mostly European firms, each well below 4%.

China is not only the second-largest country by number of HCPs in Canada, it also has the by-far largest growth, increasing its HCPs over the years more than 100-fold. Another emerging country, Singapore, has grown strongly with a CAGR of 9%, although the absolute number of HCPs account for only 2% of HCPs. From the developed countries, Sweden has clearly gained in importance, with a CAGR of 6%, followed by other European countries.

Host-Country Patents by Technological Field

Table 5-16: Host-Country Patent Breakdown for Canadian Inventors by IPC[336]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	2,055	2,899	2,888	2,302	0.8
Total Host-Country Patents	928	1,407	1,472	1,255	2.0
Share Host-Country Patents (%)	*45.2*	*48.5*	*51.0*	*54.5*	-
H04: Electric Communication	175	389	520	399	5.6
A61: Medical	257	265	215	194	-1.9
G06: Computing	106	143	222	169	3.2
G01: Measuring	115	98	90	101	-0.9
H01: Electric Elements	55	70	65	82	2.7
C07: Chemistry	164	148	95	77	-4.9
C12: Biochemistry	115	84	51	45	-6.1
B01: Processes	43	38	46	43	0.0
B64: Aviation	2	8	15	41	22.3
G02: Optics	34	25	35	37	0.6

Note: Full-counting leads to some double counting.

For Canada we can observe a quite high share of Host-Country Patents which even increased over the years until 2015 to 55%. That means that more than every second patent with a Canadian inventor has a foreign-based applicant, i.e. gets filed by a foreign MNC. The technological fields show mostly a rather dynamic development with comparably strong CAGRs.

[336] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 5-17: Total and Host-Country Patent Shares for Canadian Inventors by IPC[337]

	Share of CA Inventors in Worldwide Patents (%)		Share of HCPs to all patents of CA Inventors (%)	
IPC Class	**2000**	**2015**	**2000**	**2015**
H04: Electric Communication	2.3	2.8	47.9	75.4
A61: Medical	2.7	2.0	48.8	43.5
G06: Computing	2.0	2.0	45.9	53.7
G01: Measuring	2.1	1.9	48.3	43.2
H01: Electric Elements	1.2	1.2	36.9	58.6
C07: Chemistry	2.6	2.6	57.3	38.9
C12: Biochemistry	3.3	2.7	47.9	32.8
B01: Processes	1.5	1.9	55.8	51.2
B64: Aviation	1.5	3.5	25.0	68.3
G02: Optics	1.9	1.6	47.2	56.1

The fields with a positive CAGR and increase in worldwide share are Electric Communication which, despite a decrease in patent numbers from 2012 to 2015 is the, by far, biggest technological field. Another uprising technological field, which is also quite unique for Canada, is Aviation. Companies such as Bombardier might be the reason for Canada possessing competencies in that field and attracting R&D activities by foreign firms, outlined by the strong increase in HCP to total share. With a CAGR of 3% the technological field Computing has kept is relative worldwide relevance of 2% between 2000 and 2015.

Technological fields with stagnation or decreases are Medical, Chemistry and Biochemistry. For these strong fields other countries are apparently becoming slightly more attractive for R&D activities than Canada.

5.2.6. Japan Inward Host-Country Patents

This part summarizes the inward international patenting activities of foreign firms in Japan. As shown in Table 5-1, Japan, an economic power in Asia, ranked eighth in number of inward HCPs in the 2015-2017 period, behind the emerging country India.

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337 Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 5-18: Development of Japanese Inward Host-Country Patents[338]

Inward Host-Country Patents, Japan			2000-2002	2006-2008	2011-2013	2015-2017	*CAGR '00-'17 (%)*	*Share HCPs '15-'17 (%)*
Total Patents			38,726	82,512	128,185	130,298	*8.5*	-
Total Host-Country Patents			2,438	3,318	3,970	3,788	*3.1*	-
Share Host-Country Patents (%)			*6.3*	*4.0*	*3.1*	*2.9*	-	-
HCPs with Applicants from	Developed Countries	United States	1,353	1,770	1,948	1,413	*0.9*	*37.3*
		Germany	317	332	341	432	*3.5*	*11.4*
		France	111	209	310	411	*10.0*	*10.9*
		Switzerland	138	127	147	132	*-0.9*	*3.5*
		Sweden	49	123	147	104	*0.4*	*2.7*
		United Kingdom	69	60	65	76	*-0.3*	*2.0*
		Netherlands	148	158	113	74	*-6.4*	*2.0*
		Finland	41	101	59	68	*3.6*	*1.8*
		Belgium	11	14	51	53	*15.5*	*1.4*
		Luxembourg	8	24	183	36	*9.9*	*1.0*
	Emerging Countries	China	14	63	121	381	*24.0*	*10.1*
		South Korea	52	77	185	233	*11.7*	*6.2*
		Hong Kong – China	13	94	36	110	*16.0*	*2.9*
		Thailand	1	12	23	69	*25.1*	*1.8*
		Singapore	10	55	110	66	*18.5*	*1.7*
		Chinese Taipei	8	17	14	39	*9.1*	*1.0*
		India	1	1	7	16	*9.9*	*0.4*
		Saudi Arabia	0	5	4	10	-	*0.3*
		Malaysia	0	3	8	8	-	*0.2*
		Israel	5	5	6	7	*2.4*	*0.2*

Japan has a comparably low share of HCPs, which even decreased over the years: from 6% in 2000-2002 to 3% in 2015-2017. The number of HCPs has increased from 2,438 to 3,788 in the same period, indicating that there is some relevant interest in conducting R&D in Japan, which is however not on a relevant scale compared to domestic patenting activities.

[338] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

Japan strongest partner is the US with 37% of HCPs, followed at a large distance by Germany and France with 11% each, and China with 10%. Korea follows at 6%.

The biggest growth can be observed for China with 24%, and Hong Kong – China, with 16%. South Korea, another emerging country has also strongly increased its HCPs in Japan with a CAGR of 12%. From the developed economies France has clearly ramped up HCPs with a CAGR of 10%, which made it the third-biggest country in terms of HCPs in the 2015-2017 period.

Host-Country Patents by Technological Field

Table 5-19: Host-Country Patent Breakdown for Japanese Inventors by IPC[339]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	22,428	22,028	21,943	20,505	-0.6
Total Host-Country Patents	1,057	1,184	1,052	986	-0.5
Share Host-Country Patents (%)	*4.7*	*5.4*	*4.8*	*4.8*	-
H04: Electric Communication	109	302	226	225	5.0
A61: Medical	267	185	141	131	-4.6
C08: Organic Compounds	131	87	114	100	-1.8
H01: Electric Elements	159	140	93	93	-3.5
B60: Vehicles	22	37	67	84	9.3
G06: Computing	112	79	66	76	-2.6
C07: Chemistry	180	118	91	62	-6.9
C09: Paints	94	58	71	60	-2.9
D06: Textile Treatment	10	6	2	57	12.3
G01: Measuring	121	89	54	52	-5.5

Note: Full-counting leads to some double counting.

Japan is one of the few countries with an overall decrease of patent numbers since 2000. In fact, some technological fields show a negative CAGR, whereas some others are quite positive. The share of Host-Country Patents is comparably small and after a small increase

[339] Source: Own analysis, based on REGPAT database by the OECD (2020h).

from 4.7% in 2000 to 5.4% in 2007, that share has decreased to 4.8% again in 2012 and 2015. That means that less than every twentieth patent with a Japanese inventor has a foreign-based applicant.

Table 5-20: Total and Host-Country Patent Shares for Japanese Inventors by IPC[340]

	Share of JP Inventors in Worldwide Patents (%)		Share of HCPs to all patents of JP Inventors (%)	
IPC Class	**2000**	**2015**	**2000**	**2015**
H04: Electric Communication	23.1	12.6	3.0	9.5
A61: Medical	10.5	10.3	13.0	5.7
C08: Organic Compounds	24.6	29.3	9.5	6.1
H01: Electric Elements	33.3	24.5	4.0	3.3
B60: Vehicles	22.5	24.2	1.8	4.9
G06: Computing	23.6	12.4	4.1	3.9
C07: Chemistry	13.0	9.9	12.4	8.1
C09: Paints	26.2	27.6	10.7	6.4
D06: Textile Treatment	12.8	14.1	7.2	38.8
G01: Measuring	15.5	14.7	7.0	2.9

The breakdown by technological fields shows interesting developments. The strong and increasing fields are related to industries in which Japan is strong, which, again, relates to the concept of lead markets: Electric Communication and Vehicles. On the other side, Medical and Chemistry have strongly decreased in patent numbers and share in worldwide HCPs, whereas the share of Organic Compounds with Japanese inventors increased to 29% in 2015. Other and rather less common technological fields are Paints and Textile Treatment.

Compared to other countries we immediately notice the small internationalization rate, i.e. the share of HCPs to all patents with a Japan-based inventor, which even decreases until 2015 for almost all technological fields. In relation to Japanese firms, foreign MNCs play a relatively small role in conducting R&D in Japan.

[340] Source: Own analysis, based on REGPAT database by the OECD (2020h).

5.3. Emerging Countries

In this part I show and discuss the six most relevant emerging countries as a location for R&D activities by foreign multinational corporations. These six countries are China, India, Israel, South Korea, Singapore and Russia and have been selected based on their global HCP numbers outlined in Table 5-1. That means we look at patents filed for by multinational firms based outside China, India etc. respectively and look at host-country patents, i.e. patents with a Chinese- / Indian- etc. based inventor.

5.3.1. China Inward Host-Country Patents

This part summarizes the inward international patenting activities of foreign firms in China. As shown in Table 5-1, China, the most dynamic and strongest emerging country, has surpassed Germany in number of inward HCPs and ranked second in the 2015-2017 period, behind the US.

Table 5-21: Development of China Inward Host-Country Patents[341]

Inward Host-Country Patents, China		**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	***CAGR ’00-’17 (%)***	***Share HCPs ’15-’17 (%)***
Total Patents		3,716	18,489	61,613	127,521	*22.6*	-
Total Host-Country Patents		906	3,658	8,884	11,957	*18.1*	-
Share Host-Country Patents (%)		*24.4*	*19.8*	*14.4*	*9.4*	-	-
HCPs with Applicants from – Developed Countries	United States	419	1,329	3,475	3,934	*14.6*	*32.9*
	Japan	50	119	638	1,231	*23.1*	*10.3*
	Germany	63	377	844	890	*18.0*	*7.4*
	France	26	405	734	588	*19.5*	*4.9*
	Sweden	6	165	532	541	*39.5*	*4.5*
	Switzerland	31	144	326	440	*27.0*	*3.7*
	Finland	29	204	583	387	*27.2*	*3.2*
	Netherlands	41	223	279	260	*23.5*	*2.2*
	United Kingdom	34	98	194	221	*15.2*	*1.8*
	Canada	16	35	72	75	*13.8*	*0.6*
HCPs with Applicants from – Emerging Countries	Cayman Islands	0	105	271	2,306	-	*19.3*
	Hong Kong – China	125	141	164	452	*10.0*	*3.8*
	South Korea	28	87	170	267	*29.8*	*2.2*
	Singapore	12	57	127	151	*17.9*	*1.3*
	Chinese Taipei	33	101	103	130	*9.6*	*1.1*
	Malaysia	0	1	13	15	-	*0.1*
	Israel	0	15	8	13	-	*0.1*
	Saudi Arabia	0	2	1	13	-	*0.1*
	United Arab Emirates	0	0	4	6	-	*0.1*
	Lebanon	0	0	0	4	-	*0.0*

China has become the second most important target country for HCPs during recent years, with strong increases particularly after 2010. The number of HCPs has increased 13-fold from 906 to 11,957 in the periods 2000-2002 to 2015-2017. This growth is still outnumbered by the

[341] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

number of total patents, i.e. including domestic applicants. Here the number of patents even increased 34-fold in the periods analyzed.

This has led to a drop in the HCP share from 24.4% to 9.4%, which in turn has a profound impact on the global HCP developments, as discussed in Chapter 3.1. In earlier years China was more dependent on foreign knowledge and investments. Over the years it has ramped up its capabilities and strongly pushed local R&D activities, so that the number of HCPs, while strongly increasing in absolute numbers, has lost in relative relevance to patents with Chinese applicants.

The strongest investor in China is the US, with around 33% of all HCPs. Japan follows at a distance, followed again by Germany. Emerging countries do not play a relevant role.

The surprisingly high value for the Cayman Islands in the period 2015-2017 is not due to a data error (there is not on outlying data value, but instead each respective year's value is similarly high). Instead it can be assumed that the companies filing for patents with Chinese inventors are registered in the Cayman Islands for tax and other legal reasons. For example, car manufacturer Geely is incorporated in the Cayman Islands. Hong Kong, a special administrative region of China, is home for many companies, also for tax reasons.[342]

Particularly strong growth rates can be observed by Japan and a number of European countries. Japan might be interested in investing in China due to the geographic proximity and relatively cultural closeness.

[342] Cf. PwC (2019).

Host-Country Patents by Technological Field

Table 5-22: Host-Country Patent Breakdown for Chinese Inventors by IPC[343]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	269	2,551	6,664	8,833	26.2
Total Host-Country Patents	165	867	1,997	2,177	18.8
Share Host-Country Patents (%)	*61.3*	*34.0*	*30.0*	*24.6*	-
H04: Electric Communication	26	264	781	781	25.5
G06: Computing	15	92	238	324	22.7
A61: Medical	29	108	189	251	15.5
C07: Chemistry	32	102	157	170	11.8
C08: Organic Compounds	8	59	149	141	21.1
H01: Electric Elements	14	69	124	140	16.6
G01: Measuring	15	40	91	88	12.5
C09: Paints	4	22	69	69	20.9
B01: Processes	24	27	53	64	6.8
H02: Electric Power	1	23	67	62	31.7

Note: Full-counting leads to some double counting.

The number of patents with a Chinese inventor has strongly increased since 2000 and grown with a CAGR of 26%. The sub-set of patents with a Chinese inventor and a foreign, i.e. non-Chinese applicant has grown at a smaller, yet impressive rate of 19%. While in 2000 two out of three patents (61%) of patents with a Chinese inventor had a foreign applicant, that share has dropped to one out of four patents (25%). This shows us two things: first, China has grown in high relevance as a R&D location for foreign firms and second, Chinese firms themselves have increased their patent numbers immensely.

[343] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 5-23: Total and Host-Country Patent Shares for Chinese Inventors by IPC[344]

IPC Class	Share of CN Inventors in Worldwide Patents (%)		Share of HCPs to all patents of CN Inventors (%)	
	2000	**2015**	**2000**	**2015**
H04: Electric Communication	0.4	17.4	44.8	24.0
G06: Computing	0.2	9.6	71.4	21.1
A61: Medical	0.3	4.2	52.7	26.6
C07: Chemistry	0.4	6.9	65.3	32.0
C08: Organic Compounds	0.3	3.9	47.1	65.3
H01: Electric Elements	0.2	6.4	66.7	19.1
G01: Measuring	0.2	3.4	75.0	20.7
C09: Paints	0.1	2.8	100	71.9
B01: Processes	0.6	3.4	82.8	42.4
H02: Electric Power	0.1	5.1	33.3	23.2

The share of patents with a China-based inventor across all relevant technological fields has increased from negligible figures of less than 1% in 2000 to, partly, two-digit shares in 2015. The most relevant technological field, both in terms of absolute patent numbers, as well as worldwide share is Electric Communications, followed at a distance by Computing. Other relevant technical field is Electric Elements. From the natural sciences Medical, Chemistry, Organic Compounds and Paints stand out. For the engineering side we have measuring. The IPC class G01, being the first class in the section G (Physics) is a rather general class encompassing measuring instruments and other signaling or control devices dealing with measurement or testing.

The share of HCPs to all patents with a China-based inventor has mostly dropped strongly between 2000 and 2015, yet remains at relatively high rates: while in earlier years China was very dependent on foreign MNCs to conduct R&D in China and subsequently patent. In more recent years Chinese MNCs have stepped up and file an increasing share of patents.

[344] Source: Own analysis, based on REGPAT database by the OECD (2020h).

5.3.2. India Inward Host-Country Patents

This part summarizes the inward international patenting activities of foreign firms in India. As shown in Table 5-1, India, the uprising emerging country, ranked seventh in number of inward HCPs in the 2015-2017 period and second across all emerging countries.

Table 5-24: Development of Indian Inward Host-Country Patents[345]

		Inward Host-Country Patents, India	2000-2002	2006-2008	2011-2013	2015-2017	*CAGR '00-'17 (%)*	*Share HCPs '15-'17 (%)*
		Total Patents	1,646	4,491	7,544	8,684	*13.8*	-
		Total Host-Country Patents	487	1,782	3,678	4,270	*15.5*	-
		Share Host-Country Patents (%)	*29.6*	*39.7*	*48.8*	*49.2*	-	-
HCPs with Applicants from	Developed Countries	United States	263	927	2,072	2,248	*15.0*	*52.6*
		Netherlands	84	207	285	372	*13.3*	*8.7*
		United Kingdom	79	190	216	261	*10.1*	*6.1*
		Switzerland	11	104	220	244	*20.8*	*5.7*
		Germany	42	96	239	242	*10.7*	*5.7*
		Sweden	9	19	101	164	*17.4*	*3.8*
		France	18	56	134	123	*19.9*	*2.9*
		Finland	1	20	146	93	*24.0*	*2.2*
		Japan	3	7	32	76	*21.4*	*1.8*
		Ireland	3	8	18	68	*19.3*	*1.6*
	Emerging Countries	South Korea	0	81	163	261	-	*6.1*
		China	0	9	25	59	-	*1.4*
		Singapore	11	10	29	57	*10.3*	*1.3*
		Bermuda	0	9	3	19	-	*0.4*
		Israel	3	37	10	17	*9.9*	*0.4*
		Malaysia	0	5	12	7	-	*0.2*
		Iceland	0	41	4	5	-	*0.1*
		Cyprus	0	0	0	5	-	*0.1*
		Cayman Islands	0	5	2	4	-	*0.1*
		Hong Kong – China	1	4	0	4	*4.2*	*0.1*

[345] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

India's share of HCPs has strongly increased, with almost every second patent coming from a foreign applicant: the share increased from 30% to 50% in the periods 2000-2002 to 2015-2017.

We can observe a very high concentration of applicant countries, where the US is clearly leading and dominating incoming R&D activities. Other countries, including the emerging country Korea follows at a large distance. Following the US with 9% is the Netherland and with 6% the UK. India is one of the few countries, where it is not China which is leading for the emerging countries in terms of HCPs. Apart from a general lack of interest, strong political rivalries might guide China to focus its activities elsewhere.

India, being an emerging country, has experienced generally quite high growth rates in incoming HCPs, i.e. the respective CAGR is relatively high. Particularly outstanding, though, in terms of growth rate, is South Korea, followed by Switzerland, which both have grown their number of HCPs with a CAGR of over 20% each.

Host-Country Patents by Technological Field

Table 5-25: Host-Country Patent Breakdown for Indian Inventors by IPC[346]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	230	814	1,498	1,709	14.3
Total Host-Country Patents	100	493	1,058	1,110	17.4
Share Host-Country Patents (%)	*43.5*	*60.6*	*70.6*	*65.0*	-
H04: Electric Communication	13	91	238	239	21.4
G06: Computing	10	69	214	213	22.6
A61: Medical	26	87	129	160	12.9
C07: Chemistry	22	93	103	109	11.3
G01: Measuring	7	14	62	64	15.9
C08: Organic Compounds	8	38	58	58	14.1
F01: Machines	0	7	82	57	..
H01: Electric Elements	7	38	31	57	15.0
A01: Agriculture	1	13	21	49	29.6
H02: Electric Power	3	20	36	45	19.8

Note: Full-counting leads to some double counting.

India has, typical for an emerging economy, strong growth rates both for the total patent numbers and for the respective technological fields between 2000 and 2015. Between 2012 and 2015 the total number of patents grew stronger than the Host-Country Patents, meaning that after an overall increase in share until 2012, we can observe a decrease to 65% until 2015. In other words: two out of three patents with an Indian inventor have a foreign-based applicant. This shows that relatively speaking foreign firms are quite active in India, whereas Indian firms have yet to increase their own capabilities and patent numbers. The more recent developments, i.e. between 2012 and 2015, can, however, be indicative of a paradigm shift.

[346] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 5-26: Total and Host-Country Patent Shares for India Inventors by IPC[347]

	Share of IN Inventors in Worldwide Patents (%)		Share of HCPs to all patents of IN Inventors (%)	
IPC Class	**2000**	**2015**	**2000**	**2015**
H04: Electric Communication	0.1	1.6	81.3	80.2
G06: Computing	0.1	2.2	62.5	59.7
A61: Medical	0.5	1.5	28.9	48.2
C07: Chemistry	0.7	3.1	26.8	45.4
G01: Measuring	0.1	0.8	58.3	64.0
C08: Organic Compounds	0.3	1.6	57.1	65.9
F01: Machines	0.0	1.8	-	98.3
H01: Electric Elements	0.1	0.6	70.0	82.6
A01: Agriculture	0.4	1.8	10.0	87.5
H02: Electric Power	0.1	1.0	100	88.2

The strongest technological fields are in ICT and technology, namely Electric Communication, Computing and Electric Elements. Medical, Chemistry and Organic Compounds also plays a somewhat relevant role. The share of patents with an India-based inventor has increased from less than 1% in 2000 to a somewhat visible one-digit rate in 2015 for several fields.

The unsurprisingly high share, for an emerging country, of HCPs to all patents with an India-based inventor has increased until 2015 for many fields, indicating that MNCs play a strongly growing role for conducting R&D in India.

5.3.3. Israel Inward Host-Country Patents

This part summarizes the inward international patenting activities of foreign firms in Israel. As shown in Table 5-1, Israel, a close political ally of the US, ranked twelfth in number of inward HCPs in the 2015-2017 period.

[347] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 5-27: Development of Israeli Inward Host-Country Patents[348]

Inward Host-Country Patents, Israel			2000-2002	2006-2008	2011-2013	2015-2017	*CAGR '00-'17 (%)*	*Share HCPs '15-'17 (%)*
Total Patents			4,619	6,417	6,417	7,303	*2.2*	-
Total Host-Country Patents			1,299	1,621	2,224	2,193	*2.3*	-
Share Host-Country Patents (%)			*28.1*	*25.3*	*34.7*	*30.0*	-	-
HCPs with Applicants from	Developed Countries	United States	945	1,115	1,711	1,490	*1.3*	*67.9*
		Netherlands	49	38	92	261	*9.6*	*11.9*
		Germany	31	69	32	60	*3.9*	*2.7*
		United Kingdom	78	75	65	52	*-2.2*	*2.4*
		Switzerland	21	103	45	44	*7.8*	*2.0*
		France	9	19	25	26	*7.9*	*1.2*
		Luxembourg	1	7	22	22	-	*1.0*
		Italy	2	7	11	14	-	*0.6*
		Canada	24	19	11	11	*-4.4*	*0.5*
		Australia	5	5	5	9	*2.4*	*0.4*
	Emerging Countries	Singapore	4	11	27	21	*11.1*	*1.0*
		China	0	6	6	16	-	*0.7*
		Russia	5	7	3	15	*15.7*	*0.7*
		Cyprus	9	16	12	14	*0.0*	*0.6*
		Bermuda	9	19	22	10	*9.9*	*0.5*
		Hong Kong – China	4	13	9	9	*6.7*	*0.4*
		Cayman Islands	4	3	3	9	*-1.7*	*0.4*
		Chinese Taipei	0	4	4	9	-	*0.4*
		Poland	0	0	4	7	-	*0.3*
		Croatia	0	0	0	5	-	*0.2*

Israel, a small country with a strong national innovation system, has a moderately high share of HCPs. The share of HCPs has increased from 28% in the period 2000-2002 to 30% in 2015-2017, with a peak of 35% in 2011-2013.

[348] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

It comes as little surprise that the US, a close strategic ally of Israel dominates the incoming patenting activities with two out of three HCPs coming from a US applicant. Other countries follow at a large distance. The only other somewhat relevant partner country is the Netherlands with 12% of all HCPs in 2015-2017.

The Netherlands has increased its HCPs in Israel the strongest, with a CAGR of 10%, making the country the second-biggest partner in terms of HCPs in 2015-2017. Other strongly growing countries are France and Switzerland, with a CAGR of 8% each, and Germany with 4%. These three countries do not have a significant absolute number of HCPs in Israel, though.

Host-Country Patents by Technological Field

Table 5-28: Host-Country Patent Breakdown for Israeli Inventors by IPC[349]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	1,168	1,397	1,458	1,625	2.2
Total Host-Country Patents	446	414	493	485	0.6
Share Host-Country Patents (%)	*38.2*	*29.6*	*33.8*	*29.8*	-
G06: Computing	115	92	141	122	0.4
A61: Medical	152	162	126	121	-1.5
H04: Electric Communication	131	59	162	114	-0.9
G03: Photography	25	13	20	42	3.5
G01: Measuring	49	28	39	39	-1.5
C07: Chemistry	45	44	18	29	-2.9
B41: Printing	17	15	15	21	1.4
H01: Electric Elements	26	12	19	17	-2.8
C09: Paints	1	7	14	17	20.8
C12: Biochemistry	40	29	22	16	-5.9

Note: Full-counting leads to some double counting.

Israel's Host-Country Patents have only slightly increased in number between 2000 and 2015, whereas the number of total patents, i.e. all patents with an Israeli inventor, regardless of

349 Source: Own analysis, based on REGPAT database by the OECD (2020h).

applicant, have increased at a higher rate. Consequently, the share of HCPs has decreased from 38% in 2000 to 29% in 2015.

Table 5-29: Total and Host-Country Patent Shares for Israeli Inventors by IPC[350]

IPC Class	Share of IL Inventors in Worldwide Patents (%) 2000	2015	Share of HCPs to all patents of IL Inventors (%) 2000	2015
G06: Computing	1.8	1.9	54.8	40.8
A61: Medical	2.1	2.6	37.4	20.6
H04: Electric Communication	1.9	1.2	45.0	51.6
G03: Photography	1.7	4.1	56.8	68.9
G01: Measuring	1.3	1.4	34.8	22.5
C07: Chemistry	1.3	1.2	32.1	30.2
B41: Printing	1.3	2.6	51.5	53.8
H01: Electric Elements	0.5	0.6	43.3	23.6
C09: Paints	0.1	0.9	50.0	54.8
C12: Biochemistry	1.5	1.8	37.0	17.4

A majority of major technological fields are technical in nature: Computing, Electric Communication and Measuring. For Photography Israel accounts for 4% of all HCPs in that field. We have already discussed that IPCs and industries can only be indirectly linked, so it is unclear whether Photography stems from civilian development, or, more likely from defense and reconnaissance areas, which are strong in Israel. Medical, despite decreasing HCP patent numbers, holds a noticeable and increasing global share of almost 3%. Two additional and rather unusual fields in which Israel has a noticeable number of HCPs are Printing and Paints.

The share of HCPs to all patents with an Israel-based inventor is high, but not as high, as for many other emerging countries and partly decreasing, indicating that Israeli MNCs also hold a relevant, or even growing share in conducting R&D activities in Israel.

[350] Source: Own analysis, based on REGPAT database by the OECD (2020h).

5.3.4. South Korea Inward Host-Country Patents

This part summarizes the inward international patenting activities of foreign firms in South Korea. As shown in Table 5-1, South Korea, an uprising Asian nation, was on rank 15 in number of inward HCPs in the 2015-2017 period.

Table 5-30: Development of South Korean Inward Host-Country Patents[351]

Inward Host-Country Patents, South Korea		**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	***CAGR ’00-’17 (%)***	***Share HCPs ’15-’17 (%)***
Total Patents		6,937	21,342	34,993	45,276	*12.7*	-
Total Host-Country Patents		376	805	1,328	1,321	*8.4*	-
Share Host-Country Patents (%)		*5.4*	*3.8*	*3.8*	*2.9*	-	-
HCPs with Applicants from – Developed Countries	United States	239	423	601	621	*5.7*	*47.0*
	Japan	52	124	155	199	*13.9*	*15.1*
	Sweden	6	2	204	115	*9.0*	*8.7*
	Germany	15	58	82	101	*15.9*	*7.6*
	Netherlands	4	8	14	46	*5.9*	*3.5*
	France	6	19	40	45	*12.6*	*3.4*
	Belgium	0	17	29	41	-	*3.1*
	Switzerland	1	15	18	22	*15.1*	*1.7*
	Finland	3	6	3	14	*13.0*	*1.1*
	United Kingdom	6	10	13	12	*5.9*	*0.9*
HCPs with Applicants from – Emerging Countries	China	18	43	56	47	*17.4*	*3.6*
	Singapore	5	15	41	18	*13.8*	*1.4*
	Saudi Arabia	0	2	1	11	-	*0.8*
	Hong Kong – China	2	15	17	7	*2.4*	*0.5*
	Malaysia	0	1	1	4	-	*0.3*
	India	0	0	0	3	-	*0.2*
	Thailand	0	0	1	1	-	*0.1*
	Philippines	0	0	0	1	-	*0.1*
	Lithuania	0	0	0	1	-	*0.1*
	Bosnia & Herzegovina	0	0	0	1	-	*0.1*

[351] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

South Korea has a quite low share of HCPs, which even decreased over the years: from 5% in 2000-2002 to 3% in 2015-2017. The number of HCPs has increased from 376 to 1,321 in the same period, indicating that there is nascent interest in conducting R&D in South Korea, which is however not on a relevant scale compared to domestic patenting activities. In this regard, the situation in South Korea is quite similar to that of its close neighbor Japan, as described in Chapter 5.2.6.

The biggest partner country for Korea is the US, with 47% of all HCPs, followed by Japan with 15%. Other somewhat relevant countries are European, namely Sweden with 9% and Germany with 8%. China accounts for 4% of all HCPs.

Being an emerging country, overall growth rates in HCPs is rather high with an average CAGR of 8%. China and Germany have grown particularly strong, with a CAGR of 17% and 16% respectively. Japan has grown at a strong rate of 14%, making it the second-biggest partner country in terms of HCP. The US are a rather strong historic partner with a CAGR of comparably low 6%.

Host-Country Patents by Technological Field

Table 5-31: Host-Country Patent Breakdown for South Korean Inventors by IPC[352]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	1,309	4,906	6,266	6,753	11.6
Total Host-Country Patents	96	314	382	354	9.1
Share Host-Country Patents (%)	*7.3*	*6.4*	*6.1*	*5.2*	-
H04: Electric Communication	21	72	163	77	9.0
H01: Electric Elements	19	39	73	69	9.0
A61: Medical	10	25	39	47	10.9
G06: Computing	13	20	32	38	7.4
C07: Chemistry	11	25	25	34	7.8
C09: Paints	6	23	10	26	10.3
G01: Measuring	5	17	14	22	10.4
C08: Organic Compounds	3	9	12	17	12.3
G02: Optics	4	8	10	17	10.1
B01: Processes	1	8	11	14	19.2

Note: Full-counting leads to some double counting.

As several other emerging economies, we can see in South Korea strong growth rates, both in total patent numbers, as well as within the industrial fields. The strong increase in Host-Country Patent numbers is surpassed by a stronger increase in Total Patents, i.e. all patents with at least one South Korean-based inventor. That means that the already rather small share of HCPs decreased over the years, namely from 7% in 2000 to 5% in 2015. Nevertheless, the number of HCPs has more than tripled in the 15 years between 2000 and 2015, whereas the overall relevance of HCPs with South Korean inventors has remained rather small.

352 Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 5-32: Total and Host-Country Patent Shares for South Korean Inventors by IPC[353]

IPC Class	Share of KR Inventors in Worldwide Patents (%)		Share of HCPs to all patents of KR Inventors (%)	
	2000	2015	2000	2015
H04: Electric Communication	2.1	8.4	6.3	4.9
H01: Electric Elements	1.3	10.4	11.9	5.8
A61: Medical	0.8	3.3	6.6	6.4
G06: Computing	1.6	7.0	7.0	3.4
C07: Chemistry	1.1	4.4	9.2	10.0
C09: Paints	0.9	6.0	20.0	12.7
G01: Measuring	0.6	2.7	8.1	6.6
C08: Organic Compounds	1.6	6.0	3.4	5.1
G02: Optics	1.7	9.5	6.0	4.4
B01: Processes	0.8	3.8	2.4	8.2

Technical fields are leading, including Electric Communication, Electric Elements and Computing. For Electric Elements, patents with a South Korean-based inventor account for over 10% of worldwide patents in 2015. Medical, Chemistry and Organic Compounds have strongly increased, with a noticeable one-digit share in patents. Paints can be considered technologically related to Chemistry, also indicated by the code (C07 is close to C09).

The share of HCPs to all patents with a South Korean-based inventor is comparably small and partly decreasing. South Korean MNCs play a big role in conducting R&D in the country, compared to foreign MNCs. This observation is somewhat comparable to the geographically close Japan, outlined in Chapter 5.2.6.

5.3.5. Singapore Inward Host-Country Patents

This part summarizes the inward international patenting activities of foreign firms in Singapore. As shown in Table 5-1, Singapore, an island-city state, was on rank 16 in number of inward HCPs in the 2015-2017 period.

353 Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 5-33: Development of Singaporean Inward Host-Country Patents[354]

Inward Host-Country Patents, Singapore		**2000-2002**	**2006-2008**	**2011-2013**	**2015-2017**	***CAGR '00-'17 (%)***	***Share HCPs '15-'17 (%)***
Total Patents		1,110	2,133	2,696	3,117	*7.2*	-
Total Host-Country Patents		395	782	1,089	1,280	*9.0*	-
Share Host-Country Patents (%)		*35.6*	*36.7*	*40.4*	*41.1*	-	-
HCPs with Applicants from – Developed Countries	United States	146	324	485	693	*9.5*	*54.1*
	Japan	49	95	102	108	*19.6*	*8.4*
	Germany	86	125	138	107	*4.2*	*8.4*
	France	21	40	64	91	*7.0*	*7.1*
	Switzerland	14	33	69	62	*10.7*	*4.8*
	Netherlands	5	44	34	51	*13.6*	*4.0*
	United Kingdom	15	33	35	26	*3.3*	*2.0*
	Denmark	0	26	37	16	-	*1.3*
	Australia	15	10	11	9	*-2.4*	*0.7*
	Italy	3	10	1	8	*6.7*	*0.6*
HCPs with Applicants from – Emerging Countries	China	4	6	34	52	*17.3*	*4.1*
	Chinese Taipei	0	4	1	16	-	*1.3*
	India	1	2	3	12	*10.6*	*0.9*
	South Korea	4	4	6	12	*6.7*	*0.9*
	Hong Kong – China	2	6	14	11	*7.6*	*0.9*
	Malaysia	6	3	4	9	*3.3*	*0.7*
	Israel	1	1	7	7	*6.7*	*0.5*
	Bermuda	0	1	11	5	-	*0.4*
	United Arab Emirates	0	0	4	5	-	*0.4*
	Saudi Arabia	0	1	2	3	-	*0.2*

Singapore, an uprising emerging country, has a comparably high share of HCPs. The share of HCPs has increased from 26% in the period 2000-2002 to 41% in 2015-2017.

The by far strongest partner country in Singapore in terms of HCPs is the US with 54%, meaning that more than every second patent with a Singaporean inventor and foreign applicant comes from a US firm. Japan and Germany follow with a share of 8% each. France

[354] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

accounts for 7% and Switzerland for 5%. China is the leading emerging country and ranks sixth on the overall scale with a share of 4%.

Being an emerging country, the growth rates of HCPs per country are relatively high, with an average of 9%. Yet some countries stand out particularly: The strongest growing partner countries are Japan with a CAGR of 20% and China with 17%. Switzerland has increased its number of HCPs with a CAGR of 11% and the US has increased slightly above average with a CAGR of 9%[355]

Host-Country Patents by Technological Field

Table 5-34: Host-Country Patent Breakdown for Singaporean Inventors by IPC[356]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	197	358	404	490	6.3
Total Host-Country Patents	116	220	246	292	6.3
Share Host-Country Patents (%)	*58.9*	*61.5*	*60.9*	*59.6*	-
A61: Medical	9	40	53	65	14.1
G01: Measuring	12	9	24	39	8.2
G06: Computing	13	15	32	37	7.2
H01: Electric Elements	29	33	28	29	0.0
H04: Electric Communication	18	40	22	24	1.9
B01: Processes	6	9	20	17	7.2
C08: Organic Compounds	6	16	19	17	7.2
E21: Mining	2	2	7	16	14.9
C07: Chemistry	7	27	17	15	5.2
G02: Optics	5	7	8	12	6.0

Note: Full-counting leads to some double counting.

355 The CAGR for the US is 9.466% which rounds to 9.5% or 9%.

356 Source: Own analysis, based on REGPAT database by the OECD (2020h).

The small state of Singapore highly depends on foreign R&D activities. Both the number of total patents and Host-Country Patents has grown in step, leading to a quite constant share of HCPs of around 60% between 2000 and 2015.

Table 5-35: Total and Host-Country Patent Shares for Singaporean Inventors by IPC[357]

	Share of SG Inventors in Worldwide Patents (%)		**Share of HCPs to all patents of SG Inventors (%)**	
IPC Class	**2000**	**2015**	**2000**	**2015**
A61: Medical	0.1	0.6	47.4	52.4
G01: Measuring	0.2	0.5	66.7	59.1
G06: Computing	0.3	0.5	39.4	46.8
H01: Electric Elements	0.3	0.4	72.5	67.4
H04: Electric Communication	0.2	0.2	62.1	57.1
B01: Processes	0.1	0.7	100	51.5
C08: Organic Compounds	0.1	0.4	75.0	85.0
E21: Mining	0.3	1.6	100	84.2
C07: Chemistry	0.1	0.6	46.7	34.1
G02: Optics	0.1	0.4	100	66.7

The strongest technological field in HCPs is Medical with 65 HCPs in 2015. Technical industries, namely Computing, Electric Elements, Electric Communication are quite relevant. Measuring and Processes are a quite broad field in the section G (Physics) and B (Performing Operations, Transportation), respectively. Mining is a technological field rather unusual to show up as leading Top-10 technological field for a country, although a HCP-number of 16 in 2015 is not necessarily high and therefore could lead us to an overestimation of that field. Mining is also the only technological field where the share of patents with a Singapore-based inventor is >1%, precisely 1.6%.

The share of HCPs to all patents with a Singapore-based inventor is mostly very high, indicating that it is mostly foreign MNCs which conduct R&D in Singapore. Overall, patents seem to be rather distributed across technological fields, with no clear dominance appearing.

[357] Source: Own analysis, based on REGPAT database by the OECD (2020h).

5.3.6. Russia Inward Host-Country Patents

This part summarizes the inward international patenting activities of foreign firms in Russia. As shown in Table 5-1, Russia, was on rank 17 in number of inward HCPs in the 2015-2017 period.

Table 5-36: Development of Russian Inward Host-Country Patents[358]

		Inward Host-Country Patents, Russia	2000-2002	2006-2008	2011-2013	2015-2017	*CAGR '00-'17 (%)*	*Share HCPs '15-'17 (%)*
Total Patents			2,079	2,784	3,861	3,669	*3.7*	-
Total Host-Country Patents			735	938	1,260	1,146	*2.2*	-
Share Host-Country Patents (%)			*35.4*	*33.7*	*32.6*	*31.2*	-	-
HCPs with Applicants from	Developed Countries	United States	264	326	575	602	*5.0*	*52.5*
		Germany	102	96	155	91	*0.4*	*7.9*
		Switzerland	22	38	60	75	*2.0*	*6.5*
		Netherlands	25	138	94	73	*6.7*	*6.4*
		France	22	115	98	71	*13.0*	*6.2*
		United Kingdom	45	32	43	41	*-2.4*	*3.6*
		Canada	26	10	13	18	*-5.8*	*1.6*
		Finland	11	27	21	13	*7.6*	*1.1*
		Italy	5	9	22	10	*0.0*	*0.9*
		Japan	24	59	16	9	*-4.0*	*0.8*
	Emerging Countries	South Korea	22	22	31	50	*5.7*	*4.4*
		Cyprus	7	21	25	22	*3.5*	*1.9*
		China	2	0	8	20	*10.5*	*1.7*
		Ukraine	19	52	10	17	*1.1*	*1.5*
		Israel	40	15	6	13	*-11.2*	*1.1*
		Kazakhstan	2	1	6	12	*6.7*	*1.0*
		Estonia	2	10	2	7	*4.2*	*0.6*
		Hong Kong – China	2	3	2	7	*6.7*	*0.6*
		Singapore	0	3	2	6	-	*0.5*
		Seychelles	0	4	12	4	-	*0.3*

[358] Own analysis, based on PCT patent-data by MSTI – OECD (2020c).

Russia, the by far largest country in the world by area, and an emerging country by economic strength, has a relatively high share of HCPs. This share has decreased from 35% in the period 2000-2002 to 31% in 2015-2017. The number of HCPs in that period has increased from 735 to 1,146, indicating that while foreign presence is strong and relevant in Russia, domestic patenting activities grow at a relatively stronger rate.

Interestingly enough, over half of all HCPs, i.e. 53% of all HCPs come from Russia's political rival, the US. Second place in terms of HCP numbers in the latest 2015-2017 period goes to Germany with 8%, a country which is one of Russia's closes Western business partners[359] Switzerland follows at 7%, the Netherlands and France at 6% each. South Korea is the only relevant and leading emerging country with a share of 4%, and the UK, another political adversary of Russia follows at 4%.

The overall number of HCPs in Russia has grown with a CAGR of 2%, which is rather low, particularly considering that Russia is an emerging country, for which we have seen much higher CAGRs in the previous chapters.

France, or more precisely patent numbers by French applicants with Russia-based (co-)inventors, has grown comparably strong with a CAGR of 13%. China, while accounting for a negligible amount of only 20 HCPs in the 2015-2017 period, has grown strongly with a CAGR at 11%. Recent geopolitical developments and closer cooperation between Russia and China might increase this trend further. South Korea, another emerging country has grown its HCPs with CAGR of 6%.

Cyprus, a Mediterranean island country, accounts for a certain number of HCPs, which might be attributable to its tax-friendly regime.[360]

Relevant developed countries with above-average CAGR, include the Netherlands with 7% and the US with 5%.

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[359] Cf. German Federal Foreign Office (2020). Despite current political tensions between Germany and Russia, both countries share a deep interlinked history, e.g. Trenin (2018).

[360] Cf. Deloitte (2020); Effenberger (2017).

Host-Country Patents by Technological Field

Table 5-37: Host-Country Patent Breakdown for Russian Inventors by IPC[361]

IPC Class	Number of HCPs per Priority Year 2000	2007	2012	2015	CAGR '00-'15 (%)
Total Patents	292	319	449	364	1.5
Total Host-Country Patents	195	181	261	185	-0.4
Share Host-Country Patents %	*66.8*	*56.7*	*58.1*	*50.8*	-
G06: Computing	11	7	24	45	9.8
H04: Electric Communication	21	10	61	42	4.7
A61: Medical	23	46	51	30	1.8
H01: Electric Elements	30	16	22	12	-5.9
G01: Measuring	23	22	32	10	-5.4
C08: Organic Compounds	12	5	14	9	-1.9
G02: Optics	16	5	1	8	-4.5
C07: Chemistry	23	28	24	7	-7.6
B01: Processes	23	5	10	7	-7.6
C12: Biochemistry	20	14	9	7	-6.8

Note: Full-counting leads to some double counting.

Russia, an emerging country, has unusually decreased both in absolute and relative relevance as a location for foreign R&D and is one of the few countries with a negative CAGR for HCPs. Consequently, the share of HCPs decreases from 67% in 2000 to 51% in 2018. After increases in HCP-numbers until 2012, we can see particularly 2012 and 2015 declines in patent number for several technological fields.

[361] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 5-38: Total and Host-Country Patent Shares for Russian Inventors by IPC[362]

IPC Class	Share of RU Inventors in Worldwide Patents (%)		Share of HCPs to all patents of RU Inventors (%)	
	2000	**2015**	**2000**	**2015**
G06: Computing	0.2	0.5	61.1	53.6
H04: Electric Communication	0.2	0.3	80.8	70.0
A61: Medical	0.2	0.3	47.9	47.6
H01: Electric Elements	0.3	0.1	83.3	75.0
G01: Measuring	0.3	0.2	79.3	47.6
C08: Organic Compounds	0.2	0.3	100	64.3
G02: Optics	0.5	0.2	84.2	88.9
C07: Chemistry	0.3	0.2	76.7	50.0
B01: Processes	0.5	0.3	88.5	58.3
C12: Biochemistry	0.3	0.3	90.9	43.8

Russia has the most HCPs in Computing with a particularly strong increase between 2012 and 2015. Overall 0.5% of all patents in that field have a Russia-based (co-)inventor in 2015. Electric Communication, the second-biggest field in 2016 displays a drop in HCP-numbers by one third between 2012 and 2015, but has slightly increased in worldwide share. Medical is another industry where the share in worldwide HCPs has slightly increased. Other fields are small in absolute HCP numbers and decreased their worldwide shares quite significantly. Adding the mostly decreasing share of HCPs to all patents with a Russia-based inventor, we can see that Russia is clearly of increasingly small interest for foreign R&D activities. Similar to Singapore, patents seem to be rather distributed across technological fields, with no clear dominance appearing.

5.4. Conclusion Outward & Inward Host-Country Patents

In this part, I summarize and condense the major findings from the two previous sub-chapters, i.e. the analysis of Outward HCPs in Chapter 4 and the analysis of Inward HCPs in Chapter 5.

[362] Source: Own analysis, based on REGPAT database by the OECD (2020h).

The analysis of Host-Country Patents reveals several main trends and conclusions in patent internationalization over time. We can observe changes and shifts, justifying not a static, but this dynamic analysis.

1. **Firms stay close**: A significant share of foreign collaboration occurs with inventors from countries which are either geographically close (e.g. European Union) or politically / economically or historically close (USA and Israel, UK and India). In several cases we can explain strong connections of HCP with strong political bonds, such as Germany-France or USA-Canada. In other cases, countries account for high shares in HCPs, despite political distances, such as USA-Russia.
   This fuels the hypothesis that R&D internationalization is not an isolated and unsystematic phenomenon, but that there rather is a tendency to "stay close" in order to exploit existing channels. This closeness might be attributable to cooperation on other levels, such as political, e.g. Airbus in Germany & France and indicates that R&D Internationalization has to be analyzed holistically in connection with other forms of collaboration. Furthermore, we can observe that patenting is somewhat reciprocal across countries, i.e. we see that if country A holds lots of HCPs with country B, the opposite holds true (e.g. France → Germany and Germany → France). The reasons and motivators to conduct R&D strongly with a particular partner country can be valid in both directions.
2. **Emerging Countries are relevant**: Emerging economies, most notably China and India, have greatly increased in significance as hosts or destinations for foreign R&D Internationalization activities. This means that we can see from patent filings that foreign MNCs increasingly conduct inventive activities in emerging countries. While R&D Internationalization into developed countries is still relevant, host-county patent numbers mostly grow, if even, with one-digit annual growth rates, R&D Internationalization into emerging countries has grown at very high rates.
   Emerging countries are not only relevant as a host, but also increasingly as a home country: some emerging countries, particularly China, have benefited from the influx of knowledge and in turn started to internationalize their own R&D to other countries – mostly with two-digit annual growth rates. That means that Chinese MNCs conduct R&D in other countries, including developed nations.

The relative importance of developed host-countries has decreased in favor of emerging countries. Not all emerging countries are similarly attractive as R&D hosts for foreign MNCs though, so it would be incorrect to regard this group as homogenous: while, for example China and India have succeeded in attracting foreign R&D activities in relevant fields, other countries, such as Russia have failed to do so and lost in attractiveness over the last years, as displayed by drops in Host-Country Patent numbers.

3. **Emerging Countries are selective**: Developed countries invest R&D in numerous other relevant economies, but emerging economies are much more selective. Companies from these countries, mostly China, invest in R&D only at a handful of countries e.g. the US or Germany. Countries in the second line, for example France or the UK do not seem to have a particular appeal to emerging country firms. It could be argued, that with a lack of historic or other ties (see point 1) and reasons to invest in a certain country, emerging economy firms focus their, sometimes scarce, resources on the most relevant economies and markets from the first line. The observation of "reciprocity" (see point below) does not seem to hold for a developed – emerging country relationship.

   We can observe the selectiveness also in another aspect: R&D Internationalization into emerging countries by technological fields differs in pattern to R&D Internationalization into developed countries. For China and India most Host-Country Patents are in technological areas, whereas for developed countries Natural Sciences (Medical, Chemistry, Biotechnology) are mostly leading. We can often observe an increasing share of the leading fields in the worldwide patent share, indicating an increasing specialization and concentration. This supports the idea that R&D Internationalization, particularly into emerging countries, is very targeted and specific in order to capture specific competencies. Emerging economies which are also large markets and economies, such as China and India, are naturally at an advantage here, as they (also) can serve as relevant distribution and sales markets. It is therefore a somewhat trivial observation that the number of patents coincides with economic strength, whereas smaller economies (e.g. Switzerland) naturally have a generally higher share of HCPs, i.e. higher internationalization rate.

4. **Patent internationalization is concentrated**: Each home-country has a significant number of host-countries, where patent activities are being conducted. The number of respectively significant countries is, however, rather small: usually around ½ of all HCPs can be attributed to the respective top five or less host-countries. As introduced in the point 3, we can argue with the concept of “lead markets” that R&D Internationalization leads to an increasing specialization and concentration of strength, meaning that multinational corporations tend to conduct R&D in markets where they can capture best specific competencies in relevant fields.
5. **The US is strong but losing towards Asia**: Despite certain political changes in recent years and the uprise of other economies, the US is a constantly strong leader in worldwide patenting activities and in many cases the country with the largest share of HCPs. While this observation is of a trivial nature, the interesting finding is the increasing pressure and loss of share observable for the US in many areas: It will be interesting to repeat this analysis in a few years, to observe potential decreases by the US due to (re-)nationalization efforts by the US and aspiring activities by countries, such as China. This is indicated that while the absolute number of HCPs by US firm is often strong, the CAGR tends to be rather low, i.e. there have not been particular upswings in recent years, compared to other ambitious countries. The biggest uprise can be observed in several emerging Asian countries, most notably China, which has strongly both been invested in and invested in other countries. For most countries, China is the by far biggest emerging target country for R&D and China also invests strongly in numerous developed countries.

   This also means that the four BRIC-countries Brazil, Russia, India and China, once unified by their similar economic figures and potential have moved apart. China has catapulted itself as a highly sought-after host-country. The US now even have their most HCPs with China. India is also relevant for many economies, with HCP growth-rates in the double-digits. The other two BRIC-countries Brazil and Russia are relatively far behind as a location for foreign HCP. The term BRIC (or BRICS, when including South Africa) as a representation for emerging countries has lost its relevance.

6. Industry Trends and Shifts in R&D Expenditure Patterns

In this chapter the global R&D activities are broken down to their respective industries, in order to answer the following research questions:

RQ6.1:	What are the top R&D spending industries worldwide in 2000, 2007 and 2018?
RQ6.2:	What is the distribution of top R&D spending industries broken down to major economies?

6.1. Overview Top R&D Industries

R&D and innovation are characterized with a high degree of heterogeneity across industries, but also across firms within the same industry. Outlining the R&D Expenditures and R&D Intensity of industries over the years outlines structural changes, i.e. how some industries have risen and fallen in global relevance.

In the following overviews the R&D spending by industry is given. The tables are sorted decreasingly by the R&D spending of the most recent time-period of 2018 and complemented with data for 2010 and 2007.[363]

The analysis is based on data provided by the EU Commission's R&D Scoreboard, an annual data collection of the world's largest R&D spending companies. The number of companies analyzed in the scoreboard has been continuously increased from 500 companies in the first scoreboard of 2004 to currently 2500.[364] In Table 6-1 I show the business R&D Expenditure worldwide, as well as for the biggest 500, 1000 and 2500 firms for 2018 and outline why focusing on the Top 1000 / 2500 R&D spending companies is sufficiently precise, as it captures a major share of the (estimated) entirety. In fact, an absolute full data completeness could never be ensured, as particularly smaller and usually not publicly listed companies do not have the same reporting requirements as the big and listed firms.

[363] Note: Very shortly before printing this dissertation the Scoreboard covering business data from 2019 has been published by the European Commission (2020). A first analysis shows no surprising findings: The R&D Expenditures have continued to increase, particularly driven by ICT and Health industries. External shocks, as can be expected through the Covid-19 pandemic at a later point in time, are not apparent. The 2018 data therefore can still be considered sufficiently current.

[364] The scoreboard publishes data for the previous year. E.g. the Scoreboard 2004 provides data for 2003. Since the Scoreboard 2004 gives growth rates for the three previous years, it was possible to calculate the values for the year 2000.

Table 6-1: Overview Concentration of R&D Expenditure on Biggest Firms in 2018[365]

R&D Expenditure	Absolute Expenditure in m$	Share of R&D Expenditure (%)		
		Top 2500	Top 1000	Top 500
Worldwide (BERD)	1,266,399	76.8	68.9	61.5
Top 2500	972,473	-	89.7	80.1
Top 1000	872,222	-	-	89.3
Top 500	779,043	-	-	-

Note: Worldwide BERD calculated as sum of BERD by OECD and available Non-OECD countries (China, Russia and Taiwan).

We can observe a heavy concentration of R&D Expenditure on the biggest R&D spending firms: around 77% of the worldwide business R&D Expenditure comes from the largest 2500 firms. These 2500 firms are very concentrated on the top firms themselves: over 66% of the worldwide R&D Expenditure comes from the Top 1000 firms.

When looking at the Top 2500 firms, the Top 500, i.e. biggest 20% of the firms, account for 80% of the R&D Expenditure.

The EU estimates that the R&D Expenditure of the 2500 largest R&D spending firms in 2018 account for “approximately 90%” of the global BERD.[366] It remains unclear on which global figure this ratio is based on. As a global BERD is based on many assumptions and differing data sources, the true figures might deviate. However, the big picture remains: R&D Expenditure by businesses is heavily concentrated on the biggest firms worldwide.

Therefore, restricting the analysis on the Top 500, 1000 or 2500 firms does not distort the findings substantially, yet is required through the availability of data.

The industries are classified in sectors according to the ICB (Industry Classification Benchmark)[367] and NACE Rev. 2 standard.[368] Some category names differ slightly in labelling

365 Own analysis, based on EU R&D Scoreboards: European Commission (2019), MSTI database: Business-financed BERD – OECD (2020c); World Bank (2020): Exchange rates shown in Appendix-Table 6.

366 Scoreboard – European Commission (2019, p. 4).

367 Cf. FTSE Russell (2019).

368 NACE abbreviates a French name, which translates to “Statistical classification of economic activities in the European Community”. Cf. EUROSTAT (2008).

over the years and are harmonized, for clarity.[369] The tables show only the relevant industries of the analyzed years: from the over 30 industry categories of the Scoreboard, some, such as “Forestry & Paper”, do not have significant R&D activities. The technology level (high, medium, low) indicates the level of R&D complexity helps to further categorize and cluster industries.[370]

Some corrections in industry labelling are necessary, as the EU classification is, in parts, rather broad or imprecise. For example, Northrop Grumman is labelled under ‘Electronic & Electrical Equipment’, although the category ‘Aerospace & Defense’ would be much more accurate and in line with the business focus.[371]

In this chapter I will show the dynamics and diverse developments of R&D conducting industries. Namely we can observe a structural change towards more IT-related fields and away from classical manufacturing industries. Furthermore, we can observe a shift towards more high-tech fields over the years.

6.1.1. Current Distribution of R&D Expenditure

Table 6-2 gives an overview of the R&D Expenditure distribution of the Top 1000 firms in 2018 across technology level and industry.

[369] For example, the Scoreboard for the years 2000-2003 lists the category “Pharma & biotech (48)”, whereas for the year 2018 this industry is labelled “Pharmaceuticals & Biotechnology”. Both labels obviously describe the same industry.

[370] Cf. Hatzichronoglou (1997). The OECD differentiates between Medium-High-tech and Medium-Low-tech. For clarity these categories are subsumed under medium- and low-tech respectively.

[371] Cf. Northrop Grumman (2020).

Table 6-2: R&D Expenditure by Relevant Industries of Top 1000 Firms in 2018[372]

Technology Level & Industry		R&D Expenditure of Top 1000 Firms in m€	Share of total R&D Expenditure (%)
Total Top 1000 Firms		**738,539**	**100**
High-tech	Total High-tech	398,208	53.9
	Pharmaceuticals & Biotechnology	137,305	18.6
	Technology Hardware	120,062	16.3
	Software & Computer Services	108,107	14.6
	Aerospace & Defense	18,874	2.6
	Health Care Equipment & Services	13,860	1.9
Medium-tech	Total Medium-tech	268,735	36.4
	Automobiles & Parts	123,778	16.8
	Electronic & Electrical Equipment	56,544	7.7
	Industrial Engineering	22,996	3.1
	Chemicals	17,753	2.4
	General Industrials	17,748	2.4
	Construction & Materials	13,651	1.8
Low-tech	Total Low-tech	71,596	9.7
	Leisure	14,389	1.9
	Banks	11,267	1.5
	Oil & Gas	10,006	1.4

Note: Only relevant industries (R&D Expenditure > 10bn€) shown. For clarity and comparability, the Top 1000, instead of the Top 2500 companies are used here. The percentage-wise distribution across industries does not differ significantly when analyzing the Top 2500.

We can draw two major conclusions from the table: First, R&D Expenditure is concentrated in high technology industries: over half of the R&D Expenditure is spent within the few high-tech industries. Second, around 66%, is spent within the four biggest industries: Pharmaceuticals & Biotechnology, Technology Hardware, Software & Computer Services and Automobiles & Parts. These four industries are the only ones which individually account for a two-digit share

[372] Own analysis, based on EU R&D Scoreboard – European Commission (2019).

of total R&D Expenditure. The fifth largest R&D spending industry is Electronic & Electrical Equipment.

In the following sub-chapters, the growths across the years are shown to display the key changes, which are a shift towards high-tech industries and particularly IT-related fields, whereas traditional manufacturing industries became relatively less relevant in terms of R&D Expenditure.

6.1.2. Recent Developments in R&D Expenditure Distribution

In Table 6-3 the R&D Expenditures between 2007 and 2018 of the Top 1000 firms are compared. By calculating the respective Compound Annual Growth Rate (CAGR) we can see which industries have grown particularly in terms of their R&D Expenditure in the last decade and which have not. The figures, additionally visualized with an arrow, indicate the shift in relative importance.

The benchmark is the overall growth rate of 6.7% of all Top 1000 firms. The arrows indicate the development of each industry: industries with a CAGR of R&D Expenditure somewhat (↗) or particularly larger (↑) than this 6.7% benchmark are indicated with an upwards facing arrow and industries with a CAGR somewhat (↘) or particularly smaller (↓) than the benchmark with a downwards facing arrow.

Note: A potential distorting effect can be caused as the sample of firms is not identical over the years. Considering that over the years a multitude of factors can influence the status of a company (M&A, spin-off, bankruptcy etc.) only few companies continue with their same focus, and organizational structure over the years.

Table 6-3: Development of Top 1000 R&D Spending Companies by Industry[373]

Technology Level & Industry		R&D Expenditure in m€ 2007	2018	CAGR '07-'18 (%)	Develop-ment
Total Top 1000 Firms		360,063	738,539	6.7	-
High-tech	Total High-tech	181,513	398,208	7.4	↗
	Pharmaceuticals & Biotechnology	69,567	137,305	6.4	→
	Technology Hardware	66,151	120,062	5.6	↘
	Software & Computer Services	25,024	108,107	14.2	↑
	Aerospace & Defense	14,935	18,874	2.2	↓
	Health Care Equipment & Services	5,836	13,860	8.2	↗
Medium-tech	Total Medium-tech	132,027	268,735	6.7	→
	Automobiles & Parts	68,699	123,778	5.5	↘
	Electronic & Electrical Equipment	25,100	56,544	7.7	↗
	Industrial Engineering	4,342	22,996	16.4	(↑)
	Chemicals	15,838	17,753	1.0	↓
	General Industrials	7,861	17,748	7.7	↗
	Construction & Materials	1,898	13,651	19.6	(↑)
Low-tech	Total Low-tech	46,524	71,596	4.0	↓
	Leisure	13,622	14,389	0.5	↓
	Banks	2,729	11,267	13.8	↑
	Oil & Gas	7,023	10,006	3.3	↓

Note: Only relevant industries (R&D Expenditure > 10bn€) shown. Arrows show the development compared to the Global CAGR of the Total Top 1000 Firms. Developments marked in brackets have to be interpreted carefully and are discussed in the text below.

[373] Own analysis, based on EU R&D Scoreboards: European Commission (2019), European Commission (2008).

In terms of technology level, we can observe a shift away from low-tech, towards high-tech industries: in the last decade the high-tech industries have, on average, grown at a larger rate than low-tech, whereas medium-tech has grown at an average rate.

Within these classes of technology levels, we can observe significant differences.

- **Large increases:** The biggest increases, with a two-digit CAGR, are Software & Computer Services, Industrial Engineering, Construction & Materials, and Banks. The uprise in IT, driven by companies such as Alphabet (Google) or Facebook, explains the increase in R&D Expenditure in Software & Computer Services. The other industries are smaller in absolute numbers and require a closer look at a more detailed country-level breakdown in the following sub-chapters. The strong increases of Industrial Engineering and Construction & Materials is almost exclusively attributable to strong increases by Chinese (state-owned) corporations. It can be argued to what degree expenditures labelled as R&D by a construction firm are driven by signaling and regulatory effects.[374]
- **Large decreases:** The industries growing with an only small CAGR and well below the worldwide average of 6.7% are Aerospace & Defense, Chemicals and Leisure. These traditional, classical industries have lost in relative importance to the uprising industries named above.
- **Smaller changes:** The other industries, not named previously, have experienced a CAGR of comparably close to the worldwide average. A more detailed discussion and country-level breakdown will be required.

In a next step we replicate this analysis for a longer range to see structural developments and changes in a better way.

6.1.3. Long-term Developments in R&D Expenditure Distribution

I replicate the previous analysis, but include the year of earliest data availability from the Scoreboard: 2000. While the Scoreboard was first published in 2004 and therefore directly only includes data of 2003, it is possible to back-calculate the values for 2000 with the year-on-year growth rates. Due to the smaller sample sizes in the earlier Scoreboards, I analyze the Top 500 companies here. With a high concentration of R&D Expenditure on the largest firms, as shown in Table 6-1, the comparability to the Top 1000 firms as still given.

[374] Cf. Wu (2017).

The CAGR for all Top 500 from 2000 to 2018 and therefore the benchmark is 5.3%. Once again, the arrows indicate the respective development of the CAGR compared to this overall benchmark.

Table 6-4: Development of Top 500 R&D Spending Companies by Industry[375]

Technology Level & Industry		R&D Expenditure in m€ 2000	2007	2018	CAGR '00-'18 (%)	Develop-ment
Total Top 500 Firms		258,588	327,528	659,641	5.3	-
High-tech	Total High-tech	126,006	167,581	364,520	6.1	↗
	Pharmaceuticals & Biotechnology	38,843	65,727	126,026	6.8	↑
	Technology Hardware	61,356	60,976	113,376	3.5	↓
	Software & Computer Services	13,871	22,703	97,014	11.4	↑
	Aerospace & Defense	8,138	13,760	17,540	4.4	↓
	Health Care Equipment & Services	3,797	4,415	10,564	5.8	↗
Medium-tech	Total Medium-tech	110,683	119,307	239,727	4.4	↘
	Automobiles & Parts	48,891	67,219	118,299	5.0	→
	Electronic & Electrical Equipment	28,888	22,150	49,319	3.0	↓
	Industrial Engineering	7,223	2,350	17,771	5.1	(→)
	General Industrials	5,116	7,128	15,747	6.4	↗
	Chemicals	13,917	12,656	13,346	-0.2	↓
	Construction & Materials	1,623	1,055	12,045	11.8	(↑)
Low-tech	Total Low-tech	21,899	40,641	55,393	5.3	→
	Leisure	0	13,158	12,491	-	-
	Banks	0	2,207	9,528	-	-
	Oil & Gas	3,411	6,251	8,317	5.1	→

Note: Only relevant industries (R&D Expenditure > 8bn€) shown. Arrows show the development compared to the Global CAGR of the Total Top 500 Firms. Developments marked in brackets have to be interpreted carefully and are discussed in the text below.

[375] Own analysis, based on EU R&D Scoreboards: European Commission (2019), European Commission (2008), European Commission (2004).

We can make two major observations. First, in terms of technology level, we can observe a shift towards High-tech industries and away from Low-tech. Second, the overall CAGR is smaller for the period 2000-2018 compared to the period 2007-2018, as analyzed in Table 6-3. This indicates that a major boost in R&D Expenditure has occurred in the last decade. Therefore, we do not have a linear growth here, but rather an exponential one.[376]

Across the industries we can observe again significant differences:

- **Large increases:** The biggest increases are Software & Computer Services, Construction & Materials, and Pharmaceuticals & Biotechnology. Software & Computer Services has a higher CAGR for the more recent period 2007-2018, indicating that the biggest push in R&D Expenditure occurred in recent years, i.e. the last decade. A similar observation can be made for Construction & Materials, as the R&D Expenditure between 2000 and 2007 plummeted. For Pharmaceutical & Biotechnology the opposite holds true: the CAGR is higher for the whole period 2000-2018, indicating that in the beginning of the century we can observe a bigger growth, than in the last decade.
- **Large decreases:** The industries growing with an only small CAGR and well below the worldwide average of 5.3% are Aerospace & Defense, Chemicals, Technology Hardware and Electronic & Electrical Equipment. For the first two industries we have already made a similar observation for the period 2007-2018 in Table 6-3. For the last two industries we can observe a very clear drop in absolute R&D Expenditure between 2000 and 2007, explaining why the CAGR is comparably lower for the overall period 2000-2018, compared to the period 2007-2018.

Once again, we see the strong increases between 2007 and 2018 for Industrial Engineering and Construction & Materials. These industries drop in R&D Expenditure between 2000 and 2007, showing that the push generated by Chinese firms, discussed in the previous part, only occurred in recent years.

The conclusion stays largely the same: traditional, classical industries have lost in relative importance, with several experiencing a drop in absolute expenditure between 2000 and 2018. The biggest profiteers can be found in the high-tech sector, such as Software & Computer Services, although certain weak developments, for example by Aerospace & Defense, contribute to the cluster's heterogeneity.

[376] The sample size is different: In Table 6-3 the Top 1000 firms are analyzed, and in Table 6-4 the Top 500. However, the respective CAGR for the period 2007-2018, but only for the Top 500, are very similar. This means, that even with the exact same dataset, the conclusion does not change.

In the following we will look down in the developments of R&D Expenditure on a country level.

6.2. Relevant R&D Industries by Country

In the previous sub-chapter, I have analyzed the R&D Expenditures across industries. Their development and distribution across countries are certainly different, so in this chapter I break down the R&D Expenditures further by country. This step can help to understand which technological competencies countries develop and what their competitive competencies compared to other countries are.

In a first step I show the R&D Expenditures by country. Next, I break down the R&D Expenditures of relevant industries, as shown in the previous sub-chapter, by country to show which country has a focus on which industry. These relevant industries are the four industries which accounted for 66% of the global R&D Expenditure in 2018: the three high-tech industries Pharmaceuticals & Biotechnology, Technology Hardware, Software & Computer Services and the medium-tech industry Automobiles & Parts.

6.2.1. Aggregated R&D Expenditure by Country

The economic uprise of emerging countries in the last decades can be observes in R&D Expenditure, as well. Table 6-5 shows the distribution of R&D Expenditure between firms from developed and emerging countries.

Table 6-5: Distribution of R&D Expenditures between Country Types[377]

	Share of R&D Expenditure (%)		
Development Level	**2000**	**2007**	**2018**
Developed Countries	98.2	94.5	82.8
Emerging Countries	1.8	5.5	17.2

Note: Share of R&D Expenditure calculated as shares of Top 500 firms for 2000 and Top 1000 firms for 2007 and 2018.

In 2000 MNCs from emerging countries had practically no relevance in terms of R&D Expenditure: less than 2% were spent by companies from emerging countries. Of this amount almost 40% can be attributed to the R&D Expenditure of one single company: South Korean Samsung. Over the years firms from emerging countries have increased their share and

[377] Own analysis, based on EU R&D Scoreboards: European Commission (2019), European Commission (2008), European Commission (2004).

accounted for over 17% in 2018 of all R&D Expenses. In other words: almost every fifth Dollar on R&D has been spent by a company from an emerging country.

Table 6-6 breaks the R&D Expenditure further down to a country level, separated by developmental status and sorted decreasingly by the 2018 value. As in the previous subchapters, I compare the Top 1000 firms in 2007 and 2018. I indicate with an arrow the development of the CAGR of each listed country, compared to the global benchmark of 6.7%.

Table 6-6: Development of Top 1000 R&D Spending Companies by Country[378]

Development Level & Country		R&D Expenditure in m€ 2007	2018	CAGR '07-'18 (%)	Develop-ment
Total Top 1000 Firms		360,063	738,539	6.7	-
Developed Countries	Total Developed	340,103	611,656	5.5	↓
	US	138,466	286,693	6.8	→
	Japan	67,041	99,306	3.6	↓
	Germany	39,895	79,397	6.5	→
	France	24,586	29,080	1.5	↓
	Switzerland	14,258	26,463	5.8	↘
	UK	18,483	25,216	2.9	↓
	Netherlands	8,587	17,906	6.9	→
Emerging Countries	Total Emerging	19,960	126,883	18.3	↑
	China	1,234	76,805	45.6	↑
	South Korea	10,089	28,744	10.0	↑
	Taiwan	3,646	12,730	12.0	↑
	India	930	3,511	12.8	↑
	Israel	661	2,439	12.6	↑

Note: Only relevant countries shown: listed countries account for 93% of total R&D Expenditure in 2018. Arrows show the development compared to the Global CAGR of the Total Top 1000 Firms.

[378] Own analysis, based on EU R&D Scoreboards: European Commission (2019), European Commission (2008).

Firms from developed and emerging countries have undergone a substantially and structurally different development, so the interpretation is accordingly separated:

- **Developed Countries:** In general, developed countries have increased their CAGR at a lower rate compared to the global total. This means they have lost in share towards emerging countries. However, differences across countries can be observed:
  - USA, Japan and Germany consistently have the first three ranks in terms of R&D Expenditure. However only US, German (and Dutch) firms have more or less kept their share in R&D Expenditure, as the CAGR is comparable to the global total.
  - Japan, France and UK have significantly lost in relative relevance, with a CAGR much below the global total. Switzerland has somewhat lost in relative importance
- **Emerging Countries:** The emerging countries clearly justify the term “emerging” in terms of R&D Expenditure, with a two-digit CAGR each.
  - China has particularly increased its R&D Expenditures and ranks fourth in 2018. More than every tenth Dollar of R&D Expenditure worldwide has been spent by Chinese MNCs.
  - The other Emerging Countries have increased their R&D Expenditures at remarkable rates. However, in absolute terms of R&D Expenditure they still play a comparably smaller role.

In the following sub-chapters I scrutinize the R&D Expenditures of selected industries by country, in order to identify competencies and specializations.

6.2.2. R&D Expenditures in Pharmaceuticals & Biotechnology

In the following table, I break down the R&D Expenditure by firms in the industry Pharmaceuticals & Biotechnology in 2007 and 2018. For a very detailed company-level analysis, I will separate firm-level data for pharmaceutical and biotechnology companies, as the R&D structure can be quite different. For this purpose of a country-level analysis, however, I will stick to the categorization of the EU. I will show the high R&D expenditures by firms from developed countries, although Germany is the only developed country with growth rates above the global average. In turn, several emerging countries have strongly increased their R&D expenditures in this field.

The arrows indicate the development of R&D Expenditure compared to the total CAGR of 6.4%.

Table 6-7: Pharmaceuticals & Biotechnology R&D Expenditure by Country[379]

	Pharmaceuticals & Biotechnology	R&D Expenditure in m€ 2007	2018	CAGR '07-'18 (%)	Develop-ment
Total Pharma & Biotechnology		69,567	137,305	6.4	-
Developed Countries	Total Developed	68,854	132,348	6.1	↘
	US	34,202	65,866	6.1	↘
	Switzerland	9,644	18,236	6.0	↘
	Germany	2,947	10,879	12.6	↑
	Japan	5,519	10,698	6.2	→
	UK	8,399	9,323	1.0	↓
	France	4,784	7,296	3.9	↓
Emer. Countries	Total Emerging	713	4,957	19.3	↑
	China	0	2,512	-	↑
	Israel	397	1,059	9.3	↑
	India	183	1,013	16.8	↑

Note: Only relevant countries are shown. Sample drawn from Top 1000 MNCs. Arrows show the development compared to the Global CAGR of the Total Top 1000 Firms.

Overall, we can observe a slight shift from developed to emerging countries. These countries still account for a comparably little R&D Expenditure, but have shown strong growth rates. We can observe significant differences and developments across the countries.

- **Large increases:** The biggest absolute increase can be observed with Germany, which relatively gained strongly in the Pharmaceuticals & Biotechnology. Furthermore, the three relevant emerging countries China, Israel and India have all increased their R&D Expenditure in Pharmaceuticals and Biotechnology to more than 1 Billion EUR per year.
- **Large decreases:** With a CAGR far below the industry average, the developed countries UK and France have lost some relative importance in terms of R&D Expenditure in the industry Pharmaceuticals & Biotechnology.

[379] Own analysis, based on EU R&D Scoreboards: European Commission (2019), European Commission (2008).

- **Smaller changes:** The other countries, namely US, Switzerland and Japan have kept or only lost marginally their relative importance in the industry Pharmaceuticals & Biotechnology.

Conclusion: With only small shifts, the developed countries maintain a leading position in terms of R&D Expenditure, with Germany particularly pushing forward. China accounts for around a half of the R&D Expenditure by Emerging Countries.

6.2.3. R&D Expenditures in Technology Hardware

In the following table, I break down the R&D Expenditure by firms in the industry Technology Hardware in 2007 and 2018. I outline the complexity and heterogeneity of this highly complex field, requiring an additional analysis.

The arrows indicate the development of R&D Expenditure compared to the total CAGR of 5.6%.

Table 6-8: Technology Hardware R&D Expenditure by Country[380]

Technology Hardware		R&D Expenditure in m€ 2007	2018	CAGR '07-'18 (%)	Develop-ment
Total Technology Hardware		66,151	120,062	5.6	-
Developed Countries	Total Developed	62,242	92,487	3.7	↓
	US	34,279	69,589	6.6	↗
	Japan	9,983	6,745	-3.5	↓
	Netherlands	3,014	4,263	3.2	↓
	Finland	5,281	4,044	-2.4	↓
	Sweden	2,911	3,484	1.6	↓
	Germany	1,254	1,087	-1.3	↓
Emer. Countries	Total Emerging	3,909	27,575	19.4	↑
	China	367	17,959	42.4	↑
	Taiwan	2,150	7,039	11.4	↑
	South Korea	431	2,263	16.3	↑

Note: Only relevant countries are shown. Sample drawn from Top 1000 MNCs. Arrows show the development compared to the Global CAGR of the Total Top 1000 Firms.

Overall, we can observe a strong shift from developed to emerging countries, particularly pushed by China.

- **Large increases:** The biggest absolute increase can be observed with Germany, which relatively gained strongly in the Pharmaceuticals & Biotechnology. Furthermore, the three relevant emerging countries China, Israel and India have all their R&D Expenditure in Pharmaceuticals and Biotechnology by at least approximately 1bn€.
- **Large decreases:** All developed countries, except the US, have experienced strong drops in relative R&D Expenditure. For Japan, Finland and Germany we can even observed an absolute drop in R&D Expenditure with a negative CAGR.

[380] Own analysis, based on EU R&D Scoreboards: European Commission (2019), European Commission (2008).

Conclusion: Emerging Countries, particularly China, have strongly increased their share in R&D Expenditure. The relative importance for all developed countries, except the US, has decreased.

The classification 'Technology Hardware' is particularly broad, as discussed in the beginning of this chapter. In the following this industry cluster is therefore manually broken down further. Eight unique subcategories of Technology Hardware have been defined, into which the all companies found in the Technology Hardware in the Top 500 of 2019 have been sorted, i.e. 67 firms, based on their respective business focus. The purpose of this step is to further drill down on country-specific competences and differences within the field Technology Hardware. For illustration I give an example: Huawei, HP and Seiko Epson are all classified in Technology Hardware. The first is a Chinese firm focusing on Telecommunications equipment, the second a US firm producing Computer Hardware and the third is a Japanese firm producing Computer Peripherals, e.g. printer.

Table 6-9 shows the breakdown of Technology Hardware into the seven categories Computer Hardware, Computer Peripherals, IT Services, Optical Equipment, Semiconductor Manufacturing, Semiconductors and Telecommunication Equipment. This table is comparable, yet not identical in sample to Table 6-8: being a more recent analysis, in Table 6-9 I show values for the year 2019, not 2018 and furthermore I analyze the Top 500, not 1000 firms.

Table 6-9: Breakdown of Technology Hardware R&D Expenditure by Country[381]

Technology Hardware, Breakdown		R&D Expenditure in m€ 2007	2019	CAGR '07-'19 (%)	Firms
Computer Hardware	US	3,473	20,512	16.0	APPLE, DELL, HP
	Taiwan	585	3,008	14.6	ASUSTEK COMPUTER, INVENTEC, MEDIATEK, QUANTA COMPUTER
	China	179	1,460	15.9	LENOVO, UNISPLENDOUR
Computer Peripherals	Japan	3,651	3,905	0.6	BROTHER INDUSTRIES, CANON, RICOH, SEIKO EPSON
	US	370	2,237	16.2	HARRIS, WESTERN DIGITAL
	Ireland	-	866	-	SEAGATE TECHNOLOGY
	Israel	-	369	-	MELLANOX TECHNOLOGIES
IT Service	US	357	1,874	10.0	F5 NETWORKS, NETAPP, SNAP
	China	-	332	-	SINA
Optical Equip.	US	386	741	5.6	CORNING
	Japan	442	553	1.9	KONICA MINOLTA
Semicond. Manufact.	US	1,220	2,884	7.4	APPLIED MATERIALS, KLA, TERADYNE
	Netherlands	489	1,844	11.7	ASML HOLDING
	Japan	529	1,308	7.8	ADVANTEST, TOKYO ELECTRON
Semiconductors	US	10,516	30,543	8.9	ADVANCED MICRO DEVICES, ANALOG DEVICES, BROADCOM, CIRRUS LOGIC, CYPRESS SEMICONDUCTOR, INTEL, LAM RESEARCH, MARVELL TECHNOLOGY, MAXIM INTEGRATED PRODUCTS, MICROCHIP TECHNOLOGY, MICRON TECHNOLOGY, NVIDIA, ON SEMICONDUCTOR, QORVO, SKYWORKS SOLUTIONS, TEXAS INSTRUMENTS, XILINX
	Taiwan	646	3,513	15.2	REALTEK SEMICONDUCTOR, TAIWAN SEMICONDUCTOR, UNITED MICROELECTRONICS
	Netherlands	2,224	2,661	1.5	NXP SEMICONDUCTORS, STMICROELECTRONICS
	South Korea	431	2,417	15.4	SK HYNIX
	Germany	1,169	1,068	-0.8	INFINEON TECHNOLOGIES
	China	66	598	20.1	SEMICONDUCTOR MANUFACTURING
	Austria	-	294	-	AMS
Telecommunication Equipment	China	301	19,259	15.3	HUAWEI, XIAOMI, ZTE
	US	7,871	12,610	4.0	CIENA, CISCO SYSTEMS, JUNIPER NETWORKS, MOTOROLA, QUALCOMM
	Finland	5,281	4,411	-1.5	NOKIA
	Sweden	2,911	3,682	2.0	ERICSSON
	Taiwan	93	479	14.6	WISTRON
	Australia	842	458	-5.0	TELSTRA

Note: Not all firms in for 2019 existed in 2007. CAGR is calculated based on firms existing in both years.[382]

[381] Own analysis, based on EU R&D Scoreboards: European Commission (2020), European Commission (2008).

We can see strong growth rates in many categories and by many countries. As explained in footnote 382, I calculate the CAGR based on firms existing in both years, to avoid sample mismatching.

We see a very strong position of US firms in Computer Hardware, with larger growth rates compared to the Asian firms and an absolutely much higher R&D Expenditure in 2019. For Computer Peripherals, i.e. equipment connected to a computer, Japanese firms are, in turn, investing very strongly in R&D, putting US firms on a distant second rank. An absolute dominance of US firms can be observed in Semiconductors: the numerous US firms spent in 2019 in sum almost ten times as much as the following country Taiwan. There is clearly a strong competence and focus of R&D activities in the area of Semiconductors in the US, although this is also one of the few fields where European firms are somewhat visible. Chinese firms, strongly uprising in many aspects, dominate the field of Telecommunication Equipment: with very strong growth rates they have overtaken US firms in terms of R&D expenditure and spent over 50% of the aggregated US R&D expenditure in 2019.

This analysis and table expands the analysis and discussion of Table 6-8: Technology Hardware is a highly heterogenous field: for example, while we see a strong growth of Chinese firms' R&D expenditures, this growth is not equally distributed, but heavily focused in the area of Telecommunication Equipment, a field where China's strength regularly leads to political discussions[383], whereas the US lead, by far, the field Semiconductors. Breaking down these numbers in Table 6-9 helps us to further understand where firms from which countries possess relative strengths.

6.2.4. R&D Expenditures in Software & Computer Services

In the following table, I break down the R&D Expenditure by firms in the industry Software & Computer Services in 2007 and 2018: I show the strong growth of R&D expenditures worldwide, underlining the increase in global relevance, with particularly large growth rates by firms from emerging countries.

The arrows indicate the development of R&D Expenditure compared to the total CAGR of 14.2%.

[382] In 2019 there are 67 firms in the Top 500 of Technology Hardware, of which 56 firms exist in the Scoreboard for 2007. These 11 missing companies are AMS, CIRRUS LOGIC, HUAWEI, MAXIM INTEGRATED PRODUCTS, MELLANOX TECHNOLOGIES, QORVO, SEAGATE TECHNOLOGY, SINA, SNAP, UNISPLENDOUR, XIAOMI.

[383] Cf. Gold (2020): Some states have excluded Huawei from supplying their nations' 5G network, out of safety concerns.

Table 6-10: Software & Computer Services R&D Expenditure by Country[384]

	Software & Computer Services	R&D Expenditure in m€ 2007	2018	CAGR '07-'18 (%)	Develop-ment
Total Software & Computer Services		25,024	108,107	14.2	-
Developed Countries	Total Developed	24,519	92,502	12.8	↓
	US	19,353	78,532	13.6	↘
	Germany	1,620	3,846	8.2	↓
	Japan	1,556	3,382	7.3	↓
	UK	676	1,814	9.4	↓
	France	762	1,634	7.2	↓
	Spain	141	1,106	20.6	↑
Emer. Countries	Total Emerging	505	15,604	36.6	↑
	China	0	13,885	-	↑
	Taiwan	0	845	-	↑
	Israel	55	542	23.0	↑
	South Korea	61	215	12.2	↗
	India	389	117	-10.4	↓

Note: Only relevant countries are shown. Sample drawn from Top 1000 MNCs. Arrows show the development compared to the Global CAGR of the Total Top 1000 Firms.

Overall, we can observe a strong increase in relevance of the industry Software & Computer Services, with the two-digit CAGR. While all countries have therefore strong absolute increases between 2007 and 2018, the relative increase is very visible for emerging countries.

- **Large increases:** All emerging countries (apart from India, which is less relevant here) and the developed country Spain have increased their relative R&D Expenditure in Software & Computer Services. In absolute terms, the industry is dominated by the US and China.

384 Own analysis, based on EU R&D Scoreboards: European Commission (2019), European Commission (2008).

- **Large decreases:** With a CAGR far below the industry average, most developed countries, except the US and Spain, have significantly lost in relevance between 2007 and 2018.

Conclusion: The industry Software & Computer Services is highly concentrated on the two countries US and China, which together account for 85% of the total industry's R&D Expenditure in 2018. Other countries have much smaller R&D Expenditures and smaller growth rates, indicating that this concentration even increased over the years. In this relative new industry, we can observe a quick and strong concentration across countries, indicating that only few countries had and have the capabilities to maintain their competitive advantages in this high-tech industry.

6.2.5. R&D Expenditures in Automobiles & Parts

In the following table, I break down the R&D Expenditure by firms in the industry Automobile & Parts in 2007 and 2018. While the previous three industries are considered high-tech, Automobiles & Parts is a medium-tech industry. We will see the strength and strong growth of the leading country Germany, but also several emerging countries have grown strongly over the years.

The arrows indicate the development of R&D Expenditure compared to the total CAGR of 5.5%.

Table 6-11: Automotive & Parts R&D Expenditure by Country[385]

Automotive & Parts		R&D Expenditure in m€ 2007	2018	CAGR '07-'18 (%)	Develop-ment
Total Automotive & Parts		68,699	123,778	5.5	-
Developed Countries	Total Developed	66,597	109,957	4.7	↘
	Germany	20,563	43,987	7.2	↑
	Japan	18,912	31,764	4.8	↘
	US	16,470	17,862	0.7	↓
	France	5,993	9,779	4.6	↘
	Netherlands	0	4,651	-	↑
	UK	158	1,365	21.7	↑
Emer. Countries	Total Emerging	2,101	13,821	18.7	↑
	China	0	7,309	-	↑
	South Korea	1,844	4,222	7.8	↑
	India	258	2,138	21.2	↑

Note: Only relevant countries shown. Sample drawn from Top 1000 MNCs. Arrows show the development compared to the Global CAGR of the Total Top 1000 Firms.

Despite an uprise in emerging countries, the developed countries still dominate the R&D Expenditure in Automotive & Parts. Across the developed countries we can observe diverse findings and developments.

- **Large increases:** All emerging countries, particularly China and India have increased their R&D expenditures in the automotive industry. China is clearly leading in the group of emerging countries. Globally and across the developed countries, Germany spends the most and even increased its global share. More than every third R&D Dollar in this industry is spent by a German firm. Further increases in share can be observed for the Netherlands and UK.
- **Large decreases:** With a CAGR far below the industry average, the US have lost in relevance.

[385] Own analysis, based on EU R&D Scoreboards: European Commission (2019), European Commission (2008).

- **Smaller changes:** Japan has slightly lost its international share in Automotive & Parts, with a below industry CAGR.

Conclusion: The medium-tech industry Automotive & Parts has a broad band width of development. Traditional car-making nations have developed in different directions in terms of their R&D Expenditure: German has gained, Japan stagnated and the US has lost in international relevance. The emerging countries, most notably China, have increased their share in R&D Expenditure. However, on an absolute scale, they do not play a major role in 2018.

In the next sub-chapter, I will outline and summarize the leading industries for each relevant country, i.e. show in which fields countries have particular competencies.

6.3. Country-Analysis

In this sub-chapter, I summarize and scrutinize the findings from the previous sub-chapters for the four largest countries in terms of R&D Expenditure per the EU R&D Scoreboard: USA, Japan, Germany and China.

This chapter shows stronger and weaker industries per country and the changes over time. The developed countries USA, Japan and Germany lose in respective global shares in almost all industries, which can be attributed to rises by China and other emerging countries. For the respective countries, we can also see the relative increase in relevance for certain high-tech and technological industries, such as Pharma & Biotech and Software & Computer Services.

For each country I list the biggest R&D spending industries, sorted decreasingly by their 2018 R&D Expenditure and add the respective technology status: H (High-tech), M (Medium-tech) or L (Low-tech).

I list the “Global Industry Share” for 2000 and 2018, which shows the percentage of each country’s firms in the respective industry spent in relation to all firms worldwide in that industry. For example, the analysis for the US in Table 6-12 shows that US firms in Software & Computer Services have spent 88.5% in 2000 of all R&D Expenditure worldwide in the Software & Computer Services industry and 72.6% in 2018. This figure helps to indicate the relative relevance of a country in a respective industry’s R&D activities. Therefore, a high percentage indicates, that the respective country holds a big share of global R&D activities in that field. This high percentage implies a comparably high competence, compared to other countries. A decrease over the years indicates, that this country has lost in relative relevance in terms of R&D expenditures.

I also list the “Country Industry Share” for 2000 and 2018, which indicate the respective industry’s R&D Expenditure to the country’s total R&D Expenditure in that year. For example, the analysis for the US in Table 6-12 shows that the R&D Expenditure of US firms in Software & Computer Services accounts for 12.8% in 2000 and 27.4% in 2018 of the whole US R&D Expenditure. This figure helps to indicate the relative relevance of an industry within that country. Therefore, a high percentage indicates that the country’s R&D Expenditures are highly concentrated in that field. A high concentration can imply competency, but also dependency.

6.3.1. R&D Expenditure by USA

Table 6-12: R&D Expenditure Development by US MNCs by Industry[386]

Industry	Tech-Status	R&D Expenditure 2018 (Million €)	Global Industry Share (%)		Country Industry Share (%)	
			2000	2018	2000	2018
Total	**-**	**286,693**	**37.1**	**38.8**	**-**	**-**
Software & Computer Services	H	78,532	88.5	72.6	12.8	27.4
Technology Hardware	H	69,589	49.3	58.0	31.6	24.3
Pharmaceuticals & Biotechnology	H	65,866	39.1	48.0	15.8	23.0
Automobiles & Parts	M	17,862	29.2	14.4	14.9	6.2
Aerospace & Defense	H	7,935	41.2	42.0	3.5	2.8
Health Care Equipment & Services	H	7,358	74.2	53.1	2.9	2.6

Note: Only relevant industries (R&D Expenditure > 7 billion €) shown. Shares based on Top 500 firms for 2000 and Top 1000 firms for 2018.

The US as the biggest R&D spending country worldwide, accounting for almost 40% of worldwide R&D spending: 37.1% in 2000 and 38.8% in 2018.

Around 3 out of 4 R&D Dollars were spent the three High-tech industries Software & Computer Services, Technology Hardware and Pharmaceuticals & Biotechnology. Particularly Software & Computer Services has increased in relative importance, i.e. increased the share of US R&D Expenditure from 12.8% in 2000 to 27.4% in 2018.

[386] Own analysis, based on EU R&D Scoreboards: European Commission (2019), European Commission (2004).

Country-specific strengths

The three High-tech industries Software & Computer Services, Technology Hardware and Pharmaceuticals & Biotechnology are clearly dominated by US firms. Globally seen, all three industries each account for more than 20% of the global R&D Expenditure. These three industries are strongly concentrated in the US with a global share of between approximately 48% and 73% in 2018.

Software & Computer Services: Companies such as Alphabet, Microsoft, Facebook and Oracle account for the strong US dominance in this industry. Due to the uprise of other countries, the strong dominance of US firms has been slightly reduced over the years, the relevance for the US R&D portfolio has, however, increased, with every fourth US R&D Dollar spent in this industry.

Technology Hardware: The strong concentration of R&D Expenditures by companies such as Apple, Intel, Cisco and Qualcomm have even increased over the years. It can be argued that Software & Computer Services rather addresses intangible products which can be produced or provided in an easier way from other places in the world, than physical products as provided in this industry. The relative share of the US R&D Expenditure portfolio has decreased to around 24%. With a certain degree of generalization, we can argue that there has been a slight shift from Hardware to Software over the years for US R&D activities. Even with breaking down the heterogeneous field of Technology Hardware into its components (see Chapter 6.2.3), a strong and increasing strength of US firms in terms of R&D Expenditure can be observed.

Pharmaceuticals & Biotechnology (Health Care Equipment & Services): Approximately half of the worldwide R&D activities in this industry are pushed by US firms. Companies such as Johnson & Johnson, Merck & Co. (not to be confused with the German Merck Group), Pfizer, Bristol Myers Squibb, Abbvie or Celgene have increased R&D activities, so that more than every fifth R&D Dollar in the US nowadays can be attributed to firms from this industry. Related to Pharmaceuticals & Biotechnology, but somewhat different is Health Care Equipment & Services, represented by companies such as Boston Scientific, Becton Dickinson, Thermo Fisher Scientific or Stryker. While this industry is generally small and accounts for less than 2% of worldwide R&D Expenditure, US firms are here again overrepresented and above world-average. Nevertheless, firms from other countries have gained in relative importance here.

Country-specific weaknesses

Automobiles & Parts: This medium-tech industry, accounting for approximately 15% of worldwide R&D Expenditure is underrepresented in the US. Not only has the contribution of US firms such as Ford, GM or Tesla to this industry almost halved relatively, also the importance within the US has shifted more towards other high-tech industries. With Tesla and its focus on e-mobility as a somewhat exception, the US Automotive Industry is not the most relevant industry on a global scale in terms of R&D activities.

Country-specific constants

Aerospace & Defense: This industry, represented by companies such as Boeing, United Technologies and Lockheed Martin has more or less maintained its position and relevance: both the share of this industry in the global scale has remained rather constant, also the share to the total US R&D Expenditure changed only slightly. It appears that this industry in the US has remained rather robust to developments in the last decade.

6.3.2. R&D Expenditure by Japan

Table 6-13: R&D Expenditure Development by Japanese MNCs by Industry[387]

Industry	Tech-Status	R&D Expenditure 2018 (Million €)	Global Industry Share (%) 2000	Global Industry Share (%) 2018	Country Industry Share (%) 2000	Country Industry Share (%) 2018
Total	**-**	**99,306**	**22.0**	**13.4**	**-**	**-**
Automobiles & Parts	M	31,764	24.2	25.7	20.8	32.0
Electronic & Electrical Equipment[388]	M	23,092	47.2	34.8	24.0	23.3
Pharmaceuticals & Biotechnology	H	10,698	9.0	7.8	6.1	10.8
Technology Hardware	H	6,745	22.5	5.6	24.3	6.8
Chemicals	M	6,464	21.5	36.4	5.3	6.5

Note: Only relevant industries (R&D Expenditure > 6bn€) shown. Shares based on Top 500 firms for 2000 and Top 1000 firms for 2018.

Japan is the location of major R&D investing corporations with the aggregated second largest R&D expenditures worldwide[389], which accounts for a strongly decreasing share of the worldwide R&D spending, as already seen in Table 6-6: In 2000 Japanese MNCs accounted for 22% of the worldwide spending, whereas until 2018, this share has almost halved to 13%.

Around half of Japanese R&D Expenditure is spent in the top three industries Automobiles & Parts, Electronic & Electrical Equipment and Pharmaceuticals & Biotechnology, with the former significantly increasing the relative share from 21% to 32%.

387 Own analysis, based on EU R&D Scoreboards: European Commission (2019), European Commission (2004).

388 Data merged with category 'Leisure', which includes for Japan technical firms such as Panasonic, Sony and Nintendo. The industry classification 'Leisure' is rather vague and includes a broad array of firms. For example, American toy producer Hasbro is also classified as Leisure underlining the industry's breadth. Interestingly enough the EU classified Sony in the earlier scoreboards in the industry Electronic & Electricals. Therefore, my correction here is not only warranted, but even required.

389 This data refers to the 2018 data of EU R&D Scoreboard. In its most recent scoreboard (European Commission, 2020), data shows a dynamic for China: if only the Top 1000 firms are considered, Japan ranks second, China third and Germany fourth in terms of aggregated R&D Expenditures. If all Top 2500 firms are considered, China overtakes Japan, pushing Japan to the third rank, while Germany remains fourth.

Country-specific strengths

The two medium-tech industries Automobiles & Parts, and Electronic & Electrical Equipment are quite strong in Japan, with Japanese firms in each sector accounting for relevant share of 26 and 35% respectively of the global industry share. Furthermore, a high number of Japanese firms can be found in each industry's Top 10 by R&D expenditure, indicating the concentration of R&D expenditures by Japanese firms.

Automobiles & Parts: Companies such as Toyota, Honda and Nissan contribute strongly to the Japanese economy. These, as well as numerous other companies, have strongly increased their R&D Expenditure in the last decades, making Japanese firms a relevant global force in this industry. Around every third R&D dollar in Automotive is spent by Japanese firms and four of the Top 10 companies by R&D expenditures in Automotive are Japanese.

Electronic & Electric Equipment: This industry, represented by firms such as Hitachi, Mitsubishi, Fujifilm or Sharp is the second-largest industry in Japan in 2018, in terms of R&D Expenditure. Despite its strength, the relative positioning has declined since 2000: while in 2000 almost half, i.e. 47%, of the global R&D Expenditure in this industry was spent by Japanese firms, this share has dropped to 35%, around a third. Despite the increasing pressure by foreign firms, I still consider this industry as a strength of Japan. Five of the Top 10 companies by R&D expenditures in this industry are Japanese. Comparable to the breakdown of Technology Hardware (see Chapter 6.2.3), we can also segment this rather broad field further: particularly in the sub-fields of Electronic Components (Sumitomo, TDK, Murata, Kyocera), as well as and Conglomerate Electronics (Hitachi and Mitsubishi), Japanese firms are among the leading firms in the respective sub-fields in terms of R&D expenditure.

Chemicals: This industry, including firms such as Sumitomo Chemical or Asahi Kasei, is not very big for Japanese R&D, accounting for only 5% in 2000 and 7% in 2018. Looking at the worldwide share, we can, however, observe a competitive positioning of Japan which even increased over the years: while in 2000 around one fifth (21%) of the R&D spending in the Chemicals industry where spent by Japanese firms, this share has risen to over a third (36%) in 2018. Five of the Top 10 companies by R&D expenditures in this industry are Japanese.

Country-specific weaknesses

Technology Hardware: The industry Technology Hardware includes firms such as Hitachi, Canon or Ricoh. Once a key competence of Japan, with a worldwide share in R&D of 23% in 2000, this share has plummeted to a meager 6%, mostly due to the uprise of strong American firms. Hitachi, for example, ranking 15th for the 2000 Scoreboard ranking has dropped to rank

58 in the 2018 ranking. An overall shift in technology and thereby industries, as discussed throughout in this dissertation, accounts for such a shift. The Top 10 by R&D expenditure in this industry is dominated by US firms and one Chinese firm, Huawei, at the top. When differentiated Technology Hardware into more precise sub-fields (see Chapter 6.2.3), the picture does not change: Japan is home to of a couple of firms in the sub-field of Computer Peripherals, e.g. Canon, Ricoh or Brother Industries, but the overall relevance in comparison to other countries has generally decreased.

Country-specific constants

Pharmaceuticals & Biotechnology: Firms such as Takeda or Otsuka are far from the top in the worldwide R&D Expenditure ranking within this industry, yet they account for a noticeably share of almost 8% of all R&D spendings by pharma & biotech firms worldwide. This share has slightly decreased since 2000, but the relevance for Japan has grown, with around 10% of Japanese R&D Expenditure spent in this industry.

6.3.3. R&D Expenditure by Germany

Table 6-14: R&D Expenditure Development by German MNCs by Industry[390]

Industry	Tech-Status	R&D Expenditure 2018 (Million €)	Global Industry Share (%)		Country Industry Share (%)	
			2000	2018	2000	2018
Total	-	79,397	13.6	10.8	-	-
Automobiles & Parts	M	43,987	31.4	35.5	43.8	55.4
Pharmaceuticals & Biotechnology	H	10,879	6.8	7.9	7.5	13.7
Electronic & Electrical Equipment	M	6,497	19.6	11.5	16.2	8.2
Software & Computer Services	H	3,846	7.0	3.6	2.8	4.8
Chemicals	M	3,136	33.7	17.7	13.4	4.0

Note: Only relevant industries (R&D Expenditure > 3bn€) shown. Shares based on Top 500 firms for 2000 and Top 1000 firms for 2018.

[390] Own analysis, based on EU R&D Scoreboards: European Commission (2019), European Commission (2004).

Germany is the location of major R&D investing corporations with the aggregated third largest R&D expenditures worldwide in 2018[391], which accounts for around 14% of worldwide R&D Expenditure on R&D (BERD) in 2000 and 11% in 2018. Over 69% of the R&D expenditure by Germany's largest firms is spent in Automobiles & Parts or Pharmaceuticals & Biotechnology. German Automotive firms are known internationally and their relevance in terms of R&D Expenditure stands out clearly from Table 6-14.

Country-specific strengths

The two leading industries by R&D expenditure Automobiles & Parts, as well as Pharmaceuticals & Biotechnology show a high absolute spending on R&D, and an increase both in share within Germany, but also within their respective industry compared internationally. However only Automobiles & Parts can be considered a strength for Germany, whereas Pharmaceuticals & Biotechnology has to be considered with a more critical lens and is therefore categorized here in the 'weakness' category.

Automobiles & Parts: Automotive OEMs such as Volkswagen, Daimler or BMW, as well as Suppliers, such as Continental or ZF contribute strongly to Germany's R&D Expenditure and the German economy overall. German Automobiles & Parts firms even increased their global dominance: in 2000 German firms accounted for 31% of R&D Expenditure in that field, and that share increased to 36% in 2018. Together with the increase in share in relation to all German firms, we can see that Automobiles & Parts is not only strong and highly relevant for German and worldwide R&D activities, but that this relevance even increased until 2018. Four out of the Top 10 firms in this field and the largest two firms by R&D expenditure (Volkswagen, Daimler) are German.

Country-specific weaknesses

In terms of R&D Expenditures the two industries Electronic & Electrical Equipment and Chemicals have lost in relevance and strength in Germany, which can be attributed to strong growths in other industries. From 2000 to 2018 the share of German firms globally within both industries has almost halved.

Electronic & Electrical Equipment: Firms like Siemens are known internationally and part of this industry.[392] The share of R&D Expenditure by German firms in Electronic & Electrical

[391] For 2019, Germany has been pushed to rank 4 by China. See also footnote 389.

[392] Siemens actually has a quite broad product portfolio. The EU has classified the Munich-based firm to this industry.

Equipment in relation to firms worldwide has dropped from 20% in 2000 to 11%. Furthermore, the relative relevance within the German R&D spending firms has dropped from 16% to 8% in 2018. Siemens is the second largest firm by R&D expenditure worldwide in this field (behind Samsung) – and both firms can be classified in the sub-field of Conglomerate Electronics (see also the breakdown for Technology Hardware in Chapter 6.2.3). However, Siemens is in fact the only German firm appearing as a somewhat top-ranking German firm by R&D expenditure in that field.[393] That means that the listed R&D expenditure of 6.5 billion Euro is almost exclusively attributable to Siemens.

Chemicals: Firms such as Evonik, Bayer or its spinoff Covestro are examples for German Chemicals firms. In 2000 over 33%, i.e. one out of three Euros spent on R&D in this industry was attributable to a German firm. This share has dropped to 18% in 2018. Furthermore, the relevance of Chemicals within the German R&D landscape has decreased as the share of Chemicals to all German firms has dropped from 13% in 2000 to 4% in 2018. In the worldwide Top 10 ranking by R&D expenditure in this field only BASF and Evonik can be found and for the Top 25 only the two companies Covestro and Symrise are added.

Pharmaceuticals & Biotechnology: Firms such as Bayer, Boehringer Ingelheim or Merck[394] contribute to Germany's strength in that field. German firms in that field have a global share within that industry of 8% in 2018, a slight increase from 7% in 2000. Within the German R&D landscape firms in the Pharma & Biotech field account for a share of 14%, the second-largest industry in terms of R&D Expenditure and an increase from rank four in 2000. While the numbers by themselves look positive and show an upwards trend, a detailed analysis of the scoreboard paints a bleaker picture: in the worldwide Top 10 ranking of firms in this field by R&D expenditure, only one German firm is listed: Bayer has the eighth largest R&D expenditures in 2018 by all Pharma & Biotech firms. Even when we expand the list to the Top 25, only two firms are added: Boehringer (rank 16) and Merck (rank 19). The almost 11 billion Euro spent by German firms on R&D in 2018, therefore almost exclusively come from the aforementioned three firms, of which significant portions of R&D activities even come from other areas: Bayer spends significant shares of its R&D expenditures on in the area of plant and pest management and Merck in producing materials for the electronics industry.[395] If we focus on the Biotech industry in Germany, the situation looks even more dire, with no German firm spending significantly on R&D in an international comparison.

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[393] The second-largest German firm by R&D expenditure in Electronic & Electrical Equipment is the company Sick on rank 601 with an R&D expenditure of 194 Million Euro in 2018.

[394] The German Merck Group is not to be confused with the US Merck & Co. See also Chapter 6.3.1.

[395] Cf. Annual Reports – Bayer (2020); Merck (2020).

Software & Computer Services: This industry, including particularly famous SAP, is neither moving particularly upward or downward: while the German industry share has decreased from 7% to 4% in 2018, the relevance within the German industry has increased from 3% to 5%. In fact, we have a situation comparable to Siemens in Electronic & Electrical Equipment: almost all R&D expenditure in this field can be exclusively attributed to the activities of one company – SAP.[396] In this field, largely dominated by US firms, German firms do not play any major role. The same finding can be made when looking at the related field of Internet services: German firms, or even European firms, do not play major roles in these uprising fields.

6.3.4. R&D Expenditure by China

Table 6-15: R&D Expenditure Development by Chinese MNCs by Industry[397]

Industry	Tech-Status	R&D Expenditure 2018 (Million €)	Global Industry Share (%) 2000	Global Industry Share (%) 2018	Country Industry Share (%) 2000	Country Industry Share (%) 2018
Total	-	76,805	0.1	10.4	-	-
Technology Hardware	H	17,959	0.0	15.0	0.0	23.4
Software & Computer Services	H	13,885	0.0	12.8	0.0	18.1
Construction & Materials	M	10,600	0.0	77.7	0.0	13.8
Automobiles & Parts	M	7,309	0.0	5.9	0.0	9.5
Electronic & Electrical Equipment	M	5,963	0.0	10.5	0.0	7.8
Industrial Engineering	M	3,592	0.0	15.6	0.0	4.7
Oil & Gas	L	3,427	8.5	34.3	100	4.5

Note: Only relevant industries (R&D Expenditure > 3 billion €) shown. Shares based on Top 500 firms for 2000 and Top 1000 firms for 2018.

China is the fourth-biggest R&D spending country worldwide and somewhat different to the previous discussed three countries, as it is the only emerging country. This means, that since 2000 we can observe particular strong movements and developments. In 2000 Chinese firms did not contribute significantly to worldwide R&D Expenditures in any industry, whereas in until 2018 the share has grown to a noticeable 10%. With a development out of almost nothing, it

396 The second-largest company by R&D expenditure in Electronic & Electrical Equipment is the firm Software on rank 885 with 123 Million Euro spent on R&D in 2018.

397 Own analysis, based on EU R&D Scoreboards: European Commission (2019), European Commission (2004).

is futile to compare the years 2018 and 2000 in detail, so instead I will focus here on the particularly relevant industries. Overall, we can observe a relatively even distribution across industries: the largest R&D spending industry, Technology Hardware, accounts for 23% of Chinese R&D Expenditure. For example, Germany's industry is much more concentrated with Automobiles & Parts accounting for over 55% in 2018.

Particularly strong industries

Technology Hardware: Huawei, ZTE, Lenovo or Xiaomi are examples for Chinese firms in the Technology Hardware. Chinese firms have been highly innovative, with Huawei even taken the first spot in the ranking of patent applications with the European Patent Office in 2019.[398] These firms spend 15% of the worldwide R&D Expenditure in that industry and that industry accounts for 23% of all Chinese R&D Expenditures. Breaking down this heterogeneous industry by segment (see Chapter 6.2.3), allows for additional insights: Chinese firms are particularly strong, in terms of R&D expenditures, in the sub-fields Telecommunication Equipment (Huawei, ZTE) and Computer Hardware (Lenovo), whereas in Semiconductors firms from other countries / regions, most notably the US, but also Taiwan and South Korea, are much stronger.

Software & Computer Services: Internet companies Alibaba, Tencent or Baidu have contributed to the rise of this industry, accounting for 18% of China's R&D Expenditure. In an international comparison Chinese firms spend 13% of the R&D expenditures in the Software & Computer Services Industry. Overall this industry is still very US-dominated, with only four Chinese companies in the Top 25 list by R&D expenditures in this field. When separating this field further, we can observe that Chinese firms are rather weak in the sub-field of Software, yet comparably strong in Internet firms.

We can observe that both in Technology Hardware and Software & Computer Services, there are rather few Chinese firms in the field of leading companies: while US firms are large in R&D expenditure and numerous, R&D expenditures for Chinese firms seem to be more concentrated on few firms. This could be attributable to very different business environments, including political systems.[399]

[398] Cf. EPO (2020b).
[399] Cf. D. Zhang and Guo (2019); Wu (2017).

Other Industries

Construction & Materials: This industry, including several state-owned infrastructure companies, is not particularly known for internationally relevant R&D activities. It can be discussed to what degree these firms conduct R&D in the classic sense. Nevertheless, can the high numbers here be indicative of China's status as an emerging country, i.e. a country with strong infrastructure and construction activities. Furthermore, China's ambitious infrastructure project "New Silk Road" under the "One Belt, One Road" initiative entails heavy construction activities also abroad.[400]. The industry Oil & Gas, the only relevant Chinese industry in 2000, can be regarded similarly, as well as Industrial Engineering, which includes again construction or construction-related firms. Furthermore, it could be argued that some of the R&D expenditures are somewhat engorged due to political specifications.[401]

Automobiles & Parts: Chinese firms such as SAIC or Geely are producing heavily, particularly for the large home market. With a global industry share in R&D Expenditure of 6% in 2018, Chinese firms are currently behind the other three major economies discussed previously. In the Top 25 ranking by R&D expenditures in this field, the only China-based company is SAIC.

Electronic & Electrical Equipment: This industry includes firms such as TCL or BOE Technology. These firms, not necessarily known to a broader audience abroad, accounted for 11% of worldwide R&D expenditures in that industry. Overall, Chinese firms do not rank particularly highly in this category in terms of R&D expenditure: BYD, operating in the sub-field of Battery and BOE, operating in the sub-field of Electronic Displays are the only China-based companies in Electronic & Electrical Equipment listed within the first 200 firms of the R&D Scoreboard.[402]

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[400] Cf. Tweed (2019).

[401] Cf. Jiang et al. (2018); Mozur and Myers (2021).

[402] BYD ranked 147th with 1,046 Million Euro R&D Expenditure and BOE 187th with 838 Million Euro. BYD manufactures vehicles, yet is classified in Electronic & Electrical Equipment (with the own sub-category of Battery), as the core business and competency rely on battery-powered vehicles. Cf. Annual report – BYD (2020).

7. Patent Analysis for R&D Intensive Industries

In this chapter I analyze the most relevant industries, as discussed in the previous chapters from a patent perspective. Namely, I will break down the industries Pharmaceuticals & Biotechnology, Technology Hardware, Software & Computer Services and Automobiles & Parts. I will show general figures, such as the total number of patents, to indicate the general patenting activities of a respective industry, but also dive deeper with more sophisticated analyses. Since the focus of this dissertation is to analyze internationalization, I will show figures breaking down and evaluating the magnitude and effect of internationalization for the five most relevant technological fields. For this I will use the definitions and methodologies as detailed in Chapter 2.2.

I will show in this chapter where the most patents by technological field, both in terms of applicant, i.e. firm, and inventor, i.e. R&D conducting individual, are coming from. Furthermore, I show how internationalization mostly pays off, i.e. patents with international inventor teams generally generate better patents in terms of performance and competitiveness. A low or medium level of cultural distance in the international teams generally is best, meaning that with too culturally diverse teams patent performance decreases again.

Namely I will pursue answering the following research questions:

RQ7.1:	How have patent numbers developed since 1980?
RQ7.2:	What is the distribution and development of international patents?
RQ7.3:	How has the quality and competitiveness of patents developed?
RQ7.4:	How well perform international patents compared to non-international patents?
RQ7.5:	What patterns and distributions of internationality in patents are best for patent performance?

7.1. Overview Measurement and Methodology

In this chapter I will analyze patents, as applied for at the European Patent Office. The large-scale dataset allows for robust and rigorous time-series analysis. While there is some earlier data available, general and reliable data is available for the priority year 1980 and onward, so for the large-scale analyses I will use this year as a starting point. Due to the time-lag of patent publications, only patents up to 2016 are sufficiently complete to conduct meaningful analyses (I use the most recent patent database at the point of analysis in 2020). As patents are designed to protect technologies, they are categorized in one or several technology classes: the "International Patent Classification" (IPC), which indicates with a letter-number combination the technological field(s) the respective patent relates to. In Chapter 2.2.3 and Table 2-1 I outline the structure of the IPC and give an example.

I show the concordance, i.e. matching of industry and (major) technological fields, as indicated by the IPC in Table 7-1.

Table 7-1: Concordance of Industry and Main Patent Classes (IPC)

Industry	**Major IPC(s)**[403]
Pharmaceutical	A61K, not A61K-8
Biotechnology	C07G, K & C12M, N, P, Q, R, S
Technology Hardware	H04B, L, W & G06F
Software & Computer Services	G06F, Q, K, T & H04N
Automotive	B60K, R, W & B62D & F02B, D, M & F16H

For Pharmaceutical and Biotechnology, a clear concordance exists, i.e. there is a connection of industry and technological field.[404] It has to be pointed again that the industry's IPCs only relate to the major field of operation. In fact, patents are often assigned several and potentially unrelated IPCs, as the underlying technology fits into several categories. For example, the clearly pharmaceutical company Pfizer has also quite a number of patents in the subclass C04B, which is defined as "Lime, Magnesia, Slag, Cements, Cements, Composition thereof [..]".[405]

In order to find the relevant and major IPCs for the other three industries I follow, due to a lack of definition in Schmoch (2008) or other sources, a two-pronged approach: First, I scrutinize and analyze the IPC overview for fitting classes. For example, in Automotive, the subclass B60R "Vehicles, Vehicle Fittings, or Vehicle Parts […] is a clear fit. Second, I identify relevant IPCs by looking at the patents of major companies in that field. To pick up the example of Automotive again: I look at the patents of Daimler, BMW etc. and identify the major IPCs these companies patent in. Major, in that sense, means that a relevant share of patents is actually

[403] Cf. WIPO (2020b) and Schmoch (2008) for Pharmaceutical and Biotechnology.
[404] Cf. Schmoch (2008).
[405] Cf. WIPO (2020b), for the complete description of that subclass.

patented in the respective class, across the sample of companies.[406] For example the Automotive firm Daimler AG holds some patents in fabric technology, i.e. the subclass D03D (Woven Fabrics, Methods of Weaving, Looms)[407], which, as relevant as they might be in certain aspects, for example for the seat production, are not a core technology closely associated with the Automotive industry in general. I have cross-checked and matched by selection of IPCs to ensure a sufficient robust and reliable analysis.[408]

In order to compare patents, I compute two indices: the NRTA (Normalized Revealed Technological Advantage), as well as the PQCI (Patent Quality Composite Index), which are an indicator for the quality and comparative advantage of each company's patents within a period. An increase over the years can indicate a relatively stronger comparative positioning. The NRTA is scaled, so that $NRTA \in [-1; +1]$: A negative NRTA indicates that the firm has a smaller share of patents in the relevant fields than its competitors. In terms of patent numbers, that company is therefore relatively weaker (at a disadvantage) compared to the industry's average. A positive NRTA indicates a relative advantage, i.e. the company has a higher share of patents in the relevant fields than the competitors. The PQCI is scaled so that $PQCI \in [0; +1]$: the higher the value, the better the patent quality. Patent quality is based on number of citations (received within a certain time-frame), originality, degree of generalization and others. Due to normalization the NRTA is normally distributed, whereas the PQCI is right-skewed (positive skewed). For most industries the mean of PQCI is at approximately 0.3. For methodological details and calculation of these complex indicators, please refer to Chapter 2.2.4.

I measure Cultural Distance, i.e. the degree of internationality through an index, as introduced and discussed in Chapter 2.3, to expand on the dichotomous concept of Host-Country Patents (HCP)[409]. To recap: I put all patents with no internationalization and therefore no cultural distance in one group and distribute the remaining patents, i.e. all patents with an actual

[406] Cf. Chapter 2.2.3 for the methodological overview of analyzing patents on a company level.

[407] For example, patent EP2867396B1, titled "Woven Fabric with Light Emitting Layer" applied for by the Daimler AG is filed in D03D (OECD, 2020h).

[408] For example Neuhäusler, Frietsch, and Kroll (2019) develop a probabilistic concordance between technology fields based on the IPC-class (first three digits) and both industry sectors and scientific disciplines, based on SCOPUS.

[409] For most of this dissertation, I have used the concept of HCP: a patent is international when there is at least one foreign-based inventor. When we argue that an international team has a different impact on performance compared to a non-international team, it certainly makes a difference "how" international a team is. For example, from a US perspective, i.e. for a US applicant, collaborating with a Canadian inventor can be considered less internationalized and less distant than collaborating with a Chinese inventor. In order to quantify these cultural distances and being able to say how distant or more internationalized a US-Chinese collaboration actually is, I use the cultural classification as introduced by Hofstede (G. H. Hofstede, Hofstede, and Minkov, 2010).

cultural distance and with internationalization by the size of the distance in three equally sized groups. Therefore, I will a have a group with “low” cultural distance, one with “medium” and one with a “high” cultural distance. An example for a “low” cultural distance would be the collaboration US-Canada, for “medium” US-Germany and for “high” US-China.

Grouping the international patents in categories of their respective cultural distance will help us to find out whether strong internationalization pays off the most, if it even pays off in the first place, or whether there is a balance between internationalization. The literature, after all, finds arguments in favor and against internationalization.

For methodological details and calculation of these indicators, please refer to Chapter 2.3.3.

7.2. Patent Analysis by Industry

In this part I conduct the patent analyses per technological field, as detailed in the previous parts. I use the analysis of technological fields as a proxy for the respective industry, i.e. when I analyze patents in the field of the pharmaceutical industry, I see the results as sufficiently representative of the pharmaceutical industry. As detailed in the previous part, certain discrepancies arise, as a company which is attributed to a certain industry does not file its patents exclusively in the corresponding IPC class(es), and not all patents in the corresponding IPC class(es) are filed exclusively by firms from that industry. In order to aid comprehensibility, I mostly refer to “industries” in the following, instead of the more precise term “patents filed by firms in a technological field mainly attributed to industry X”.

Every industry is analyzed in a similar manner: First, I show the general number of patents, as well as the internationalization rate, i.e. share of international patents. Second, I calculate the quality indices and compare non-international (domestic) to international patents to see how the general quality and competitiveness has developed and whether internationality pays off. Once again, an “international patent” is any patent with at least one inventor not based in the country of the applicant. Third, I break down internationality and see how much internationalization actually pays off. As discussed in Chapter 2.3.4, there are arguments in favor and against internationalization, so the optimum does not necessarily have to be a boundary solution. As outlined in Chapter 2.3.4.2 I use a one-way ANOVA with a Bonferroni correction to show whether the difference in means between the four groups (no cultural distance / no internationalization; low cultural distance; medium cultural distance; high cultural distance) are statistically significant. I report the statistical significance levels for the respective groups, resulting six pair-wise comparisons, in the classic asterisk notation.[410]

[410] Cf. Acock (2018).

I analyze all relevant patents as filed with the EPO. Naturally, a certain home-base skew cannot be avoided, as firms headquartered in the region of a particular patent office are more likely to file patents at that patent office. Refer to Chapter 2.2.5 for a detailed discussion on the selection of patent offices. However, elaborate analyses and anecdotal evidence through interviews confirm the general trends outlined in the following parts.

7.2.1. Patent Analysis of Pharmaceutical Industry

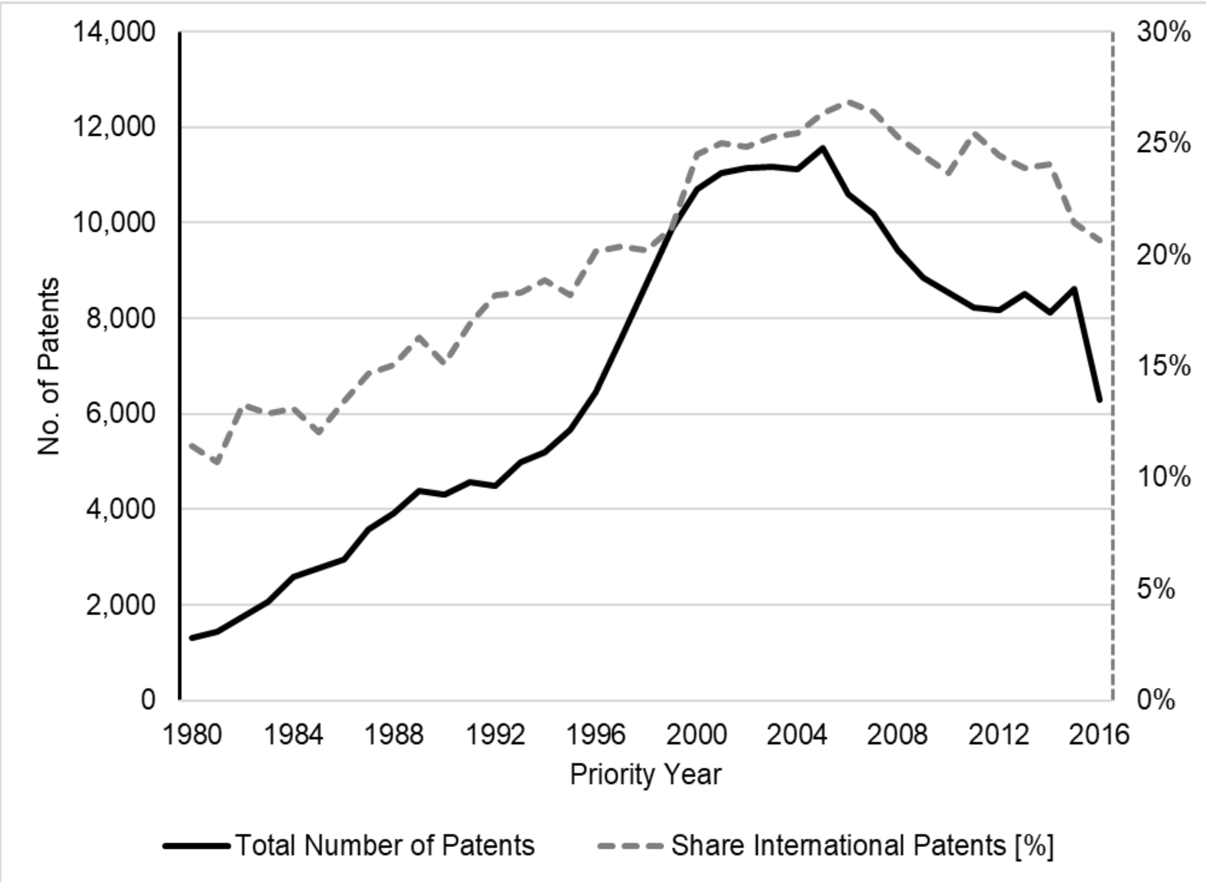
In this sub-chapter, I will analyze the pharmaceutical industry, based on the relevant IPCs, as detailed in Table 7-1.

First, I show the general development of patents between 1980 and 2016, as well as the share of international patents, i.e. patents with inventors and / or applicants from different countries.

Second, I compare non-international and international patents between 1980 and 2016, i.e. show whether international patent teams create better performing patents.

7.2.1.1. General Development in Pharmaceutical Industry

Figure 7-1: Overview Patent Development in Pharmaceutical Industry[411]



[411] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Figure 7-1 shows the total number of patents per priority year in the pharma field on the left y-axis and with the continuous black line, and the share of international to total patents on the right y-axis, with the dashed grey line.

We can identify three general stages of patent number development.

1980 – 1993: We see a constant linear growth in patent numbers at around 10% per year. With an increase in R&D Expenditure and R&D activity a growth in patent numbers and internationalization is easily explained.

1993 – 2003: Patent numbers grow exponentially with a plateau around the turn of the millennium. In the steepest stage, we can observe a growth in patent numbers of around 18% in a year. A (partly) exponential growth can be attributed to the increasing relevance and complexity of R&D activities in the pharmaceutical industry. In Chapter 6.1.3 we have looked at the R&D Expenditure within the Pharmaceutical & Biotechnology industry and observed that this industry has one of the biggest growth rates in terms of R&D Expenditure over the years.

2003 – 2015: Since 2005, the number of patents per year has decreased to 8,624 in 2015 or 6,287 in 2016. The numbers for 2016 might not be complete yet, due to publication time lags, which could partially explain the drop of over 25% from 2015 to 2016. It is interesting to observe that the number of patents has decreased substantially since 2005.

Several arguments might explain this counterintuitive trend: First, a paradigm shift: as patenting and all of the surrounding legal processes in itself are rather costly, some firms are increasingly selective whether and what to patent.[412] A drop in patent numbers therefore might not necessarily indicate a plummeting innovativeness, but rather a change in company strategy. It is therefore worthwhile to analyze in a next step not just the number of patents, but also the respective quality indices. Second, a change in firm strategy away from classic pharmaceutical activities and towards bio-pharmaceutical products, which are not necessarily patented in the same category. As we will see in the next chapter, this argument does not hold true, as the development for Biotechnology looks similar. Third, a home-country bias: as we are analyzing EPO data here a strong dominance of non-European, e.g. US, firms might result in dropping patent numbers due to an increasing underrepresentation. However, a separate analysis for the subset of German applicants, i.e. firms, shows quite the same curve. Germany as part of the EPO's home geographical area would certainly not be underrepresented in this analysis. Fourth, the downwards trend is temporarily and goes up after 2015. In fact, the EPO

[412] Cf. Heuckeroth (2017) & Weibel (2016).

as the holder of their data publishes more recent industry aggregates of its patent data. This patent data remains inaccessible in detail for some time to the public (see also Chapter 2.2.5). That data, shows the observed decrease in patent numbers in the pharmaceuticals (and biotechnology field), followed by a strong and continuous increase since 2016.[413] Furthermore, analyzing PCT-data, instead of EPO confirms the data and trends, with other publications reporting similar trends.[414] As surprising as that decrease in patent numbers therefore might be, it is correct and in line with other analyses and sources.

Overall, i.e. between 1980 and 2005, the number of patents has increased more than eightfold in the 25-year span, i.e. from 1,307 in 1980 to 11,571 in 2005.

The internationality, i.e. the share of international to all patents has developed in a similar pattern to the number of patents: from a share of around 11% in 1980, we have an increase until the share peaks at around 27% in 2006. Since then, the share of international patents has slightly fallen again and it reached around 21% in 2016. Obviously, we will observe a high spread in internationality depending on the country and company of focus: multinational pharma firms in small countries like Switzerland have obviously a much higher internationalization rate, than firms in much large countries, like the US (see also Table 7-3). Generally, the internationality in pharma patents is rather high: every fifth to fourth patent has an international inventor.

7.2.1.2. Development by Applicant Country in the Pharmaceutical Industry

In this step I break down the patent numbers by applicant country. As we focus on recent developments, I include patent data from the priority year 2000 and onward. First, I show the number of patents for the largest applicant countries. Second, I show the share of these patent numbers in relation to the worldwide total. Third, I show the share of international patents for these countries. Due to the incompleteness of data for 2016, I include 2015 as the most recent and sufficiently reliable year for the tables.

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413 Cf. EPO (2020c): by 2018 the patent numbers for Pharmaceuticals have increased over the pre-drop peak. For Biotechnology they have also strongly increased again, but in 2019 are still by around 1,000 patents less than in 2010.

414 Cf. Pugatch, Torstensson, and Chu (2012, p. 30), for an analysis of PCT-data in the biotechnology industry, showing a decrease after the year 2000.

Table 7-2: Patent Breakdown by Applicant Country in Pharma[415]

Applicant Country	Number of Patents per Priority Year				Share TOTAL (%)		CAGR
	2000	2007	2012	2015	2000	2015	'00-'15 (%)
TOTAL	10,716	10,190	8,177	8,624	100	100	-1.4
US	4,808	3,647	3,158	3,540	44.9	41.0	-2.0
Japan	943	948	663	682	8.8	7.9	-2.1
Germany	1,197	986	689	594	11.2	6.9	-4.6
Switzerland	517	738	556	451	4.8	5.2	-0.9
UK	731	516	324	424	6.8	4.9	-3.6
France	543	595	500	430	5.1	5.0	-1.5

Note: Full-counting leads to some double counting.

The table shows the six most relevant applicant countries for the number of pharmaceutical patents. As we have already seen in Figure 7-1, the general development since 2000 is downwards, leading to a negative CAGR. All countries listed, except Switzerland, have decreased more strongly than the global total, meaning that other countries have gained in relative relevance. Germany has particularly decreased its number of patents, with a CAGR of -5%. Since one patent can have applicants located in several countries, such a patent would be counted for each country respectively and thereby counted multiple times. This effect can be neglected though, as the number of unique patents in the whole sample is 253,676 and with double-counting of applicants 264,174 patents, i.e. only 4% more.

We can see a clear dominance of the US as a home-location for firms patenting in the field of pharma. In 2015 41% of all pharma patents had an US applicant. Particularly in most recent years we can generally see a downwards trend in percentages, indicating that other countries are taking a relative share from the six major countries outlined here.

[415] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 7-3: Share of Applicant Countries' International Patents in Pharma[416]

	Share of International Patents (%)			
Country	**2000**	**2007**	**2012**	**2015**
TOTAL	24.5	26.4	24.5	21.4
US	16.9	17.8	18.3	17.4
Japan	11.0	10.5	10.0	8.9
Germany	29.0	26.0	27.4	32.0
Switzerland	86.3	84.1	79.7	71.4
UK	38.0	35.9	41.0	38.2
France	26.9	30.3	28.2	26.5

Table 7-3 shows the share of international patents in relation to all patents by the respective applicant country. The small country of Switzerland clearly stands out, with 86% of all patents having at least one international, i.e. non-Switzerland based inventor in 2000. This share has decreased to 71% in 2015, but that still means that more than two out of three patents by a Swiss applicant have an international inventor. The UK also has a high share of international patents, which even slightly increased over the years from 38.0% in 2000 to 38.2% in 2016.

Overall, the share of international patents worldwide has decreased from 24% in 2000 to 21% in 2016, indicating that non-international patents have gained in relative relevance.

The US, the by far most relevant applicant country for pharma patents, has a below-average share of international patents. Clearly international inventors are not as relevant for this large country, compared to e.g. Switzerland. Japan is comparably un-internationalized with a share of international patents of only 11% in 2000 and 9% in 2015.

With internationalization generally decreasing in relative relevance, it will be interested to see how international patents perform to non-international patents. Before that, i.e. in the next step we will look at the patent development per inventor country.

7.2.1.3. Development by Inventor Country in the Pharmaceutical Industry

In this part I conduct a similar analysis as before, but in Table 7-4 I show the breakdown per inventor country, not applicant country. In order to truly understand where R&D in the pharmaceutical industry happens, we must look at the countries of inventors. The following table therefore show the number of patents with at least one inventor listed on the patent

[416] Source: Own analysis, based on REGPAT database by the OECD (2020h).

based in the respective country. This full-counting leads to some double counting: often patents have several inventors, who might even be based in different countries. Such a patent would be counted for each of the countries involved.

Table 7-4: Patent Breakdown by Inventor Country in Pharma[417]

Inventor Country	Number of Patents per Priority Year				Share TOTAL (%)		CAGR
	2000	**2007**	**2012**	**2015**	**2000**	**2015**	**'00-'15 (%)**
TOTAL	10,716	10,190	8,177	8,624	100	100	-1.3
US	5,249	4,077	3,558	3,928	49.0	45.5	-1.8
Germany	1,321	1,413	888	720	12.3	8.3	-3.7
Japan	988	954	681	678	9.2	7.9	-2.3
France	781	801	639	536	7.3	6.2	-2.3
China	45	196	304	516	0.4	6.0	16.5
UK	1,040	705	438	488	9.7	5.7	-4.6
Switzerland	364	594	404	343	3.4	4.0	-0.4

Note: Full-counting leads to some double counting.

Above table shows the absolute number of patents per inventor country. For example, from all 8,624 patents in the pharma industry in 2015, 3,928 had at least one US-based inventor. Again, we can see a strong decline in patent numbers, except for China. The emerging country has gained strongly in relevance as a location for pharma patents and became the fifth-largest nation in terms of patents with at least one inventor based in the respective country in 2015.

The table also shows the shares of patents per inventor country. We can see again the strong US-dominance in the Pharmaceutical industry: over 40% of all pharma patents have at least one US-based inventor. This clearly shows the importance and relevance of the country. The shares have decreased over the years, indicating that other countries are becoming increasingly relevant. We can see such an uprise very clearly with the case of China: in 2000 China played a negligible role in pharma patents, with less than 1% of all pharma patents having a China-based inventor. This share has risen to 6% in 2015. China-based firms, i.e. applicants do not play a relevant role at this time, so they are not included in the prior sub/chapter.

[417] Source: Own analysis, based on REGPAT database by the OECD (2020h).

We can also see strong differences to the analysis of applicant countries with the case of Switzerland: the small country is host of several major players in the pharmaceutical field, making Switzerland the fourth-largest applicant country in terms of patent numbers. However, these inventions are rather not conducted in Switzerland, as just a much smaller number of patents are having a Swiss-based inventor. In terms of inventor location, Switzerland ranks only seventh in 2015.

In the next part, I compare international to non-international patents.

7.2.1.4. Comparison Non-International and International Patents in Pharmaceutical Industry

Figure 7-2: NRTA in Pharmaceutical Industry[418]

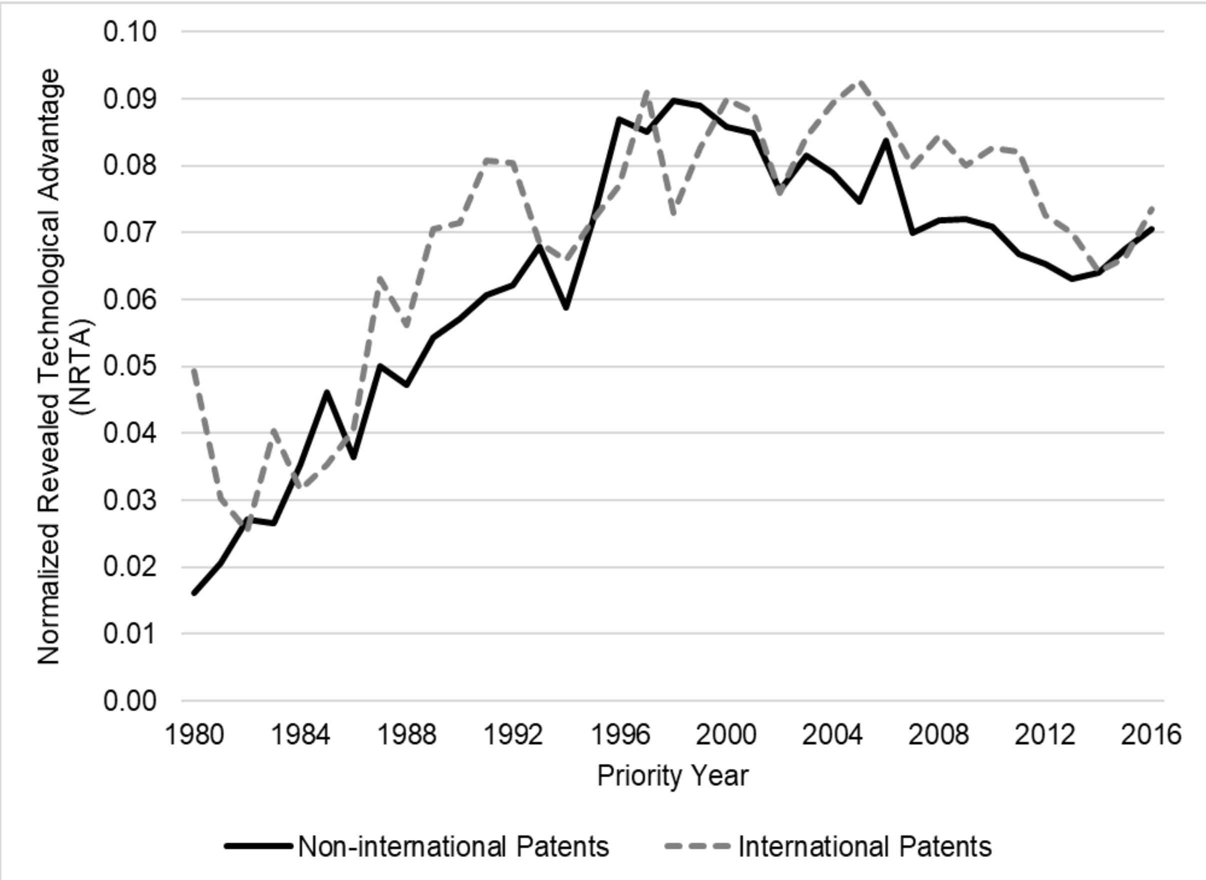


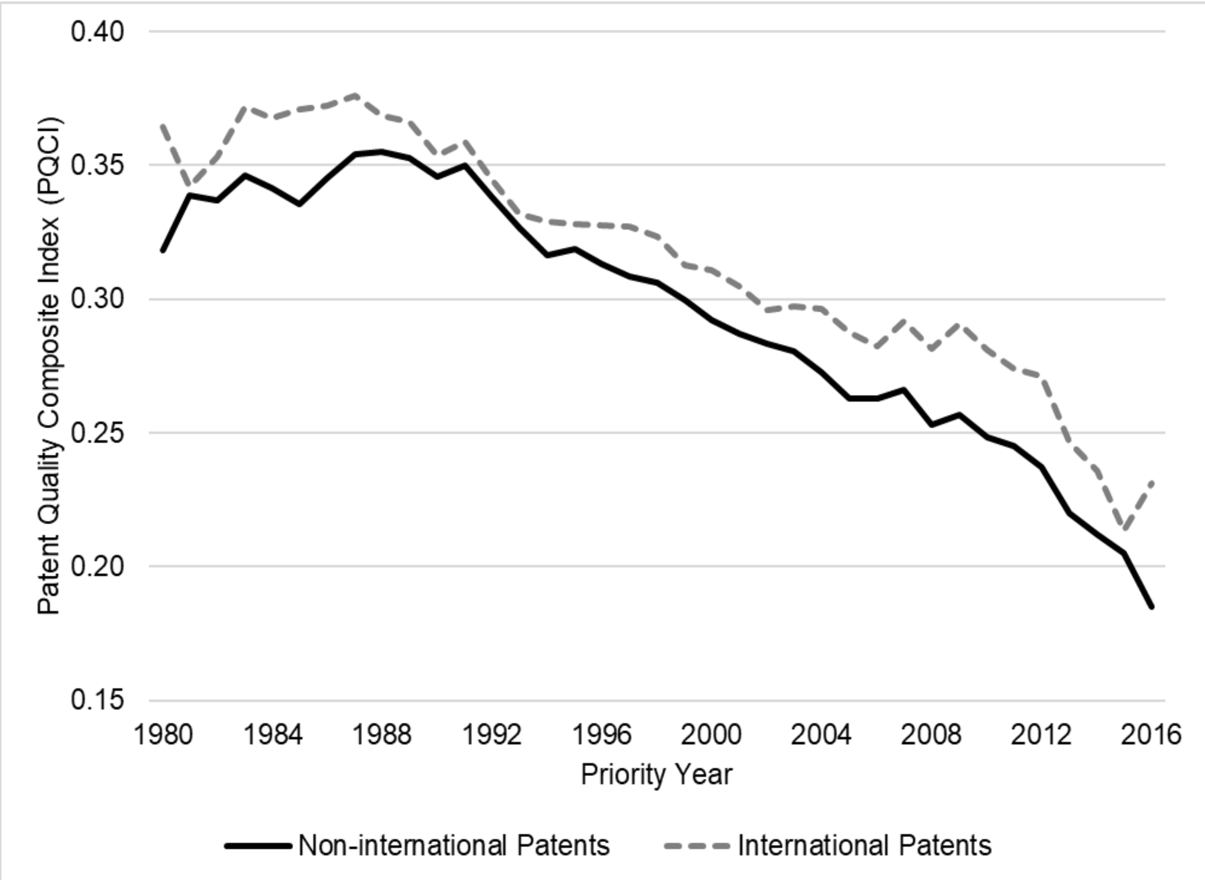
Figure 7-2 shows the average normalized RTA of patents in the pharmaceutical field, separated by patents which are international, i.e. have at least one foreign inventor, and patents which are not. Unsurprisingly, the NRTA over the years is always relatively close to 0: as the NRTA is scaled, so that $NRTA \in [-1; +1]$ and considers the comparative advantage within an industry, an analysis of a whole industry, such as conducted here for Pharma, should

[418] Source: Own analysis, based on REGPAT database by the OECD (2020a, 2020f, 2020h).

yield values around 0. The NRTA is calculated based on the number of patents in a certain field at a certain time.

For almost all years, competitiveness of international patents is higher, than for non-international patents, as the grey dashed line is mostly above the black continuous line. Patents in the field of pharma, created with an international team are more competitive than their domestic counterparts. The overall developments are interesting, as values up until approximately the year 2000 increase and then slightly decrease again. This development is therefore to a certain degree similar to that of the patent numbers, as seen in Figure 7-1. However, this development should not be overestimated: as said before the NRTA is scaled, so that $NRTA \in [-1; +1]$. An increase of 0.03 to 0.09 is therefore not that noteworthy, although the small scale on the y-axis makes such small developments visually dramatic. The distribution of the NRTA across the years (not depicted here) is quite constant. The interesting message here is that regardless of the absolute values, international patents have a higher comparative advantage than non-international ones.

Figure 7-3: PQCI in Pharmaceutical Industry[419]



[419] Source: Own illustration, based REGPAT database by the OECD (2020a, 2020f, 2020h).

Figure 7-3 shows the average quality of patents in the pharmaceutical field, based on a composite of quality indices, such as citations, originality etc. Overall patent quality decreases over the years, from around 0.34 in 1980 to 0.2 in 2016. This general decrease in quality could be partially explained with the innovation slowdown discussion: firms have to increasingly spend more money to maintain a level of innovativeness, due to the increasing complexity. However, a certain PQCI figure cannot be directly translated into economic value, i.e. we could not make a conclusion that a PQCI reduction of 30% goes in hand with an increase in costs or decrease in profitability of for example 30%. The distribution of the PQCI over the years is quite constant.

Once again, our focus in this short analysis is not so much the development of values, but rather the comparison of non-international to international patents. We can clearly see that international patents are always, i.e. in all years, of a higher quality than non-international patents. This quality distance is particularly high in the periods 1983 – 1987 and 2007 – 2012.

We have seen that international patents generally perform better than non-international ones. However, we can expect a high spread within the group of international patents. A US inventor collaborating with a Canadian inventor has certainly different implications than collaborating with a Chinese inventor. Therefore, in the next step, I will include cultural distance as a measurement of "how much" internationalization pays off.

7.2.1.5. Cultural Distance as a Measurement for International Patents in Pharmaceutical Industry

Table 7-5 shows the quality (PQCI) of patents in the pharmaceutical industry. I show the values for the whole period and also separated for the period since 2000, to further illustrate recent developments. I separate International Patents into three groups of cultural distance of the involved inventor cultures: "low" cultural distance, "medium" and "high". Furthermore, I give an example of a country pairing, to illustrate what a "low", "medium" or "high" cultural distance means.

Table 7-5: Pharma Patent Quality by Cultural Distance[420]

Patent Quality	Non-Internat. Patents	International Patents – Cultural Distance			
		Low	Medium	High	***All Patents***
All Years	0.295	0.311	0.306	0.299	*0.305*
Since 2000	0.263	0.293	0.289	0.285	*0.289*

Note: Standard Deviation for all groups ≈ 0.1. Example for cultural distances: Low: US-Canada; Medium: US-Germany; High: US-China.

We can see the average patent quality of all non-international patents, i.e. all patents with no cultural distance in the first column. For comparison I show the average patent quality for all international patents, i.e. all patents with some cultural distance in the last column. This column is the aggregate of the breakdown into three levels of cultural distance. The standard deviation is constant at around 0.1 for all groups and samples, indicating that there are no outliers distorting the analysis.

Overall, we can see that the average quality has decreased, i.e. the average for the priority years 2000 and onwards is lower than the total sample. We have already seen this in the prior sub-chapter in Figure 7-3.

Table 7-6: Group Means Differences (one-way ANOVA) in Pharma Patent Quality

Cultural Distance (CD)	Non-International Patents	Low CD	Medium CD
Low CD	Pos. sig. (***)	-	-
Medium CD	Pos. sig. (***)	Neg. insig.	-
High CD	Pos. sig. (*)	Neg. sig. (**)	Neg. sig. (**)

*Note: Significance levels given with asterisks: p-Level: * < 0.05 | ** < .01 | *** < 0.001. One-way ANOVA with Bonferroni correction. No differences between "All Years" and "Since 2000", unless explicitly noted. Detailed test statistics shown exemplified for Pharma in Appendix-Table 7.*

Two main findings can be observed: First, internationalization pays almost always off on average. For all levels of cultural distance, we always have a (significantly) higher quality average, than those patents without internationalization, although for a high cultural distance the effect is only slightly significant ($p < 0.05$). Second, a low degree of cultural distance pays off the most. A medium and high cultural distance leads to a smaller average in patent quality,

[420] Source: Own illustration, based REGPAT database by the OECD (2020a, 2020f, 2020h).

although the decrease in means between a low and medium CD is not statistically significant. In fact, it seems that the positive effects of internationalization reduce with too much internationalization. In a highly complex research setting, such as Pharma, too much internationalization can therefore be less productive. We can explain this observation with the literature, discussed in Chapter 2.3.4, which finds negative effects of too much internationalization due to a spike in coordination costs. These findings therefore lend support to an inverted U-curve hypothesis, i.e. that the optimal levels of internationalization are not a boundary solution, but somewhat in between.

7.2.1.6. Conclusion Patent Analysis of Pharmaceutical Industry

In this part we have put patents in the pharmaceutical industry under scrutiny. The overall number of patents, as well as the share of patents with international inventors has strongly grown since 1980, with a peak around 2005 and a decrease since then. We have seen a clear dominance of the US in the pharmaceutical industry, both as a location for applicant, i.e. firms, but also as a location for inventors, i.e. base for the actual inventive activities. China has strongly gained in relevance as a location for pharmaceutical R&D activities over the last decade.

International patents are of a higher quality and a higher comparative advantage than non-international patents, although too much internationalization has a diminishing marginal benefit. In fact, patents with a low cultural distance, e.g. a collaboration between US and Canada or Germany and Switzerland have the highest average quality. This is only a first indication. Clear black and white results are not possible in the complex field of Cultural Analysis, as outlined in the theoretical background in Chapter 2.3.

7.2.2. Patent Analysis of Biotechnology Industry

In this sub-chapter, I will analyze the biotechnology industry, based on the relevant IPCs, as detailed in Table 7-1. As outlined before I split pharma & biotech in this analysis, as they are similar and often overlapping industry, yet disjoint with different strategies and approaches.

First, I show the general development of patents between 1980 and 2016, as well as the share of international patents, i.e. patents with inventors and / or applicants from different countries.

Second, I compare in non-international and international patents between 1980 and 2016, i.e. show whether international patent teams create better performing patents.

7.2.2.1. General Development in Biotechnology Industry

Figure 7-4: Overview Patent Development in Biotech[421]

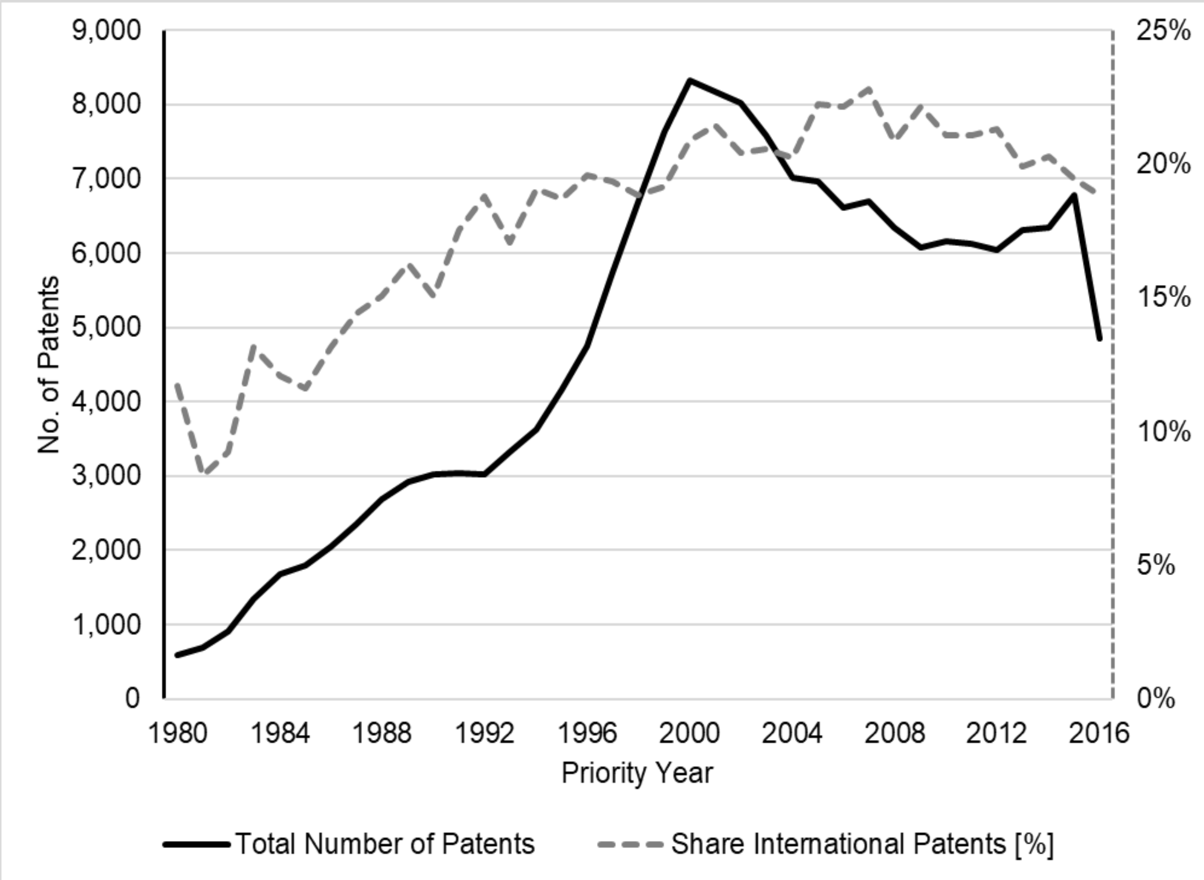


Figure 7-4 shows the total number of patents per priority year in the biotechnology field on the left y-axis and with the continuous black line, and the share of international to total patents on the right y-axis, with the dashed grey line.

We can observe a (almost) continuous and strong growth of patent numbers since 1980 until 2000. Within these 20 years, the number of patents has increased more than 13-fold, i.e. from 597 in 1980 to 8,324 in 2000. Between 1993 and 2000 we even have an approximately exponential growth in patent numbers. Since 2000, the number of patents per year has decreased to 6,782 in 2015 or 4,853 in 2016. The numbers for 2016 might not be complete yet, due to publication time-lags, which could partially explain the strong drop from 2015 to 2016, so again I will include in the tables 2015 as the most recent reliable data point.

It is interesting to observe that, similarly to the pharmaceutical industry, the number of patents has decreased substantially since 2000. For a discussion of the arguments explaining this decrease, please refer to the previous part on the Pharmaceutical Industry (Chapter 7.2.1.1).

[421] Source: Own analysis, based on REGPAT database by the OECD (2020h).

In a nutshell, the decrease is correct, although since 2016 the patent numbers are increasing again.

The similar developments in the pharma & biotech industry cannot be explained with a large overlap, i.e. the intersection of both patent data sets is rather small. Only 22% of the patents analyzed appear in both datasets, i.e. have an IPC classification from both the pharmaceutical and the biotechnology sector.[422] The overlap of firms is, however, much larger: large firms which patent numerously in the biotechnology sector are mostly not clear-cut biotech firms, but also operate strongly in the pharmaceutical sector. Novo Nordisk, a company listed as the second-largest biotech firm in 2019 worldwide[423], operates also strongly in the pharmaceutical field and describes itself more broadly as a “healthcare company”[424]. While there is a technological difference between pharma & biotech, which warrants the separate patent analysis in this chapter, it is more the small startups which actually embody this technological split – large firms mostly operate in both fields. The EPO, for example, argues that 55% of all patents in biotechnology refer to pharmaceutical products, without giving technical details.[425]

The internationality, i.e. the share of international to all patents has developed in a similar pattern to the number of patents: from a share of around 12% in 1980, we have an increase until the share peaks at around 23% in 2007. Since then, the share of international patents has slightly fallen again and it reached around 19% in 2016. Obviously, we will observe a high spread in internationality depending on the country and company of focus: multinational pharma firms in small countries like Switzerland have obviously a much higher internationalization rate, than firms in much large countries, like the US. Generally, the internationality in biotechnology patents is rather high: every fifth to fourth patent has an international inventor.

7.2.2.2. Development by Applicant Country in the Biotechnology Industry

In this step I break down the patent numbers by applicant country. As we focus on recent developments, I include patent data from the priority year 2000 and onward. First, I show the number of patents for the largest applicant countries. Second, I show the share of these patent numbers in relation to the worldwide total. Third, I show the share of international patents for these countries.

[422] In set notation: $pharma \cup biotech = 354{,}606$ | $pharma \cap biotech = 76{,}994$

[423] Cf. GEN (2019).

[424] Cf. Annual Report – Novo Nordisk (2020).

[425] Cf. EPO (2020a).

Table 7-7: Patent Breakdown by Applicant Country Biotech[426]

Applicant Country	**Number of Patents per Priority Year**				**Share TOTAL (%)**		**CAGR**
	2000	**2007**	**2012**	**2015**	**2000**	**2015**	**'00-'15 (%)**
TOTAL	8,324	6,702	6,037	6,782	100	100	-1.4
US	4,315	2,764	2,671	2,714	48.3	40.0	-2.6
Germany	858	729	592	634	13.0	9.3	-3.5
Japan	1,073	901	701	619	9.8	9.1	-1.8
France	588	396	343	408	4.3	6.0	0.9
Switzerland	468	503	436	369	3.5	5.4	1.7
UK	189	204	203	319	5.6	4.7	-2.4

Note: Full-counting leads to some double counting.

The table shows the six most relevant applicant countries for the number of biotechnology patents. As we have already seen in Figure 7-4, the general development since 2000 is downwards, leading to a negative CAGR. Germany has particularly decreased its number of patents, with a CAGR of -3.5%. Since one patent can have applicants located in several countries, such a patent would be counted for each country respectively and thereby counted multiple times. As discussed previously, this effect is negligibly small.

We can see a clear dominance of the US as a location for firms patenting in the field of biotechnology. In 2015 40% of all biotech patents had an US applicant. Particularly in most recent years we can generally see a downwards trend in percentages, indicating that other countries are taking a relative share from the six major countries outlined here.

[426] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 7-8: Share of Applicant Countries' International Patents in Biotech[427]

Country	Share of International Patents (%) 2000	2007	2012	2015
TOTAL	20.9	22.8	21.3	19.4
US	16.0	15.3	16.0	13.3
Germany	32.7	36.3	24.5	30.9
Japan	8.1	6.5	6.6	5.0
France	26.8	31.0	28.3	26.5
Switzerland	83.3	87.2	82.5	78.9
UK	32.0	29.0	30.2	21.9

Table 7-8 shows the share of international patents in relation to all patents by the respective applicant country. The small country of Switzerland clearly stands out, with 79% of all patents having at least one international, i.e. non-Switzerland based inventor in 2015. Comparable to the findings in pharma patents, we see again that Japan is comparably little internationalized with a share of international patents in the single-digits.

Overall, the share of international patents worldwide has decreased from 21% in 2000 to 19% in 2015, indicating that non-international patents have gained in relative relevance.

The US, the by far most relevant applicant country for pharma patents, has a below-average share of international patents. Clearly international inventors are not as relevant for this large country, compared to e.g. Switzerland.

With internationalization generally decreasing in relative relevance, it will be interested to see how international patents perform to non-international patents. Before that, i.e. in the next step, we will look at the patent development per inventor country.

7.2.2.3. Development by Inventor Country in the Biotechnology Industry

In this part I conduct a similar analysis as before, but in Table 7-9 I show the breakdown per inventor country, not applicant country. In order to truly understand where R&D in the Technology Hardware industry happens, we must look at the countries of inventors. The following table therefore shows the number of patents with at least one inventor listed on the patent based in the respective country. This full-counting leads to some double counting: often

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427 Source: Own analysis, based on REGPAT database by the OECD (2020h).

patents have several inventors, who might even be based in different countries. Such a patent would be counted for each of the countries involved.

Table 7-9: Patent Breakdown by Inventor Country Biotech[428]

Inventor Country	Number of Patents per Priority Year				Share TOTAL (%)		CAGR
	2000	2007	2012	2015	2000	2015	'00-'15 (%)
TOTAL	8,324	6,702	6,037	6,782	100	100	-1.4
US	4,315	2,764	2,671	3,063	51.8	45.2	-2.3
Japan	858	729	592	617	10.3	9.1	-2.2
Germany	1,073	901	701	725	12.9	10.7	-2.6
France	468	503	436	433	5.6	6.4	-0.5
UK	588	396	343	397	7.1	5.9	-2.6
China	36	94	126	261	0.4	3.8	14.1
South Korea	75	136	145	234	0.9	3.5	7.9
Switzerland	189	204	203	216	2.3	3.2	0.9

Note: Full-counting leads to some double counting.

Above table shows the absolute number of patents per inventor country. For example, from all 6,782 patents in the pharma industry in 2015, 3,063 had at least one US-based inventor. Again, we can see a strong decline in patent numbers.

We also see the shares of patents per inventor country. We can observe again the strong US-dominance in the Biotechnology industry: over 45% of all biotech patents have at least one US-based inventor. This clearly shows the importance and relevance of the country. The shares have decreased over the years, indicating that other countries are becoming increasingly relevant.

We can also see strong differences to the analysis of applicant countries with the case of Switzerland: the small country is host of several major players in the biotechnology field, making Switzerland the fifth-largest applicant country in terms of patent numbers. However, these inventions are rather not conducted in Switzerland, as just a much smaller number of patents have a Swiss-based inventor. In terms of inventor location, Switzerland ranks only eighth in 2015.

[428] Source: Own analysis, based on REGPAT database by the OECD (2020h).

In the next part, I compare international to non-international patents.

7.2.2.4. Comparison Non-International and International Patents in Biotechnology Industry

Figure 7-5: NRTA in Biotech[429]

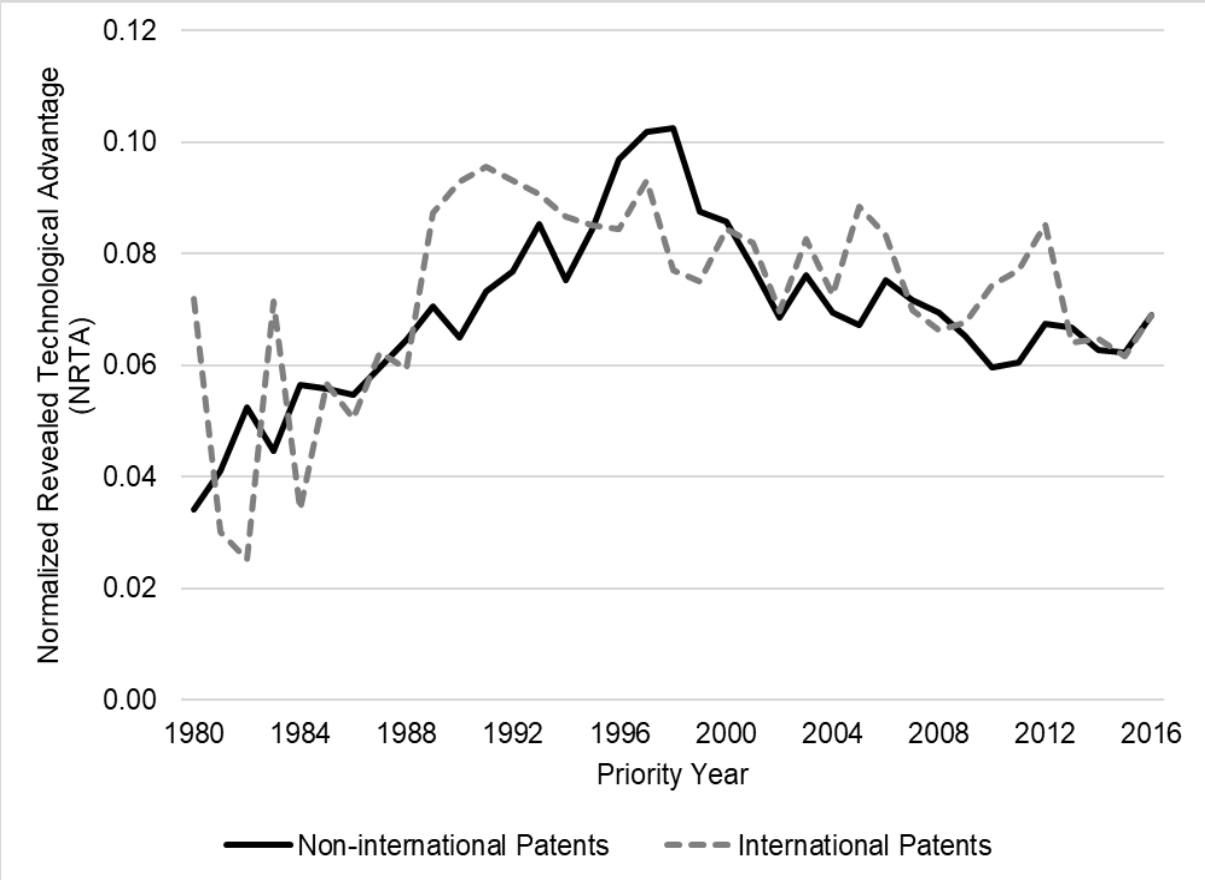


Figure 7-5 shows the average comparative advantage of patents in the biotechnology field, separated by patents which are international, i.e. have at least one foreign inventor, and patents which are not. Unsurprisingly, the NRTA over the years is always relatively close to 0: as the NRTA is scaled, so that $NRTA \in [-1; +1]$ and considers competitiveness within an industry, an analysis of a whole industry, such as conducted here for biotech, should yield values around 0. The NRTA is calculated based on the number of patents in a certain field at a certain time.

For almost all years, competitiveness of international patents is higher, than for non-international patents, as the grey dashed line is almost always above the black continuous line. Patents in the field of biotech, created with an international team have a higher comparative advantage than their domestic counterparts, meaning there are more patents in

[429] Source: Own analysis, based on REGPAT database by the OECD (2020a, 2020f, 2020h).

the relevant fields. The overall developments are interesting, as values up until approximately the year 2000 increase and then slightly decrease again. This development is therefore to a certain degree similar to that of the patent numbers, as seen in Figure 7-4. However, this development should not be overestimated: as said before the NRTA is scaled, so that $NRTA \in [-1; +1]$. The distribution of the NRTA across the years (not depicted here) is again quite constant. The interesting message here is that regardless of the absolute values, international patents are more competitive than non-international ones, except for the short period 1996 - 2000, which shows are peak and somewhat of an anomaly.

Figure 7-6: PQCI in Biotech[430]

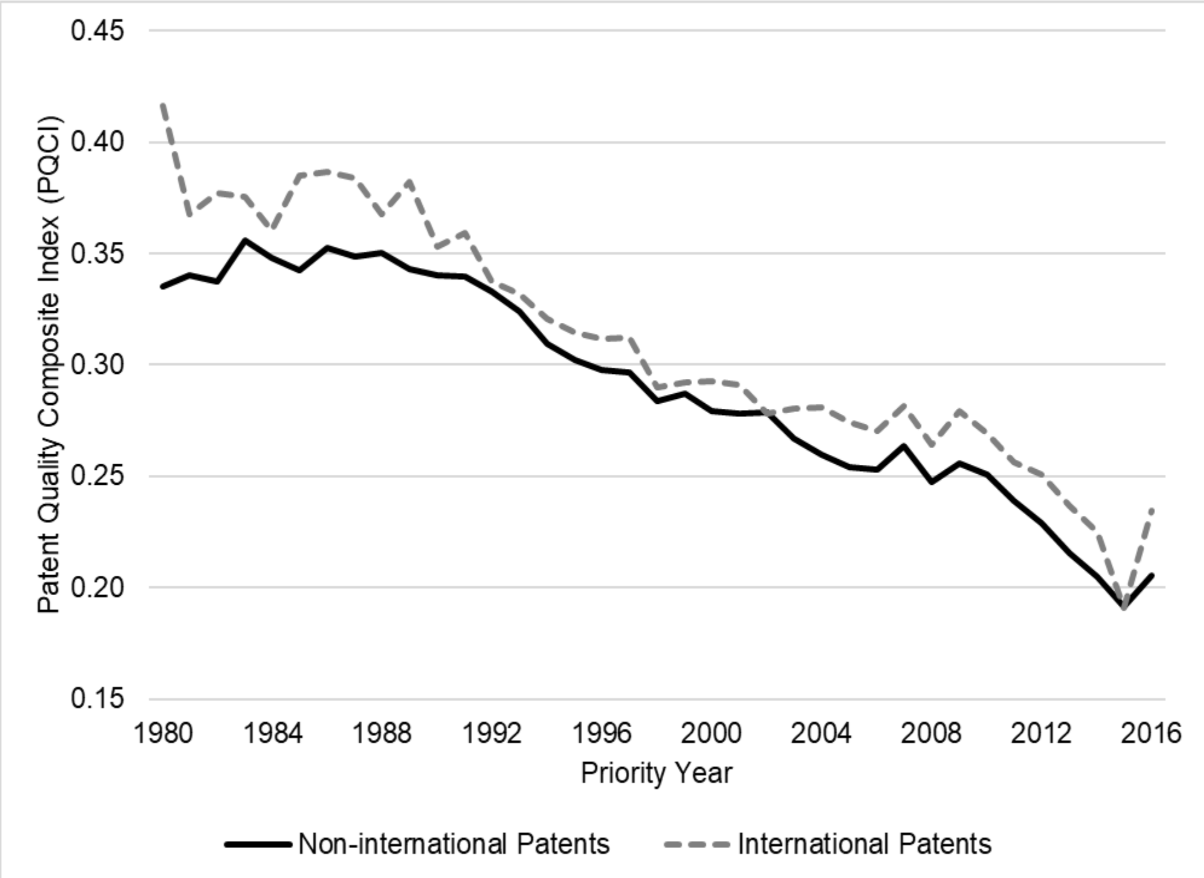


Figure 7-6 shows the average quality of patents in the biotechnology field, based on a composite of quality indices, such as citations, originality etc. Overall patent quality decreases over the years, from around 0.36 in 1980 to 0.2 in 2016. Again, we can somewhat find arguments for a potential innovation slowdown, as discussed above: firms have to increasingly spend more money to maintain a level of innovativeness, due to the increasing complexity.

[430] Source: Own illustration, based REGPAT database by the OECD (2020a, 2020f, 2020h).

Once again, our focus in this short analysis is not so much the development of values, but rather the comparison of non-international to international patents. We can clearly see that international patents are always, i.e. in all years, of a higher quality than non-international patents.

We have seen that international patents generally perform better than non-international ones. However, we can expect a high spread within the group of international patents. Therefore, in the next step, I will include cultural distance as a measurement "how much" internationalization pays off.

7.2.2.5. Cultural Distance as a Measurement for International Patents in Biotechnology Industry

Table 7-10 shows the quality (PQCI) of patents in the biotechnology industry. I show the values for the whole period and also separated for the period since 2000, to further illustrate recent developments. I separate International Patents into three groups of cultural distance of the involved inventor cultures: "low" cultural distance, "medium" and "high". Furthermore, I give an example of a country pairing, to illustrate what a "low", "medium" or "high" cultural distance means.

Table 7-10: Biotech Patent Quality by Cultural Distance[431]

Patent Quality	**Non-Internat. Patents**	**International Patents – Cultural Distance**			
		Low	**Medium**	**High**	***All Patents***
All Years	0.283	0.303	0.294	0.284	*0.286*
Since 2000	0.255	0.282	0.273	0.266	*0.258*

Note: Standard Deviation for all groups ≈ 0.1. Example for cultural distances: Low: US-Canada; Medium: US-Germany; High: US-China.

We can see the average patent quality of all non-international patents, i.e. all patents with no cultural distance in the first column. For comparison I show the average patent quality for all international patents, i.e. all patents with some cultural distance in the last column. This column is the aggregate of the breakdown into three levels of cultural distance. The standard deviation is constant at around 0.1 for all groups and samples, indicating that there are no outliers distorting the analysis. Overall, we can see that the average quality has decreased, i.e. the average for the priority years 2000 and onwards is lower than the total sample. We have already seen this in the prior sub-chapter in Figure 7-6.

[431] Source: Own illustration, based REGPAT database by the OECD (2020a, 2020f, 2020h).

Table 7-11: Group Means Differences (one-way ANOVA) in Biotech Patent Quality

Cultural Distance (CD)	Non-International Patents	Low CD	Medium CD
Low CD	Pos. sig. (***)	-	-
Medium CD	Pos. sig. (***)	Neg. insig.	-
High CD	Pos. sig. (***)	Neg. sig. (***)	Neg. sig. (***)

*Note: Significance levels given with asterisks: p-Level: * < 0.05 | ** < .01 | *** < 0.001. One-way ANOVA with Bonferroni correction. No differences between "All Years" and "Since 2000", unless explicitly noted.*

The two main findings are identical to what we have seen for patents in the pharmaceutical industry: First, internationalization pays always off on average. Regardless of the respective level of cultural distance, we always have a statistically significantly higher quality average, than those patents without internationalization. Second, a low degree of cultural distance pays off the most. A medium and high cultural distance leads to a smaller average in patent quality, although the difference between the groups of low and medium CD are, again, not statistically significant. In fact, it seems that the positive effects of internationalization reduce with too much internationalization.

Once again, in a highly complex research setting, such as Biotech, too much internationalization can therefore be less productive. We can explain this observation with the literature, discussed in Chapter 2.3.4, which finds negative effects of too much internationalization due to a spike in coordination costs. These findings therefore lend support to an inverted U-curve hypothesis, i.e. that the optimal levels of R&D Internationalization diversity are somewhat moderate: i.e. international teams perform better, if they are not "too international".

7.2.2.6. Conclusion Patent Analysis of Biotechnology Industry

In this part we have put patents in the biotech industry under scrutiny. The overall number of patents, as well as the share of patents with international inventors has strongly grown since 1980, with a peak around 2000 and a decrease since then. We have seen a clear dominance of the US in the biotech industry, both as a location for applicant, i.e. firms, but also as a location for inventors, i.e. base for the actual inventive activities.

International patents are of a higher quality and have a higher comparative advantage than non-international patents, although too much internationalization has a diminishing marginal benefit. In fact, patents with a low cultural distance, e.g. a collaboration between US and Canada or Germany and Switzerland have the highest average quality. Again, this is only a first indication. Clear black and white results are not possible in the complex field of Cultural Analysis, as outlined in the theoretical background in Chapter 2.3.

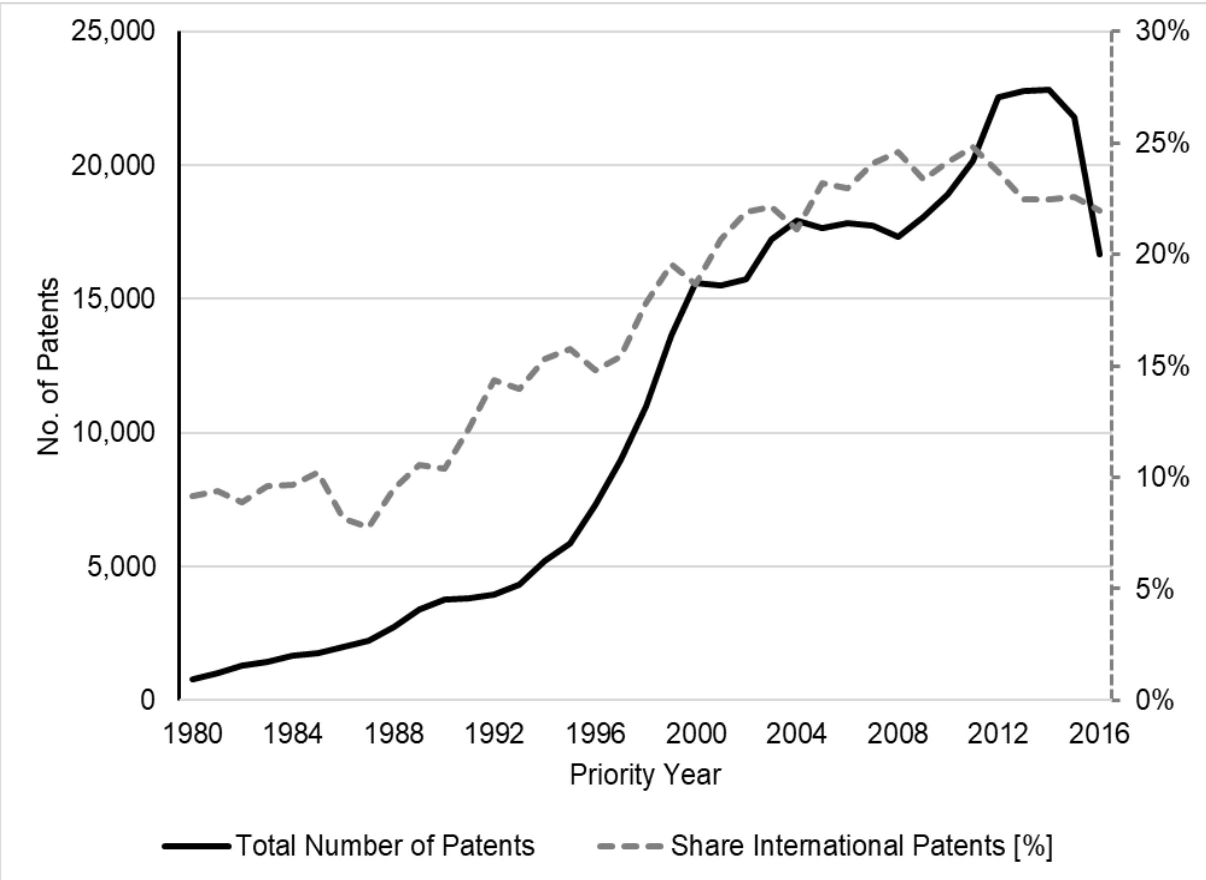
Overall, the findings of the biotech industry are quite similar to that of the pharmaceutical, although the patent sets are rather disjoint. This indicates that both industries follow similar paths in patent development. Certain differences stand out, though, most notably that while China has grown to be a relevant inventor location for pharmaceutical activities, it does not hold such a position in the biotechnology industry.

7.2.3. Patent Analysis of Technology Hardware Industry

In this sub-chapter, I will analyze the Technology Hardware industry, based on the relevant IPCs, as detailed in Table 7-1 and the same structure shown for the previous industries.

7.2.3.1. General Development in Technology Hardware Industry

Figure 7-7: Overview Patent Development in Tech Hardware[432]



[432] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Figure 7-7 shows the total number of patents per priority year in the Technology Hardware field on the left y-axis and with the continuous black line, and the share of international to total patents on the right y-axis, with the dashed grey line.

We can observe a (almost) continuous and strong growth of patent numbers since 1980. Between around 1993 and 2000 we can even observe an almost exponential growth, followed by a somewhat linear upwards trend and again exponential growth between 2008 and 2012. The numbers for 2016 might not be complete yet, due to publication time-lags, which could partially explain the strong drop from 2015 to 2016, so again I will include in the tables 2015 as the most recent reliable data point. Between 1980 and 2015 patent numbers have increased by the factor 27.

As opposed to the pharmaceutical and biotechnology field, analyzed before, we do not see real decline in patent numbers (apart from the 2016 drop), but also have the somewhat exponential growth to the 2000s.

The internationality, i.e. the share of international to all patents has developed almost always upwards: 9% in 1980 to 23% in 2015. It comes as little surprise that the internationality is somewhat lower compared to pharma and biotech patents.

7.2.3.2. Development by Applicant Country in the Technology Hardware Industry

In this step I break down the patent numbers by applicant country. As we focus on recent developments, I include patent data from the priority year 2000 and onward. First, I show the number of patents for the largest applicant countries. Second, I show the share of these patent numbers in relation to the worldwide total. Third, I show the share of international patents for these countries.

Table 7-12: Patent Breakdown by Applicant Country Tech Hardware[433]

Applicant Country	Number of Patents per Priority Year				Share TOTAL (%)		CAGR
	2000	2007	2012	2015	2000	2015	'00-'15 (%)
TOTAL	15,617	17,758	22,553	21,799	100	100	2.2
US	5,925	5,371	6,792	7,030	37.9	32.2	1.1
China	32	1,063	2,898	3,164	0.2	14.5	35.8
Japan	3,389	2,935	2,754	2,515	21.7	11.5	-2.0
South Korea	323	1,318	2,066	1,826	2.1	8.4	12.2
Sweden	634	1,094	1,580	1,340	4.1	6.1	5.1
France	944	1,220	1,444	1,255	6.0	5.8	1.9
Germany	1,432	1,265	1,236	1,180	9.2	5.4	-1.3

Note: Full-counting leads to some double counting.

The table shows the seven most relevant applicant countries for the number of Technology Hardware patents, sorted decreasingly by their most recent 2015 value. We can observe a strong dominance of firms based in the US: around 32%, i.e. every third patent, has a US-based applicant. Japan and Germany, two classic industrialized economies have slightly decreased their patent numbers, with a respectively negative CAGR between 2000 and 2015. Their respective share to total patent numbers drops, indicating that other countries have gained in relevance. The CAGR also shows us who that us, i.e. the fast climbers: emerging economies China and South Korea with a respectively two-digit CAGR. Particularly China has grown its patent numbers strongly from a mere 32 in 2000 to 3,164 in 2015, making the country the second-largest country in terms of patent applications.

433 Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 7-13: Share of Applicant Countries' International Patents in Tech Hardware[434]

	Share of International Patents (%)			
Country	**2000**	**2007**	**2012**	**2015**
TOTAL	18.7	24.1	23.7	22.6
US	20.7	20.2	21.3	19.8
China	6.3	7.8	8.8	13.9
Japan	5.8	15.8	13.6	19.5
South Korea	7.1	7.8	10.3	11.9
Sweden	42.3	47.0	52.4	50.2
France	35.1	38.8	44.5	30.0
Germany	17.0	23.0	19.5	19.9

Table 7-13 shows the share of international patents in relation to all patents by the respective applicant country. The small country of Sweden clearly stands out, with 50% of all its patents having at least one international, i.e. non-Sweden based inventor in 2015. The Asian countries China and South Korea are comparably little internationalized, with a share of international patents around 13%. Japan, a country which was usually rather un-internationalized in terms of R&D Expenditure and patents has relatively strongly increased its share of international patents: from 6% to 20% in 2015, which is only slightly below the world-average. The US, as the clearly dominating country in this field, has kept its share of international patents rather constant at around 20%.

With internationalization generally increasing in relative relevance, it will be interested to see how international patents perform to non-international patents. Before that, i.e. in the next step, we will look at the patent development per inventor country.

7.2.3.3. Development by Inventor Country in the Technology Hardware Industry

In Table 7-14 I show the breakdown per inventor country and, as before, I point out how full-counting of patents may lead to some double counting, as patents usually have several inventors.

[434] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 7-14: Patent Breakdown by Inventor Country Tech Hardware[435]

Inventor Country	Number of Patents per Priority Year				Share TOTAL (%)		CAGR '00-'15 (%)
	2000	2007	2012	2015	2000	2015	
TOTAL	15,617	17,758	22,553	21,799	100	100	2.2
US	5,574	5,814	7,438	7,345	35.7	33.7	1.9
China	55	1,223	3,453	3,596	0.4	16.5	32.1
Japan	3,321	2,761	2,587	2,259	21.3	10.4	-2.5
South Korea	325	1,281	2,015	1,694	2.1	7.8	11.6
Germany	1,728	1,738	1,603	1,555	11.1	7.1	-0.7
Sweden	496	870	1,255	1,173	3.2	5.4	5.9
France	983	1,036	1,074	1,125	6.3	5.2	0.9

Note: Full-counting leads to some double counting.

Above table shows the absolute number of patents per inventor country. For example, from all 21,799 patents in the Technology Hardware field in 2015, 7,345 had at least one US-based inventor.

We also see the shares of patents per inventor country. We can observe again the strong US-dominance in the Technology Hardware field and the uprise of China and South Korea. We cannot observe strong differences between the overview by applicant vs inventor countries, meaning that very broadly speaking inventions are more or less created in the country of the applicant, i.e. domestically, whereas international activities only complement and not replace domestic efforts. As Technology Hardware also implies significant production processes, we can explain this observation through a closeness of R&D and manufacturing.

In the next part, I compare international to non-international patents.

435 Source: Own analysis, based on REGPAT database by the OECD (2020h).

7.2.3.4. Comparison Non-International and International Patents in Technology Hardware Industry

Figure 7-8: NRTA in Tech Hardware[436]

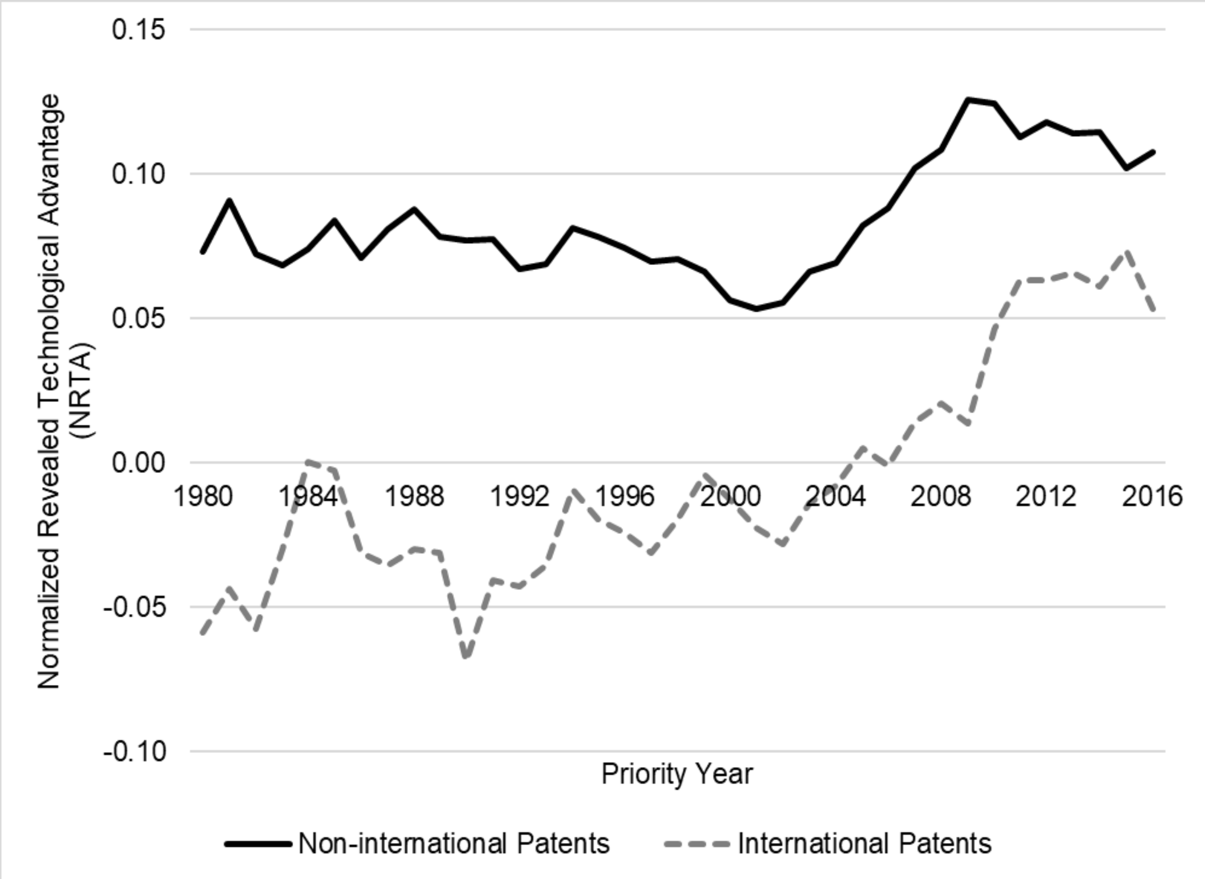


Figure 7-8 shows the average comparative advantage of patents in the Technology Hardware field, separated by patents which are international, i.e. have at least one foreign inventor, and patents which are not. Unsurprisingly, the NRTA over the years is always relatively close to 0: as the NRTA is scaled, so that $NRTA \in [-1; +1]$, and considers competitiveness within an industry, an analysis of a whole industry, should yield values around 0. The NRTA is calculated based on the number of patents in a certain field at a certain time.

Interestingly non-international patents have a consistently higher NRTA, i.e. comparative advantage than international patents due to the relatively higher number of patents. This means that non-international patents have a higher relative strength than international patents. The values for both groups highly correlate with a correlation coefficient > 0.9. This can be clearly seen at the parallel developments since the year 2003.

[436] Source: Own analysis, based on REGPAT database by the OECD (2020a, 2020f, 2020h).

The distribution of the NRTA across the years (not depicted here) is again quite constant. The interesting message here is that regardless of the absolute values, international patents are not as competitive than non-international ones.

Figure 7-9: PQCI in Tech Hardware[437]

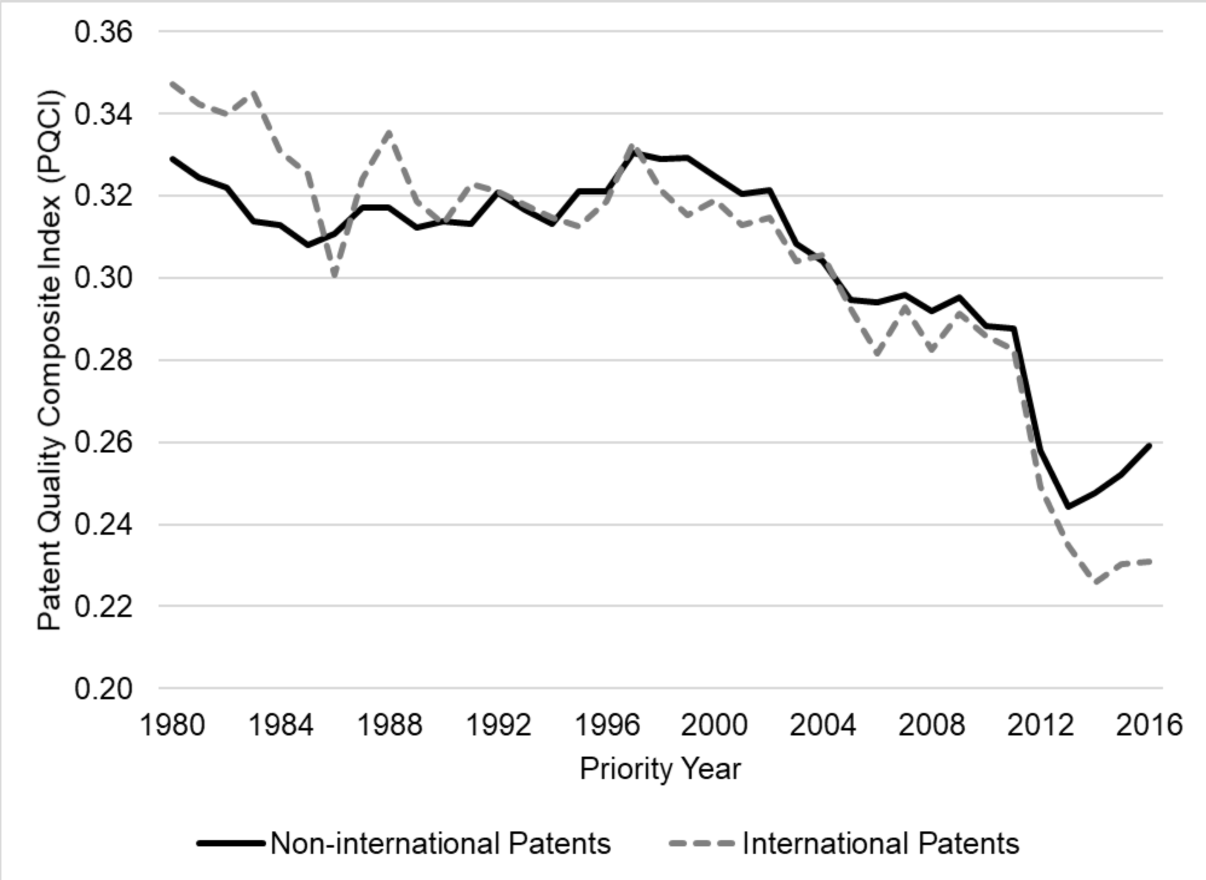


Figure 7-9 shows the average quality of patents in the Technology Hardware field, based on a composite of quality indices, such as citations, originality etc. Overall patent quality decreases over the years, particularly since 2012.

Once again, our focus in this short analysis is not so much the development of values, but rather the comparison of non-international to international patents. While non-international patents are slightly better, i.e. the line is almost always above the line for international patents, this difference is very small and we can conclude with a clear superiority of one over the other.

In the next step we differentiate internationality to show some differences within the rather heterogeneous group of international patents.

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[437] Source: Own illustration, based REGPAT database by the OECD (2020a, 2020f, 2020h).

7.2.3.5. Cultural Distance as a Measurement for International Patents in Technology Hardware Industry

Table 7-15 shows the quality (PQCI) of patents in the Technology Hardware industry. I show the values for the whole period and also separated for the period since 2000, to further illustrate recent developments. As before I separate International Patents into the three groups of cultural distance “low”, “medium” or “high”.

Table 7-15: Technology Hardware Patent Quality by Cultural Distance[438]

Patent Quality	Non-Internat. Patents	International Patents – Cultural Distance			
		Low	Medium	High	*All Patents*
All Years	0.300	0.307	0.294	0.290	*0.300*
Since 2000	0.290	0.301	0.285	0.282	*0.290*

Note: Standard Deviation for all groups ≈ 0.09. Example for cultural distances: Low: US-Canada; Medium: US-Germany; High: US-China.

We can see the average patent quality of all non-international patents, i.e. all patents with no cultural distance in the first column. For comparison I show the average patent quality for all international patents, i.e. all patents with some cultural distance in the last column. This column is the aggregate of the breakdown into three levels of cultural distance. The standard deviation is constant at around 0.9 for all groups and samples, indicating that there are no outliers distorting the analysis. Overall, we can see that the average quality has decreased, i.e. the average for the priority years 2000 and onwards is lower than the total sample. We have already seen this in the prior sub-chapter.

Table 7-16: Group Means Differences (one-way ANOVA) in Technology Hardware Patent Quality

Cultural Distance (CD)	Non-International Patents	Low CD	Medium CD
Low CD	Pos. sig. (***)	-	-
Medium CD	Neg. sig. (***)	Neg. sig. (***)	-
High CD	Neg. sig. (***)	Neg. sig. (***)	Neg. insig.

*Note: Significance levels given with asterisks: p-Level: * < 0.05 | ** < .01 | *** < 0.001. One-way ANOVA with Bonferroni correction. No differences between “All Years” and “Since 2000”, unless explicitly noted.*

438 Source: Own illustration, based REGPAT database by the OECD (2020a, 2020f, 2020h).

We can make two main findings: First, the highest patent quality can be observed on average with a low cultural distance, which is the same finding we have seen for pharma and biotech patents. Second, a medium or even high cultural distance decreases patent quality, even below to the values we have for non-international patents, although the difference between the groups of medium and high CD are not statistically significant.

This result is different to the pharma and biotech patents, where internationalization always pays off. Together with the rather unexpected findings in the previous sub-chapter, this underlines the complexity of internationalization.

However, again we can conclude that too much internationalization can be less productive. We can explain this observation with the literature, discussed in Chapter 2.3.4, which finds negative effects of too much internationalization due to a spike in coordination costs.

7.2.3.6. Conclusion Patent Analysis of Technology Hardware Industry

In this part we have put patents in the Technology Hardware industry under scrutiny. The overall number of patents, as well as the share of patents with international inventors has strongly grown since 1980. We have seen a clear dominance of the US in the Technology Hardware industry, both as a location for applicant, i.e. firms, but also as a location for inventors, i.e. base for the actual inventive activities. Emerging countries, such as China and South Korea have strongly increased their patent numbers in recent years, with the former now even ranking second worldwide.

International patents are not necessarily of a higher quality and more competitive than non-international patents: only patents with a low cultural distance show a gain compared to non-international patents. Together with the strong similarity in patterns of applicant vs. inventor distributions in patents in the Technology Hardware industry, we can conclude that highly international and culturally diverse collaborations are not key in this field.

7.2.4. Patent Analysis of Software & Computer Services Industry

In this sub-chapter, I will analyze the software and computer services hardware industry, based on the relevant IPCs, as detailed in Table 7-1.

First, I show the general development of patents between 1980 and 2016, as well as the share of international patents, i.e. patents with inventors and / or applicants from different countries.

Second, I compare in non-international and international patents between 1980 and 2016, i.e. show whether international patent teams create better performing patents.

7.2.4.1. General Development in Software & Computer Services Industry

Figure 7-10: Overview Patent Development in Software & Computer Services[439]

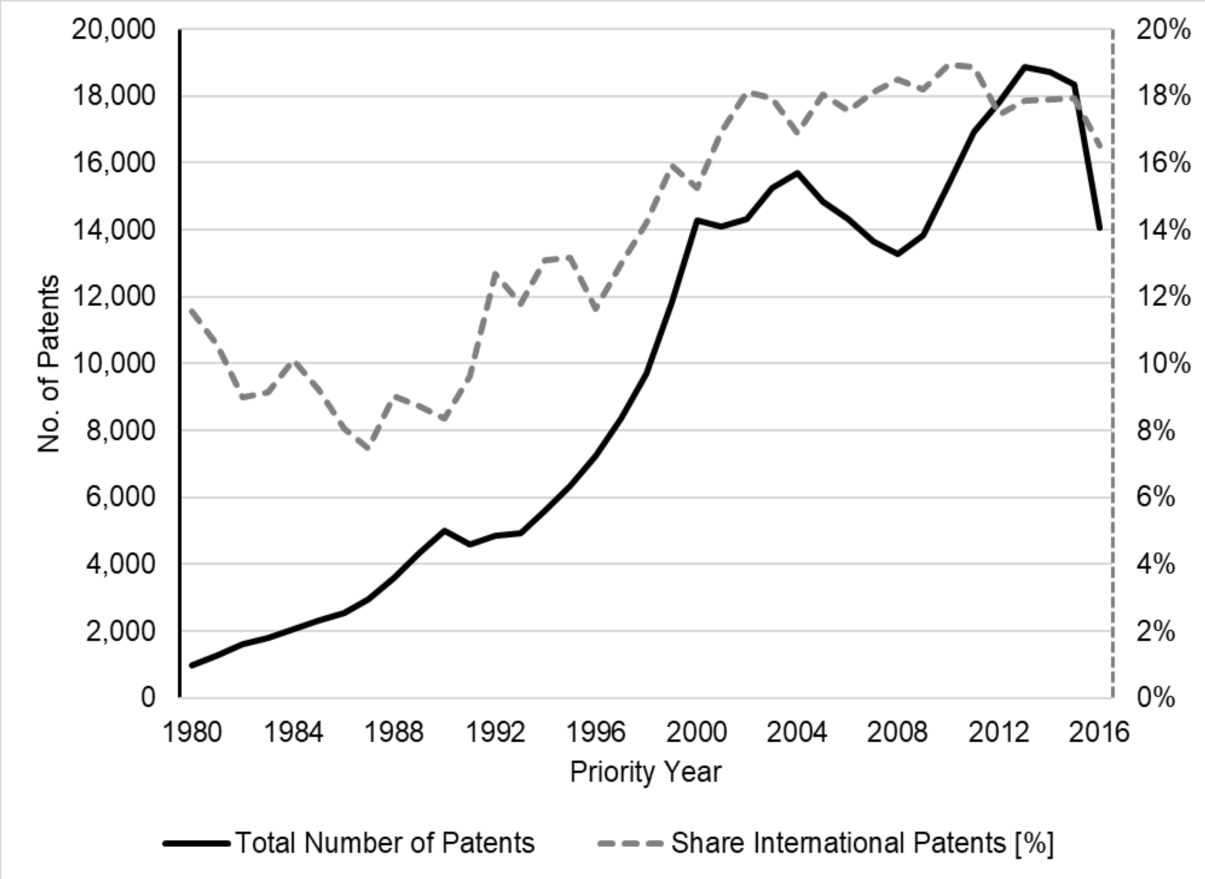

Figure 7-10 shows the total number of patents per priority year in the Software & Computer field on the left y-axis and with the continuous black line, and the share of international to total patents on the right y-axis, with the dashed grey line.

We can observe a (almost) continuous and strong growth of patent numbers since 1980. Between around 1993 and 2000 we can even observe an almost exponential growth, followed by a dip after 2004 and local minimum in 2008. 2013 has seen a peak with 18,886 patents. Once again, the number for 2016 has to be taken with a pinch of salt, due to incompleteness. Between 1980 and 2015 patent numbers have increased by the factor 19.

The overall development is comparable to that of the Technology Hardware field from before, although we have here in 2008 a more pronounced dip.

[439] Source: Own analysis, based on REGPAT database by the OECD (2020h).

The internationality, i.e. the share of international to all patents has developed almost always upwards and moved around 18% since 2003. Compared to Technology Hardware, internationality is lower for Software & Computer Services by around six percentage points.

7.2.4.2. Development by Applicant Country in the Software & Computer Services Industry

In this step I break down the patent numbers by applicant country, with the same structural approach as for the previous industries.

Table 7-17: Patent Breakdown by Applicant Country Software & Computer Services[440]

Applicant Country	Number of Patents per Priority Year				Share TOTAL (%)		CAGR
	2000	2007	2012	2015	2000	2015	’00-’15 (%)
TOTAL	14,290	13,637	17,818	18,337	100	100	1.7
US	5,274	4,315	5,963	6,272	36.9	34.2	1.2
Japan	3,784	2,863	2,919	2,668	26.5	14.5	-2.3
China	9	243	1,057	1,608	0.1	8.8	41.3
South Korea	258	1,067	1,831	1,552	1.8	8.5	12.7
France	751	932	1,112	1,286	5.3	7.0	3.7
Germany	1,165	1,174	1,241	1,175	8.2	6.4	0.1

Note: Full-counting leads to some double counting.

The table shows the six most relevant applicant countries for the number of Software & Computer Services patents, sorted decreasingly by their most recent 2015 value. We can observe a strong dominance of firms based in the US: around 34%, i.e. every third patent, has a US-based applicant. Japan, as with Technology Hardware patents, has slightly decreased its patent numbers and shows a negative CAGR, and Germany’s patent numbers have rather stagnated over the years. The relevant climbers are again emerging economies China and South Korea with a respectively two-digit CAGR. Particularly China has grown its patent numbers strongly from a negligible 9 in 2000 to 1,608 in 2015, making the country the third-largest country in terms of patent applications. Compared to Technology Hardware the developing countries have maintained a stronger position in Software & Computer services, i.e. they show a higher accumulated share compared to the emerging countries.

[440] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 7-18: Share of Applicant Countries' International Patents in Software & Computer Services[441]

	Share of International Patents (%)			
Country	**2000**	**2007**	**2012**	**2015**
TOTAL	15.2	18.1	17.5	18.0
US	19.2	17.2	19.3	18.5
Japan	5.5	8.3	7.6	8.5
China	22.2	16.0	6.4	10.0
South Korea	11.6	4.6	5.6	11.3
France	27.2	32.8	30.1	19.9
Germany	16.3	25.1	19.2	22.5

Table 7-18 shows the share of international patents in relation to all patents by the respective applicant country. The Asian countries Japan, China and South Korea are comparably little internationalized with a share of international patents at around 10%. China's internationalization degree decreased, indicating that in earlier years China was more dependent on foreign knowledge and emancipated itself over the years with growing competence. Japan, a country which is usually rather un-internationalized in terms of R&D Expenditure and patents is also the least internationalized relevant country here, with its share of international patents of 8.5% in 2015 being much below the worldwide average of 18%, unlike the relatively high value in the Technology Hardware field. The US, as the clearly dominating country in this field, has kept its share of international patents rather constant at around 18%.

With internationalization generally increasing in relative relevance, it will be interested to see how international patents perform to non-international patents. Before that, i.e. in the next step, we will look at the patent development per inventor country.

7.2.4.3. Development by Inventor Country in the Technology Hardware Industry

In this part I conduct a similar analysis as before, but in Table 7-19 I show the breakdown per inventor country, not applicant country. In order to truly understand where R&D in the biotechnology industry happens, we must look at the countries of inventors. The following table therefore show the number of patents with at least one inventor listed on the patent based in the respective country. This full-counting leads to some double counting: often

[441] Source: Own analysis, based on REGPAT database by the OECD (2020h).

patents have several inventors, who might even be based in different countries. Such a patent would be counted for each of the countries involved.

Table 7-19: Patent Breakdown by Inventor Country Software & Computer Services[442]

Inventor Country	Number of Patents per Priority Year				Share TOTAL (%)		CAGR
	2000	2007	2012	2015	2000	2015	'00-'15 (%)
TOTAL	14,290	13,637	17,818	18,337	100	100	1.7
US	5,051	4,668	6,050	6,431	35.3	34.2	1.6
Japan	3,696	2,728	2,812	2,534	25.9	20.0	-2.5
China	22	343	1,298	1,813	0.2	2.5	34.2
South Korea	244	1,046	1,783	1,423	1.7	7.7	12.5
Germany	1,342	1,221	1,342	1,315	9.4	9.0	-0.1
France	813	819	973	1,273	5.7	6.0	3.0
UK	983	642	664	825	6.9	4.7	-1.2

Note: Full-counting leads to some double counting.

Above table shows the absolute number of patents per inventor country. For example, from all 18,337 patents in the Software & Computer Services field in 2015, 6,431 had at least one US-based inventor.

We also see the shares of patents per inventor country. We can observe again the strong US-dominance in the Software & Computer Services field and the uprise of China and South Korea. We cannot observe strong differences between the overview by applicant vs inventor countries, meaning that very broadly speaking inventions are more or less created in the country of the applicant, i.e. domestically, whereas international activities only complement and not replace domestic efforts. This table includes the UK as a somewhat relevant country as a base for inventors, as opposed to the applicant-country analysis. There the UK had too few patents to be included as a relevant country, meaning that there are not many relevant firms based in the UK filing for patents in the Software & Computer Services field, but there are somewhat relevant inventor bases.

In the next part, I compare international to non-international patents.

442 Source: Own analysis, based on REGPAT database by the OECD (2020h).

7.2.4.4. Comparison Non-International and International Patents in Software & Computer Services Industry

Figure 7-11: NRTA in Software & Computer Services[443]

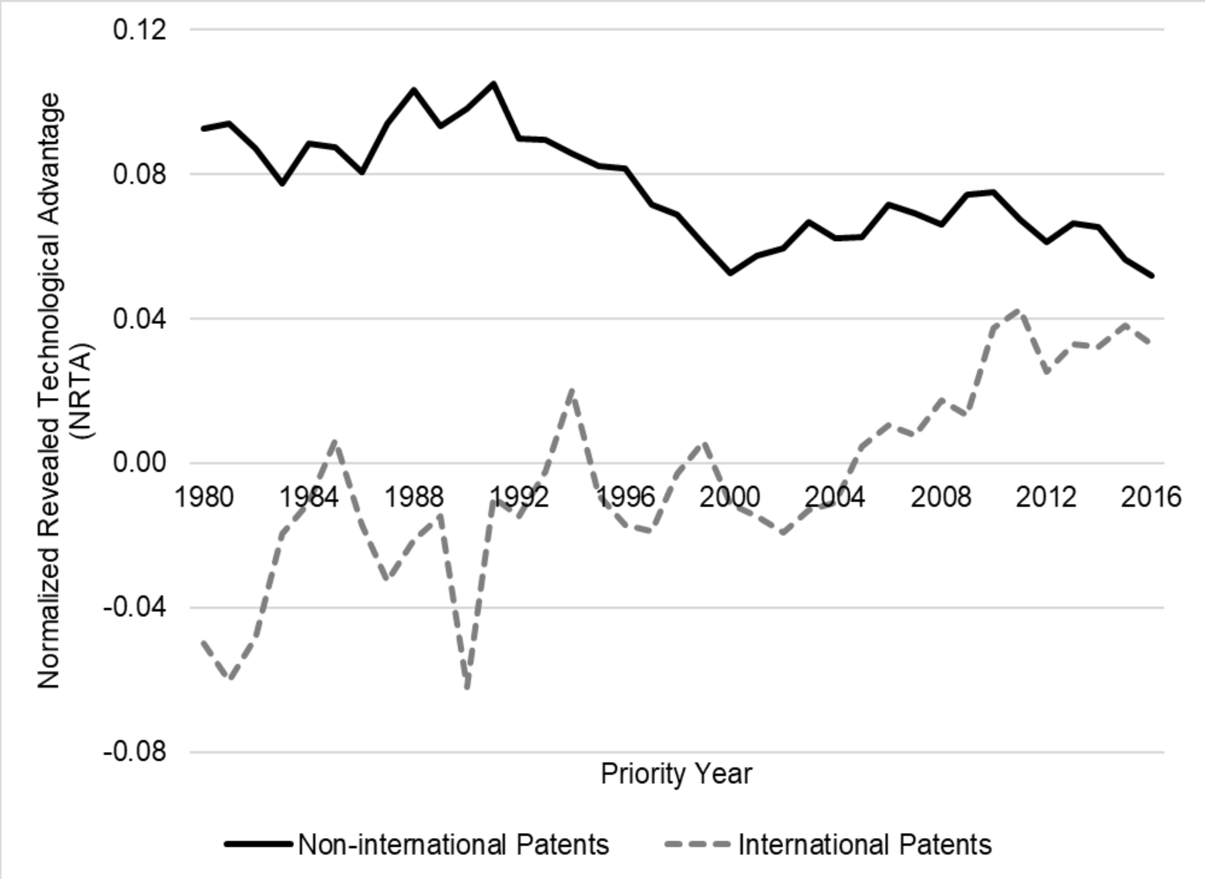

Figure 7-11 shows the average comparative advantage of patents in the Software & Computer Services field, separated by patents which are international, i.e. have at least one foreign inventor, and patents which are not. Unsurprisingly, the NRTA over the years is always relatively close to 0: as the NRTA is scaled, so that $NRTA \in [-1; +1]$ and considers competitiveness within an industry, an analysis of a whole industry, such as conducted here for biotech, should yield values around 0. The NRTA is calculated based on the number of patents in a certain field at a certain time.

Interestingly non-international patents have again a consistently higher NRTA, i.e. comparative advantage than international patents due to the relatively higher number of patents. This means that non-international patents have a higher relative strength than international patents. However, the differences seem to shrink as both lines are moving towards each other over the years.

443 Source: Own analysis, based on REGPAT database by the OECD (2020a, 2020f, 2020h).

Figure 7-12: PQCI in Software & Computer Services[444]

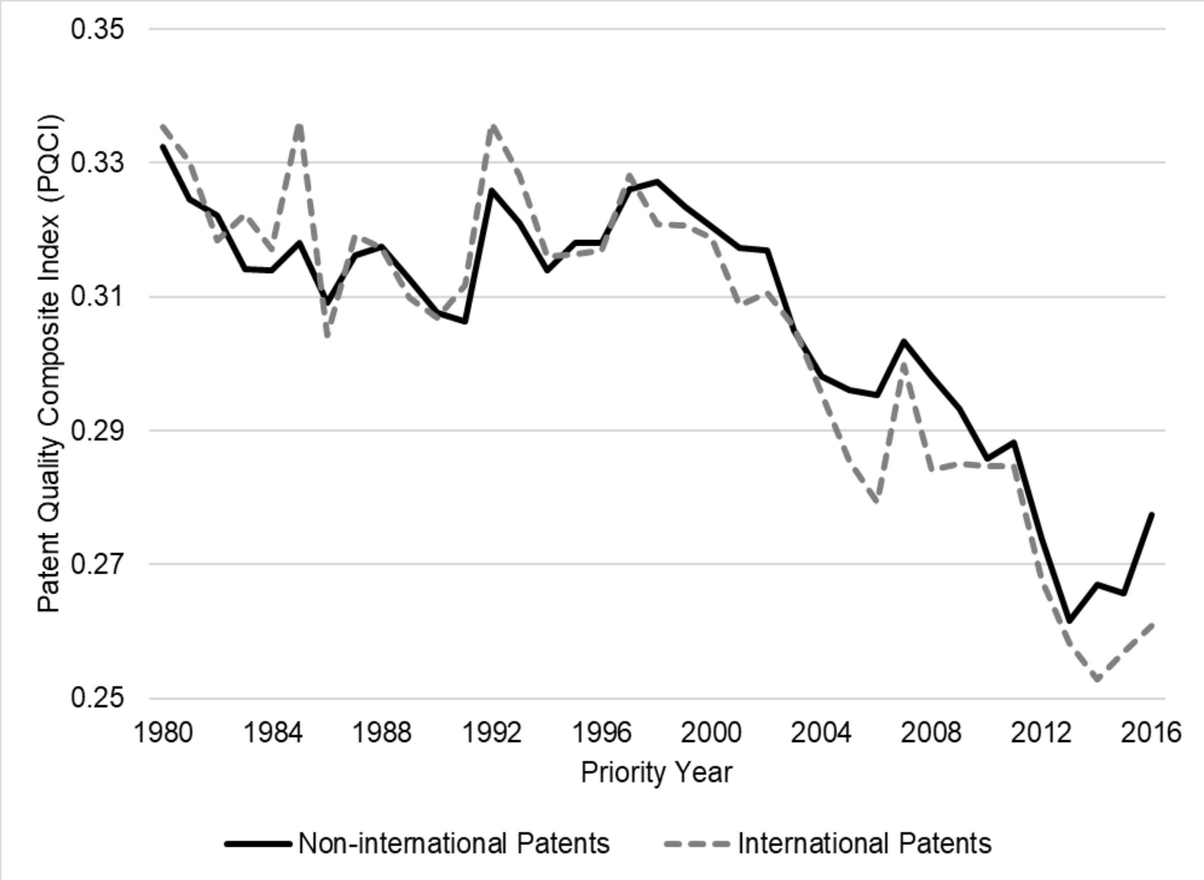

Figure 7-9 shows the average quality of patents in the Software & Computer Services field, based on a composite of quality indices, such as citations, originality etc. Overall patent quality decreases over the years, particularly since 1998, when also non-international patents (slightly) surpassed international patents.

Once again, our focus in this short analysis is not so much the development of values, but rather the comparison of non-international to international patents. The difference between both groups of patents is very small and we can conclude with a clear superiority of one over the other.

In the next step we differentiate internationality to show some differences within the rather heterogeneous group of international patents.

7.2.4.5. Cultural Distance as a Measurement for International Patents in Software & Computer Services Industry

Table 7-20 shows the quality (PQCI) of patents in the Software & Computer Services industry. I show the values for the whole period and also separated for the period since 2000, to further

444 Source: Own illustration, based REGPAT database by the OECD (2020a, 2020f, 2020h).

illustrate recent developments. I separate International Patents into three groups of cultural distance of the involved inventor cultures: “low” cultural distance, “medium” and “high”. Furthermore, I give an example of a country pairing, to illustrate what a “low”, “medium” or “high” cultural distance actually means.

Table 7-20: Software & Computer Services Patent Quality by Cultural Distance[445]

Patent Quality	Non-Internat. Patents	International Patents – Cultural Distance			
		Low	Medium	High	***All Patents***
All Years	0.305	0.317	0.306	0.303	*0.305*
Since 2000	0.294	0.309	0.296	0.295	*0.295*

Note: Standard Deviation for all groups ≈ 0.09. Example for cultural distances: Low: US-Canada; Medium: US-Germany; High: US-China.

We can see the average patent quality of all non-international patents, i.e. all patents with no cultural distance in the first column. For comparison I show the average patent quality for all international patents, i.e. all patents with some cultural distance in the last column. This column is the aggregate of the breakdown into three levels of cultural distance. The standard deviation is constant at around 0.9 for all groups and samples, indicating that there are no outliers distorting the analysis. Overall, we can see that the average quality has decreased, i.e. the average for the priority years 2000 and onwards is lower than the total sample. We have already seen this in the prior sub-chapter.

Table 7-21: Group Means Differences (one-way ANOVA) in Software & Computer Services Patent Quality

Cultural Distance (CD)	**Non-International Patents**	**Low CD**	**Medium CD**
Low CD	Pos. sig. (***)	-	-
Medium CD	Pos. insig.	Neg. sig. (***)	-
High CD	Neg. insig. (*All Years)* Pos. insig. (*Since 2000)*	Neg. sig. (***)	Neg. insig.

*Note: Significance levels given with asterisks: p-Level: * < 0.05 | ** < .01 | *** < 0.001. One-way ANOVA with Bonferroni correction. No differences between “All Years” and “Since 2000”, unless explicitly noted.*

We can make two main findings: First, the highest patent quality can be observed on average with a low cultural distance, which is consistent to the findings in prior sub-chapters. Second,

445 Source: Own illustration, based REGPAT database by the OECD (2020a, 2020f, 2020h).

a medium or even high cultural distance decreases patent quality, for the latter partly even below to the values we have for non-international patents, although the differences between the groups of non-international patents and patents with a medium or high CD are not statistically significant.

However, again we can conclude that too much internationalization, in terms of cultural diversity, can be less productive or, at least, does not pay off in a higher patent quality compared to non-internationalized patents. We can explain this observation with the literature, discussed in Chapter 2.3.4, which finds negative effects of too much internationalization, due to a spike in coordination costs.

7.2.4.6. Conclusion Patent Analysis of Software & Computer Services Industry

In this part we have put patents in the Software & Computer Services Industry under scrutiny. The overall number of patents, as well as the share of patents with international inventors has strongly grown since 1980. We have seen a clear dominance of the US in the Software & Computer Services Industry, both as a location for applicant, i.e. firms, but also as a location for inventors, i.e. base for the actual inventive activities. Emerging countries, such as China and South Korea have strongly increased their patent numbers in recent years, with the former now even ranking third worldwide, behind Japan.

International patents are not necessarily of a higher quality and more competitive than non-international patents: only patents with a low or medium cultural distance show a, somewhat, gain compared to non-international patents. Together with the strong similarity in patterns of applicant vs. inventor distributions in patents in the Technology Hardware industry, we can conclude that truly international, i.e. culturally diverse, collaborations are not key in this field.

7.2.5. Patent Analysis of Automotive Industry

In this sub-chapter, I will analyze the Automotive Industry, based on the relevant IPCs, as detailed in Table 7-1.

First, I show the general development of patents between 1980 and 2016, as well as the share of international patents, i.e. patents with inventors and / or applicants from different countries.

Second, I compare in non-international and international patents between 1980 and 2016, i.e. show whether international patent teams create better performing patents.

7.2.5.1. General Development in Automotive Industry

Figure 7-13: Overview Patent Development in Automotive[446]

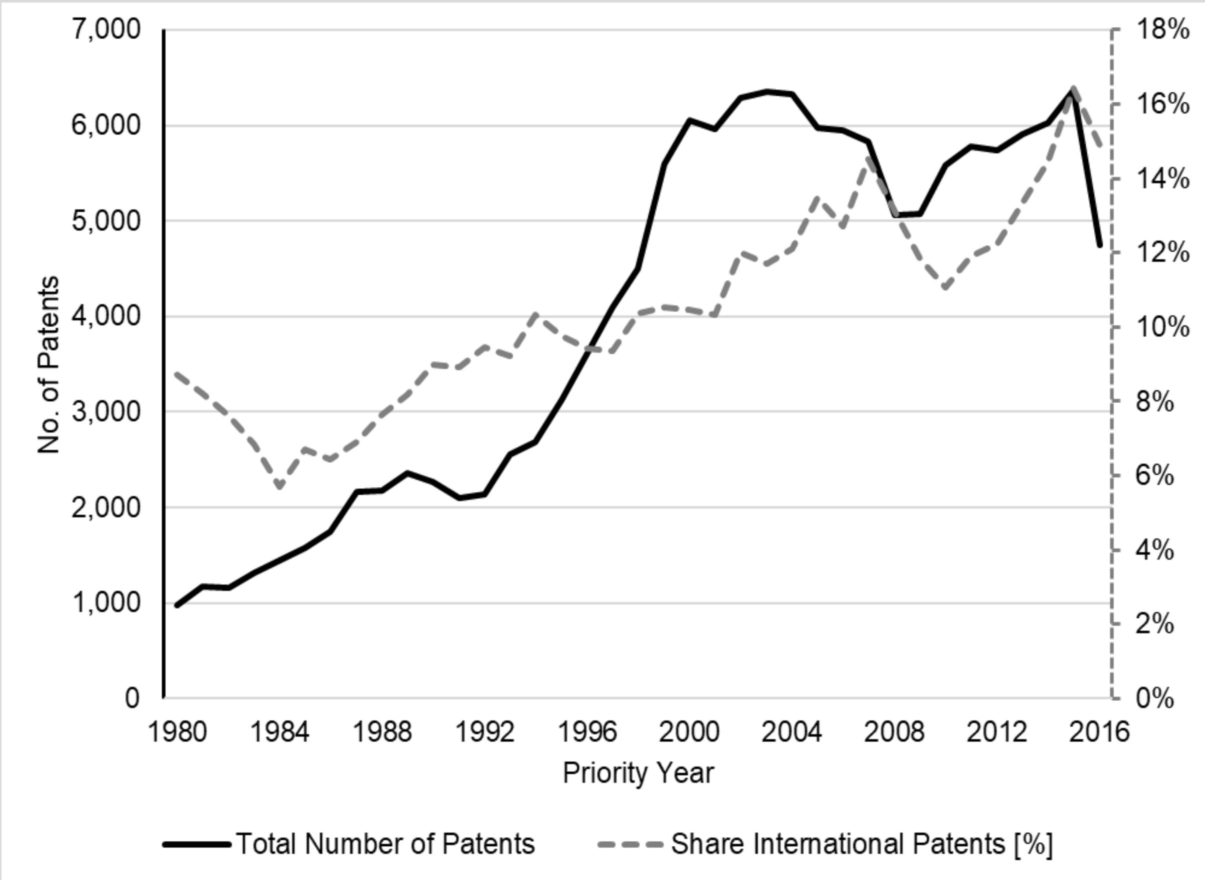

Figure 7-13 shows the total number of patents per priority year in the Automotive field on the left y-axis and with the continuous black line, and the share of international to total patents on the right y-axis, with the dashed grey line.

We can observe a (almost) continuous and strong growth of patent numbers since 1980. Between around 1980 and 1989 we have a linear growth, followed by a dip in 1991 and a stronger linear, or even partly exponential growth until 2000. After a plateau phase until 2007 and a peak of 6,353 patents in 2003, we see a dip in 2007 & 2008, followed by a pre-crisis increase to 6,367 patents in 2015.

The numbers for 2016 might not be complete yet, due to publication time-lags, which could partially explain the strong drop from 2015 to 2016, so again I will include in the tables 2015 as the most recent reliable data point. Between 1980 and 2015 patent numbers have increased by the factor 7.

[446] Source: Own analysis, based on REGPAT database by the OECD (2020h).

The internationality, i.e. the share of international to all patents has developed almost always upwards since 1984, apart from a drop in around 2011, which might be a lagged effect from the mentioned patent drop in 2007 & 2008. The internationality rate has climbed to 16% in 2015.

7.2.5.2. Development by Applicant Country in the Automotive Industry

In this step I break down the patent numbers by applicant country. As we focus on recent developments, I include patent data from the priority year 2000 and onward. First, I show the number of patents for the largest applicant countries. Second, I show the share of these patent numbers in relation to the worldwide total. Third, I show the share of international patents for these countries.

Table 7-22: Patent Breakdown by Applicant Country Automotive[447]

Applicant	**Number of Patents per Priority Year**				**Share TOTAL (%)**		**CAGR**
Country	**2000**	**2007**	**2012**	**2015**	**2000**	**2015**	**'00-'15 (%)**
TOTAL	6,056	5,828	5,737	6,367	100	100	0.3
Japan	1,660	1,795	1,656	1,679	27.4	26.4	0.1
Germany	1,982	1,738	1,547	1,564	32.7	24.6	-1.6
US	1,095	811	671	836	18.1	13.1	-1.8
France	362	538	486	540	6.0	8.5	2.7
Sweden	136	195	333	317	2.2	5.0	5.8
Italy	200	220	159	213	3.3	3.3	0.4

Note: Full-counting leads to some double counting.

The table shows the seven most relevant applicant countries for the number of automotive patents, sorted decreasingly by their most recent 2015 value. We can observe a strong dominance of Japanese and German applicants, accounting each for around 25% of all patents in 2015. Japan has surpassed Germany in terms of patent numbers since the start of the millennium with a slightly higher growth rate. No emerging country has a relevant ranking and the strongest growth, i.e. CAGR can be observed for Sweden with 6%.

[447] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 7-23: Share of Applicant Countries' International Patents in Automotive[448]

	Share of International Patents (%)			
Country	**2000**	**2007**	**2012**	**2015**
TOTAL	10.5	14.5	12.2	16.4
Japan	1.4	1.0	1.6	1.5
Germany	8.5	15.9	12.6	19.7
US	22.7	48.3	22.2	20.9
France	6.9	6.7	9.5	9.8
Sweden	25.0	35.9	25.8	34.1
Italy	6.0	2.7	11.9	11.7

Table 7-23 shows the share of international patents in relation to all patents by the respective applicant country. The small country of Sweden clearly stands out, with 34% of all its patents having at least one international, i.e. non-Sweden based inventor in 2015. The US have an internationality rate of 21%, which is unusually high, i.e. above world average, with a peak, potentially a singularity in 2007. Japan is remarkably low internationalized with only around 1% of all its patents having at least one non-Japan based inventor.

With internationalization generally increasing in relative relevance, it will be interested to see how international patents perform to non-international patents. Before that, i.e. in the next step, we will look at the patent development per inventor country.

7.2.5.3. Development by Inventor Country in the Automotive Industry

In this part I conduct a similar analysis as before, but in Table 7-24 I show the breakdown per inventor country, not applicant country. In order to truly understand where R&D in the biotechnology industry happens, we must look at the countries of inventors. The following table therefore show the number of patents with at least one inventor listed on the patent based in the respective country. This full-counting leads to some double counting: often patents have several inventors, who might even be based in different countries. Such a patent would be counted for each of the countries involved.

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[448] Source: Own analysis, based on REGPAT database by the OECD (2020h).

Table 7-24: Patent Breakdown by Inventor Country Automotive[449]

Inventor Country	Number of Patents per Priority Year				Share TOTAL (%)		CAGR
	2000	2007	2012	2015	2000	2015	’00-’15 (%)
TOTAL	6,056	5,828	5,737	6,367	100	100	0.3
Japan	1,666	1,809	1,667	1,717	27.5	31.0	0.2
Germany	2,044	1,756	1,565	1,534	33.8	30.1	-1.9
US	1,019	649	669	861	16.8	11.1	-1.1
France	438	618	547	646	7.2	10.6	2.6
Italy	206	259	190	251	3.4	4.4	1.3
Sweden	125	180	267	244	2.1	3.1	4.6

Note: Full-counting leads to some double counting.

Above table shows the absolute number of patents per inventor country. For example, from all 6,367 patents in the Automotive field in 2015, 1,534 had at least one Germany-based inventor.

We also see the shares of patents per inventor country. We can observe again the strong -dominance of Japan and Germany in the Automotive field and that no emerging country is ranking significantly as an inventor location. We cannot observe strong differences between the overview by applicant vs inventor countries, yet can notice, that the Japan-Germany domination is even stronger here, i.e. 61%, almost two out of three, patents are conducted with an inventor based in one of these two countries. Germany has, however, lost in attractiveness or relative relevance whereas Japan has gained its share.

In the next part, I compare international to non-international patents.

449 Source: Own analysis, based on REGPAT database by the OECD (2020h).

7.2.5.4. Comparison Non-International and International Patents in Automotive Industry

Figure 7-14: NRTA in Automotive[450]

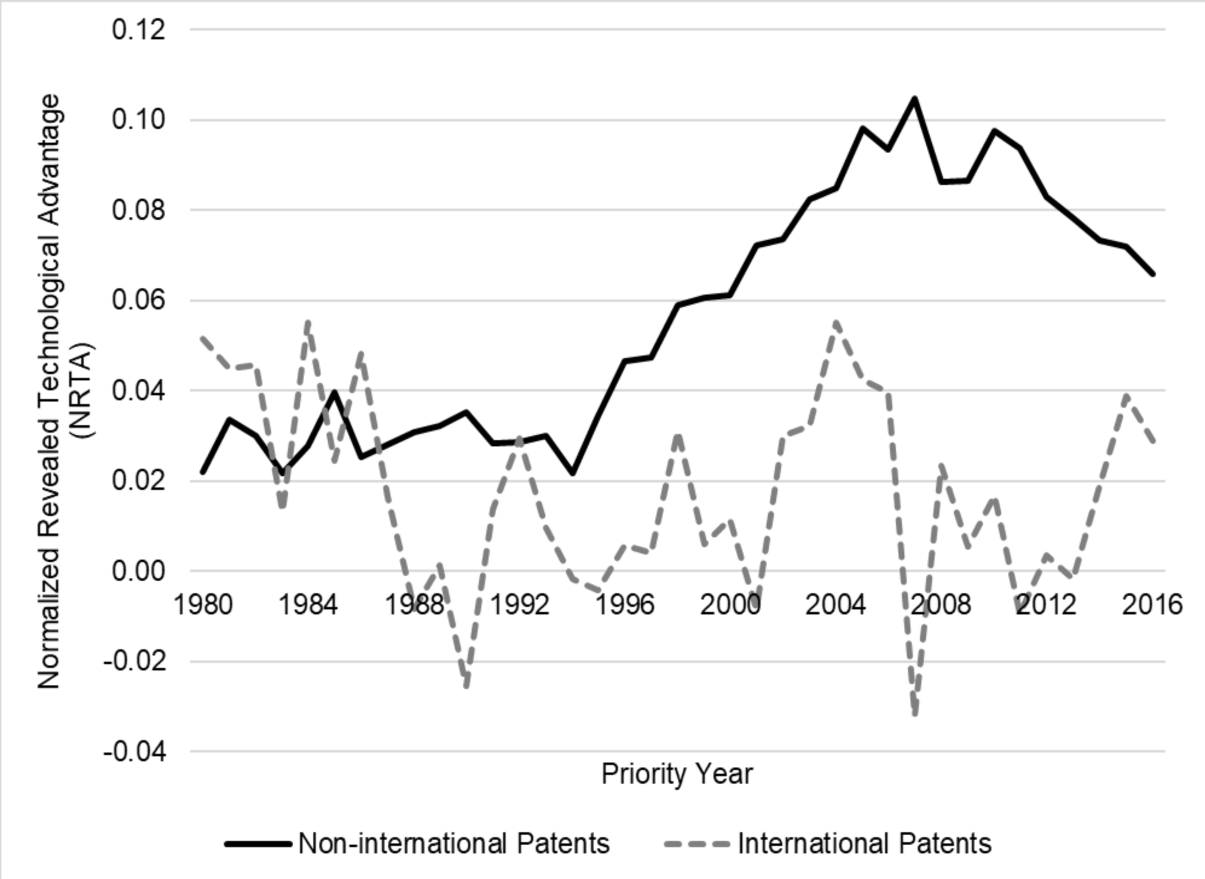

Figure 7-14 shows the average comparative advantage of patents in the Automotive field, separated by patents which are international, i.e. have at least one foreign inventor, and patents which are not. As found and discussed before, the NRTA is close to 0, which is unsurprising, as we analyze the approximately whole industry.

Interestingly non-international patents have an almost consistently higher NRTA, i.e. comparative advantage than international patents due to the relatively higher number of patents. This means that non-international patents have a higher relative strength than international patents.

The distribution of the NRTA across the years (not depicted here) is again quite constant. Therefore, international patents are not as competitive than non-international ones.

[450] Source: Own analysis, based on REGPAT database by the OECD (2020a, 2020f, 2020h).

Figure 7-15: PQCI in Automotive[451]

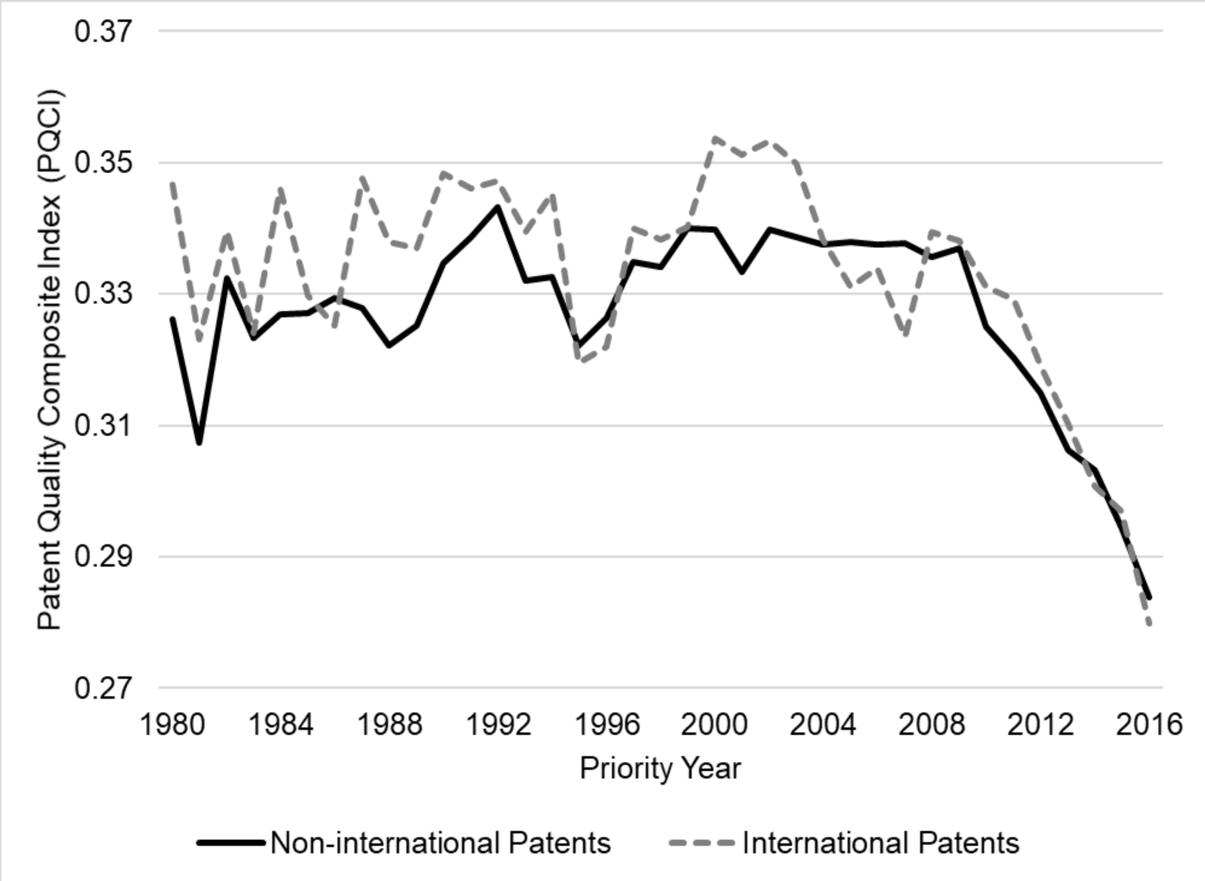

Figure 7-15 shows the average quality of patents in the Automotive field, based on a composite of quality indices, such as citations, originality etc. Overall patent quality decreases over the years, particularly since 2009.

Once again, our focus in this short analysis is not so much the development of values, but rather the comparison of non-international to international patents. While international patents are slightly better, i.e. the line is almost always above the line for non-international patents, this difference is very small and we can conclude with a clear superiority of one over the other.

In the next step we differentiate internationality to show some differences within the rather heterogeneous group of international patents.

7.2.5.5. Cultural Distance as a Measurement for International Patents in Automotive Industry

Table 7-25 shows the quality (PQCI) of patents in the Automotive Industry. I show the values for the whole period and also separated for the period since 2000, to further illustrate recent developments. I separate International Patents into three groups of cultural distance of the

[451] Source: Own illustration, based REGPAT database by the OECD (2020a, 2020f, 2020h).

involved inventor cultures: “low” cultural distance, “medium” and “high”. Furthermore, I give an example of a country pairing, to illustrate what a “low”, “medium” or “high” cultural distance means.

Table 7-25: Automotive Patent Quality by Cultural Distance[452]

Patent Quality	Non-Internat. Patents	International Patents – Cultural Distance			
		Low	Medium	High	*All Patents*
All Years	0.330	0.352	0.345	0.342	*0.331*
Since 2000	0.329	0.352	0.344	0.343	*0.330*

Note: Standard Deviation for all groups ≈ 0.09. Example for cultural distances: Low: US-Canada; Medium: US-Germany; High: US-China.

We can see the average patent quality of all non-international patents, i.e. all patents with no cultural distance in the first column. For comparison I show the average patent quality for all international patents, i.e. all patents with some cultural distance in the last column. This column is the aggregate of the breakdown into three levels of cultural distance. The standard deviation is constant at around 0.09 for all groups and samples, indicating that there are no outliers distorting the analysis. Overall, we can see that the average quality has slightly decreased, i.e. the average for the priority years 2000 and onwards is lower than the total sample.

Table 7-26: Group Means Differences (one-way ANOVA) in Automotive Patent Quality

Cultural Distance (CD)	Non-International Patents	Low CD	Medium CD
Low CD	Pos. sig. (***)	-	-
Medium CD	Pos. sig. (***)	Neg. sig. (**)	-
High CD	Pos. sig. (***)	Neg. sig. (**)	Neg. insig.

*Note: Significance levels given with asterisks: p-Level: * < 0.05 | ** < .01 | *** < 0.001. One-way ANOVA with Bonferroni correction. No differences between “All Years” and “Since 2000”, unless explicitly noted.*

We can make two main findings: First, internationalization pays off. Comparable to Pharma and Biotech, and unlike Technology Hardware and Software & Computer Services, internationalization in Automotive always give a statistically higher patent quality than no internationalization. This finding is in line with the prior chart. Second, as with pharma and

[452] Source: Own illustration, based REGPAT database by the OECD (2020a, 2020f, 2020h).

biotech, we get the highest average patent quality for a low cultural distance, meaning that the involved inventor countries are culturally relatively close (e.g. US & Canada). The difference of means between the groups of medium and high CD is not statistically significant.

While internationalization pays off, we can conclude that too much internationalization can be less productive. We can explain this observation with the literature, discussed in Chapter 2.3.4, which finds negative effects of too much internationalization due to a spike in coordination costs.

7.2.5.6. Conclusion Patent Analysis of Automotive Industry

In this part we have put patents in the Automotive Industry in the spotlight. The overall number of patents, as well as the share of patents with international inventors has grown since 1980 and particularly until 2000. We have seen a clear dominance of Japan and Germany in the Automotive Industry, both as a location for applicant, i.e. firms, and even more as a location for inventors, i.e. base for the actual inventive activities. Emerging countries, such as China and South Korea, do not play a relevant role in this field.

International patents are of a somewhat higher quality and more competitive than non-international patents – an effect that is most pronounced with a low cultural distance within the inventor team. Again, we can conclude that internationality pays off, but too much reduces the positive effects.

8. Summary and Conclusion

I complete this dissertation with three parts: First, I will summarize the major findings of this dissertation and point out my contribution to the existing knowledge. Second, I will put the findings into perspective and give implications and recommendations for practitioners, i.e. managers for the company-level and policy maker for the country or regional level. Third, I circle back to the academic side and give recommendations and an outlook for further research activities.

8.1. Summary of Findings and Contribution

The overarching research question of this dissertation was to answer to what extent and in what fields MNCs conduct R&D abroad and how these patterns have changed in the last decade.

In Chapter 1 I have presented my research outline after a detailed literature overview. The number of publications on R&D Internationalization has particularly exploded since the beginning of this millennium: while early literature has dealt with R&D Internationalization starting from the 1950s, academics focused more on the internationalization of production, distribution and sales; and R&D Internationalization remained in a niche existence for a longer time. Starting with the 1999 special issue on the topic “The Internationalization of Industrial R&D” in the prestigious journal ’Research Policy’ more relevant publications have come forward. I have discussed the reasons and motives for R&D Internationalization, based on my categorization presented in Figure 1-2: Push- & Pull-Factors, Industry-based factors and Company-based factors. The literature shows the complexity of R&D Internationalization and the interplay of numerous factors on several levels. This certainly prohibits an over-generalization and justifies this dissertation’s thorough analyses.

In Chapter 2 I have presented my methodology for analyzing R&D Internationalization, namely the quantitative measures of R&D Expenditure and patents, as well as, on a select level, qualitative interviews. From a methodological point of view, I contribute to the academic landscape particularly through my detailed approach on analyzing patents: as the actual purpose of patents is not to serve as an innovation measurement proxy for researchers, the proper analysis, i.e. including and treating relevant patents is not trivial. A simple patent count can therefore easily mislead. In turn, I explain in detail how I analyze patents and minimize measurement errors.

Chapter 3 shows R&D activities through R&D Expenditures, both on a global level, as well as for the four major economies Germany, USA, Japan and China. I show how R&D

Internationalization has not only increased in the last decades, but also shifted in target countries. From a previously small circle of major economies, a much higher number of countries, including emerging countries, have started to play relevant roles in conducting business R&D in the last years. Specifically, the amount of R&D expenditures within the respective country (BERD) has grown at very high rates in recent years, for emerging countries such as China, India and partly some Eastern European countries. This further illustrates the increasing complexity of R&D Internationalization and Globalization in general.

Chapter 4 & 5 use a similar lens of focus, but use patents instead of expenditure data. As patent data is substantially more detailed, i.e. add findings through an increase in detail and a higher amount of measurable countries. The patents, namely the Host-Country Patents shows us in which (foreign) countries MNCs, based in a particular country, have inventors based. In Chapter 4 I have analyzed the Outward Host-Country Patents (HCPs), i.e. show in which foreign countries, firms based in a particular country are conducting R&D. In turn Chapter 5 has shown Inward HCPs, i.e. where foreign-based firms are located conducting R&D in a particular country. I have shown not only the source and target countries, but also outlined in which technological fields MNCs conduct R&D activities. We have seen not only the uprise of emerging economies, e.g. China as a relevant host and home to international R&D activities, but also the shrinking of a few other economies, e.g. the UK. Furthermore R&D Internationalization is not distributed equally across industries, but we rather see how particular countries have strong activities in a select number of technological fields. This relates to a motive of R&D Internationalization discussed in Chapter 1: The Lead-Market, i.e. having competences in a particular field and thereby attracting foreign MNCs in that particular field. We have seen that R&D internationalization is not random, but rather follows two distinct trends: On the one hand firms somewhat stay close, meaning that they tend to internationalize R&D to geographically or politically close countries. On the other hand, we can see the strong uprise of Asia as a location for R&D activities. Some countries, as the USA, have kept its degree of foreign-based R&D internationalization somewhat constant, but shifted R&D activities away from developed countries in Europe and towards emerging countries in Asia. In Chapter 5.4 I condense the findings from both chapters into five precise points.

Chapter 6 drills down to the industry perspective and uses R&D Expenditure patterns as the main method of analysis. In a first step, I have looked which industries spent the most on R&D both on a rather current time-series and a longer, but smaller sized, time-series. The industries which have spent an increasing share of the global R&D Expenditure are from the life sciences and ICT field. In general, we can see a shift towards high-tech industries, whereas some classic manufacturing industries decreased in relative relevance. In a second step, I show the four most relevant industries, namely Pharmaceuticals & Biotechnology, Technology Hardware, Software & Computer Services and Automobiles & Parts in a country breakdown, i.e. outline in which countries MNCs in the respective fields are based in with relevant R&D Expenditures. We already see here the quite different distribution of industries across countries and the changes over time. Particularly firms from emerging countries have significantly ramped up R&D Expenditure, most prominently visible in the ICT fields, and, in recent years, account for relevant shares in global R&D Expenditures. Third, I have analyzed the R&D Expenditures of MNCs by industry in the four most relevant economies USA, Japan, Germany and China and created an overview of comparably strong and weak industries from a global perspective. While this chapter does not directly outline R&D Internationalization, it shows us in which fields companies possess comparative advantages and disadvantages. These, in turn, can be a strong driver of R&D Internationalization, as discussed in Chapter 1.

Chapter 7 also takes the industry perspective, but with the methodology of a patent analysis. I combine different data-sets to have a quantitative measurement for the quality and technological advantage for each patent. Furthermore, I introduce a measurement of cultural distance to quantify how international a patent inventor is. As opposed to prior analyses with a dichotomous measurement for internationalization, i.e. does the patent inventor team have an international team member or not, I group international teams in three categories depending on how big the cultural distance within the patent inventor team is. When we argue that internationality influences patent quality and eventually performance, it certainly depends how much internationality we have. For example, from a US perspective, collaborating with a Canadian inventor can be considered less internationalized and less distant than collaborating with a Chinese inventor. Combining classical patent data with both patent quality indicators and a measurement for cultural distance is a contribution and novelty of this dissertation.

I analyze the technological fields, i.e. patent classes of the major industries, namely Pharmaceutical, Biotechnology, Technology Hardware, Software & Computer Services and Automotive. I show from which country the MNCs with the most patents are coming from, where the relevant inventor locations are and compare patents with non-international inventor teams to international teams. Generally speaking, I find that while international teams generally produce better performing patents, the best effect can mostly be observed for patents with a low cultural distance. A high distance mostly leads to a reduction in average patent quality, indicating that while internationalization pays off, too much can be detrimental, as well.

8.2. Implications for Economies and Practitioners

This analysis has shown how the historically rather simple distribution of global R&D across a few developed economies has increasingly dissolved. Several emerging countries, such as China, India and some Eastern European countries have significantly caught up in select industries and partly are lead markets, located at the technological frontier. This dissertation gives results and implications for economies and their policy makers and practitioners, i.e. decision maker from companies.

Implications for Policy-makers and Economies

We have seen the increasing internationalization of R&D and specialization on certain industries and technological fields in this dissertation. For policy-makers this implies that a robust and targeted innovation strategy, support and investment schematics are key. This entails funding of relevant institutions, i.e. universities and research labs, the understanding and providing of key infrastructure and legislation required for MNCs to locate R&D in one's country. Not only MNCs are in a global competition, but also countries, meaning that, generally speaking, firms will choose to locate its R&D in a market which is considered best in a certain environment. The innovation strategies of China show vividly how a clear strategy not only attracts foreign R&D to the country, but also learns, adapts and implements the influx of knowledge in a way that turns China itself a technology leader in certain fields. Such an innovation regime and strategy must not be static but constantly observed and adapted based on the developments and roles of the foreign and domestic R&D locations in a country. The analysis of R&D Expenditures and patents, as conducted in this dissertation, can help to identify patterns, trends and areas where intervention might be advisable. A specialization and focus on certain core competencies and fields, i.e. lead market can be an advisable strategy, particularly for developed countries who have, partly, lost some influx of R&D towards emerging nations.

With a grand complexity of R&D, governmental policies and interventions must not be isolated and singular, but rather holistic, in order to not only somewhat attract foreign R&D, but also to keep it and attain the influx of knowledge in a substantial and sustainable way.

Implications for Practitioners

R&D Internationalization, if done properly, can bring substantial opportunities for an MNC and competitive edges, as discussed in Chapter 1.1. It is crucial for decision-makers to understand their respective field of business and innovation area in order to make a profound decision.

An analysis of R&D Expenditures and patents, as conducted in this dissertation, can help to not only understand a company's own quantitative R&D activities, but also that of competitors and the whole market. Such a competitive analysis can outline a company's strength and weaknesses mapped against other players. Patterns and trends can be identified, which can help an MNC to quickly find and access relevant lead markets. Having a clear, focused and comprehensive company strategy on R&D and the whole innovation chain can pay off and help to increase profitability. A company should therefore not just simply decide for or against a certain location, but also what exactly the goal of an R&D activity in each location is and how the connection to the home-base is intended to be. As we have seen in the patent analysis, there is indication that R&D Internationalization, while positive in general, can be overdone: when the cultural distance of inventor teams become too large the differentness can diminish effectiveness and performance.

8.3. Recommendations for Further Research

This dissertation joins the ranks of numerous pieces of research on the topic of Research and Development. In Chapter 1.1 I have outlined, categorized and discussed the relevant research. I have categorized the research into four streams:

1. Reasons and motives to internationalize R&D
2. Patterns and destinations of R&D Internationalization
3. Interplay and environment of home- and host-country bases of companies
4. Assessing the effect of R&D Internationalization on firms' performance

In my dissertation I have particularly touched points 1, 2 and 4. I have conducted a macro- and meso-level approach on my analysis. The micro-level has not been this dissertation's core focus, so for point 1 and 3, it can be worthwhile to conduct separate select analyses mainly through large-scale interviews. A behavioral economist approach would help to unravel the more psychological aspects of innovation, including the increasing trends of sustainability and corporate social responsibility. In fact, companies are faced with an increasing discussion on economic interests vs. human and social factors. A recent discussion in Germany on the activities of German MNCs in China are just one example here[453] and can fuel research on new influences on the motives of R&D Internationalization and location decision.

Point 2 in my dissertation relies partly on data of R&D Expenditures, where data availability varies highly. With an increasing level of reporting, particularly by emerging countries, future

[453] Cf. Handelsblatt – Fröndhoff, Höpner, and Murphy (2019); CNN – Riley (2020).

analyses could be even more fine-grained and recent.[454] This data can also aid decision-makers in business and politics to implement reasonable measurements, as discussed in Chapter 8.2.

For point 4, I combine existing literature on cultural distance measurements with patent analyses, including performance measurements. Further analyses can elaborate on the operationalization of cultural distance and data used, in order to further dissect the phenomenon of internationality in R&D. Another approach on internationality on R&D can be the analysis of career backgrounds of inventors on the micro-level and what role, for example, migration and international work experience has on innovation, inventive activities and innovation performance.[455]

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[454] The US with their Bureau of Economic Analysis (BEA) and National Science Foundation (NSF) are positive examples of providing a detail of data on R&D activities unrivaled by other countries.

[455] For example Schmid and Wurster (2017) and Suutari et al. (2018) analyze the international work experience of individuals for their professional success and career paths.

Tables

Illustrations

Abbreviations

AAGR	Annual Average Growth Rate
AE	Advanced Economies
AI	Artificial Intelligence
APAC	Asia-Pacific
BEA	Bureau of Economic Analysis of the U.S. Department of Commerce
BERD	R&D Performance by the Business Sector
CAGR	Compound Annual Growth Rate
CD	Cultural Distance
CNIPA	China National Intellectual Property Administration
CPC	Cooperative Patent Classification
DAFI	Domestic Applications of Foreign Inventions
DE	Developing Economies
EME	Emerging Market Economies
EPO	European Patent Office
EU28	European Union (28 states)
FDI	Foreign Direct Investment
GAFI	German Applications of Foreign Inventions
GERD	Gross Domestic Expenditure on R&D
GDP	Gross Domestic Product
GNI	Gross National Income
GOVERD	R&D Performance by the Government Sector
HCP	Host-Country Patent
HERD	R&D Performance by the Higher Education Sector
IC	International Corporation
ICB	Industry Classification Benchmark
ICT	Information and Communications Technology
IMF	International Monetary Fund
IP	Intellectual Property
IPC	International Patent Classification
ISIC	International Standard Industrial Classification
ISIN	International Securities Identification Number
KIPO	Korean Intellectual Property Office
KPI	Key Performance Index
M&A	Mergers and Acquisitions

METI	Ministry of Economy, Trade and Industry
MNE	Multinational Enterprise
MNC	Multinational Corporation
NACE	Statistical classification of economic activities in the European Community (French translation)
NCSES	National Center for Science and Engineering Statistics
NGO	Non-Governmental Organization
NIS	National Innovation System
NRTA	Normalized Revealed Technological Advantage
NSF	US National Science Foundation
OECD	Organization for Economic Co-operation and Development
PCT	Patent Cooperation Treaty
PNPRD	R&D Performance by the Private Non-Profit Sector
PPP	Prices and purchasing power parities
PQCI	Patent Quality Composite Index
R&D	Research and Development
ROI	Return on Investment
RTA	Normalized Revealed Technological Advantage
SD	Standard Deviation
SEZ	Special Economic Zone
SIPO	State Intellectual Property Office of China
TNC	Transnational Corporation
UBO	Ultimate Beneficial Owner
UNESCO	United Nations Educational, Scientific and Cultural Organization
WIPO	World Intellectual Property Organization

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Appendix – Tables

In this segment select original data from online sources is displayed.

Appendix-Table 1 *Total BERD, https://stats.oecd.org*

MSTI Variables	BERD at constant prices and PPP $																	
Unit	US Dollar, Millions, 2010																	
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Country																		
Australia	4,912.73	5,935.31	6,451.81	6,991.62	7,521.69	8,607.14	9,928.54	11,308.41	12,375.65	11,856.78	11,989.52	11,974.52	..	12,163.03	..	10,879.83	..	..
Austria	..	..	4,287.83	..	4,725.62	5,452.50	5,657.76	6,028.98	6,385.26	6,099.52	6,554.32	6,637.34	7,472.09	7,620.20	8,058.96	8,075.13	8,300.17	8,599.61
Belgium	5,164.77	5,527.14	5,077.11	4,905.33	4,975.28	4,928.42	5,238.17	5,528.78	5,706.69	5,571.04	6,009.40	6,577.79	7,065.82	7,229.07	7,538.40	7,911.68	8,175.90	9,001.93
Canada	12,708.77	14,388.33	13,493.78	13,597.11	14,149.93	14,168.82	14,551.74	14,331.10	13,689.12	13,502.84	12,936.31	13,396.07	13,083.71	12,781.84	13,753.26	13,686.27	13,658.67	12,985.78
Chile	..	..	..	..	..	..	..	308.86	450.79	302.21	302.42	393.43	431.86	490.20	458.99	489.92	531.14	469.72
Czech Republic	1,415.65	1,449.10	1,493.47	1,608.63	1,724.47	1,745.63	1,982.88	2,176.36	2,124.96	2,027.68	2,195.06	2,496.94	2,755.05	2,949.54	3,257.25	3,299.69	3,314.81	3,790.06
Denmark	..	3,551.33	3,771.05	3,898.13	3,796.61	3,856.04	3,945.32	4,350.29	4,773.61	4,992.20	4,664.80	4,749.57	4,736.31	4,601.24	4,617.86	4,931.67	5,259.91	5,244.73
Estonia	28.12	52.06	51.58	65.62	89.00	122.11	160.45	175.59	179.31	175.22	227.99	450.48	393.80	270.19	210.47	232.74	229.01	227.47
Finland	4,040.14	4,094.41	4,167.56	4,346.97	4,511.21	4,704.66	4,939.77	5,281.44	5,792.03	5,401.34	5,390.57	5,463.66	4,936.37	4,718.60	4,445.57	4,013.37	3,863.60	3,951.77
France	26,975.57	28,404.03	29,243.44	28,456.57	29,136.96	28,557.79	29,703.70	29,983.32	30,483.36	31,249.11	32,121.88	33,438.26	34,418.53	34,776.09	35,190.37	35,491.40	35,779.52	36,056.75
Germany	49,278.17	49,657.15	49,828.99	50,672.52	50,564.53	50,629.92	53,737.37	55,262.38	58,672.79	56,661.02	58,289.32	62,769.76	65,100.95	63,580.36	66,482.61	69,716.68	70,892.98	76,449.02
Greece	371.66	500.44	499.90	527.63	518.28	570.80	566.87	572.33	716.21	749.89	738.73	667.58	632.46	690.19	725.63	810.76	1,071.53	1,430.03
Hungary	616.66	669.20	666.49	670.29	738.08	865.99	1,071.10	1,093.82	1,179.66	1,386.33	1,467.70	1,624.77	1,785.80	2,120.04	2,218.76	2,373.84	2,166.44	2,491.53
Iceland	140.83	168.95	164.01	145.37	..	164.81	192.99	190.69	189.78	170.23	160.71	164.47	..	128.57	164.28	209.76	211.44	218.35
Ireland	1,158.63	1,158.82	1,209.02	1,300.10	1,414.31	1,507.13	1,605.81	1,734.37	1,831.94	2,127.64	2,158.27	2,224.96	2,296.70	2,336.09	2,439.96	2,407.57	2,493.05	3,000.46
Israel	5,091.11	5,446.91	5,318.25	4,967.45	5,305.48	5,864.97	6,368.92	7,410.79	7,414.56	7,190.03	7,188.09	7,768.16	8,272.27	8,488.01	9,050.57	9,521.73	10,275.37	11,055.07
Italy	10,128.57	10,499.96	10,762.56	10,316.17	10,514.95	11,116.48	11,401.62	12,817.66	13,458.02	13,283.67	13,682.53	13,798.21	13,964.79	14,261.17	15,188.03	15,709.11	16,978.48	17,199.41
Japan	86,698.03	92,435.37	94,834.04	97,908.91	99,910.72	108,432.27	114,390.18	119,580.15	119,053.68	105,284.23	107,552.61	111,767.96	111,695.94	116,871.28	122,961.16	121,259.14	117,688.49	122,204.38
Korea	15,759.50	18,197.90	18,667.11	20,189.03	22,995.49	24,826.08	28,292.54	31,211.16	33,027.10	34,554.22	39,010.13	44,699.86	50,077.03	53,486.77	56,929.63	57,027.89	59,001.35	66,902.68
Latvia	44.67	39.74	48.54	38.90	60.68	81.41	138.42	83.72	65.17	63.17	83.26	75.79	61.16	72.19	104.08	67.70	48.20	64.88
Lithuania	51.15	84.08	51.20	71.26	87.65	89.44	139.36	160.00	134.58	123.89	143.33	156.37	165.06	171.65	233.57	213.58	226.07	263.91
Luxembourg	485.65	..	..	521.29	524.48	522.57	580.36	583.63	547.05	526.86	432.10	429.12	312.05	314.26	325.62	330.15	357.32	351.25
Mexico	1,372.15	1,473.40	1,873.93	2,001.63	2,618.39	3,025.88	3,049.17	3,106.67	2,804.06	3,137.71	3,270.29	3,220.47	2,704.30	2,951.93	3,095.46	3,159.79	3,077.49	..
Netherlands	6,447.52	6,541.14	6,077.38	6,290.02	6,560.62	6,557.01	6,777.93	6,658.50	6,233.61	5,790.89	6,109.25	8,088.33	8,152.59	8,069.10	8,432.87	8,633.40	9,238.98	9,556.87
New Zealand	..	438.04	..	553.78	..	588.15	..	663.03	..	704.37	..	781.19	..	782.02	..	992.91	..	1,263.39
Norway	..	2,109.49	2,076.56	2,157.09	2,026.25	2,078.88	2,189.68	2,356.23	2,508.28	2,444.61	2,394.04	2,514.29	2,598.21	2,684.17	2,840.00	3,119.67	3,172.84	3,367.15
Poland	1,262.51	1,231.35	638.91	861.37	971.42	1,133.81	1,170.11	1,229.85	1,393.19	1,455.77	1,536.60	1,890.04	2,800.75	3,289.43	3,918.67	4,342.71	6,064.37	6,698.39
Portugal	537.73	664.94	645.55	631.30	729.59	815.49	1,259.68	1,679.02	2,114.54	2,117.40	2,032.02	1,957.14	1,863.15	1,694.81	1,624.27	1,592.83	1,746.56	1,939.04
Slovak Republic	350.99	363.11	326.84	294.92	246.62	262.81	237.06	227.37	268.42	248.90	349.01	341.19	468.19	543.98	475.58	500.50	626.14	776.80

Slovenia		333.91	381.67	401.25	382.56	459.51	433.37	508.80	502.03	638.88	658.69	792.88	1,023.86	1,084.94	1,086.72	1,037.49	970.40	909.99	872.08
Spain		5,669.57	5,788.18	6,693.63	7,289.51	7,679.83	8,313.75	9,559.07	10,515.45	11,151.43	10,426.30	10,325.48	10,171.12	9,749.08	9,457.44	9,308.41	9,446.11	9,698.82	10,391.37
Sweden		..	9,749.68	..	9,031.47	8,743.62	8,890.11	9,865.23	9,274.34	10,044.79	9,003.64	8,623.05	8,986.52	8,880.94	9,214.04	8,747.37	9,865.32	10,130.14	11,016.04
Switzerland		5,950.60	..	..	..	7,125.37	..	..	..	8,226.47	..	..	..	9,720.38	..	..	10,795.03	..	10,898.86
Turkey		1,330.71	1,420.52	1,253.11	980.40	1,196.88	2,069.73	2,375.82	3,451.07	3,735.95	3,761.64	4,283.99	4,837.84	5,507.79	6,186.08	7,174.30	7,829.83	9,386.48	10,764.08
United Kingdom		20,347.94	21,004.32	21,398.23	21,243.98	20,717.83	21,225.59	22,164.02	23,616.47	23,353.26	22,587.68	22,878.29	24,320.65	23,531.67	24,911.73	26,466.96	27,608.43	28,785.72	29,204.74
United States		246,144.75	243,338.19	229,886.15	233,676.25	236,139.79	248,639.55	264,289.71	279,820.30	296,309.96	285,683.59	278,977.00	288,074.37	290,495.19	304,637.36	315,852.25	326,353.53	339,937.97	353,521.96
European Union (28 countries)		151,435.88	156,987.67	158,390.66	159,132.78	160,749.66	163,572.76	173,665.94	180,889.33	188,499.48	183,864.43	188,066.66	199,652.76	204,115.64	205,315.52	212,700.31	220,728.91	228,621.28	241,242.20
European Union (15 countries)		146,347.59	151,725.94	153,694.50	154,104.41	155,223.81	157,754.70	167,117.50	173,986.33	181,276.95	176,559.29	180,004.58	190,279.97	193,137.27	193,497.83	199,622.23	206,576.69	212,794.49	223,663.62
OECD - Total		533,000.46	547,715.42	538,372.13	548,070.20	559,436.34	588,615.30	626,759.95	661,344.98	687,774.98	659,846.26	664,466.45	697,178.46	710,264.75	735,552.83	765,946.80	783,909.10	806,414.50	846,939.01
Non-OECD Economies	Argentina	565.90	461.40	432.29	550.21	728.36	807.27	884.10	978.79	941.93	1,114.79	1,151.80	1,258.89	1,283.15	1,224.05	940.70	1,068.67	1,008.90	1,105.44
	China (People's Republic of)	24,464.64	28,124.71	34,957.14	41,527.80	53,131.97	65,139.73	79,931.33	93,206.42	109,025.99	137,263.07	156,744.81	183,998.00	214,306.38	242,748.00	266,963.94	288,547.23	318,560.47	345,076.21
	Romania	577.39	576.13	574.19	597.19	614.81	613.00	714.94	737.06	625.85	637.66	601.38	629.42	674.38	440.33	606.71	853.86	1,104.88	1,274.52
	Russia	13,586.94	15,893.40	17,530.44	18,986.00	18,386.29	17,854.69	19,021.38	20,699.85	19,964.21	21,872.32	20,017.63	20,289.50	20,408.86	21,548.84	22,286.42	22,088.33	21,813.13	22,903.10
	Singapore	2,306.44	2,585.61	2,631.10	2,675.00	3,210.61	3,689.63	3,943.47	4,792.46	5,882.85	4,112.37	4,202.45	4,897.53	4,649.00	4,748.84	5,495.69	5,846.18	5,610.48	5,568.06
	South Africa	..	1,688.70	..	1,976.27	2,245.05	2,593.91	2,737.15	2,921.42	3,082.70	2,590.16	2,199.30	2,147.57	2,060.61	2,163.71	2,312.38	2,285.39	2,280.87	..
	Chinese Taipei	7,217.76	7,527.86	8,096.52	8,978.56	10,044.18	11,284.60	12,542.70	13,950.62	15,530.14	16,081.64	17,939.14	19,540.93	20,765.66	21,996.06	23,304.46	24,030.22	25,186.29	27,550.20

Data extracted on 26 Dec 2019 10:31 UTC (GMT) from OECD.Stat

Appendix-Table 2 *Selected Data of Majority-Owned U.S. Affiliates by Country of Ultimate Beneficial Owner 2017, US Bureau of Economic Analysis*

	Millions of dollars								Millions of dollars		
	Total assets	Gross property, plant, and equip-ment	Expenditures for property, plant, and equipment	Sales	Net income	Value added	Compensation of employees	Thousands of employees	U.S. exports of goods shipped by affiliates	U.S. imports of goods shipped to affiliates	Research and development performed by affiliates
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
All countries	**14,475,586**	**2,579,660**	**266,780**	**4,564,418**	**120,724**	**1,034,719**	**621,050**	**7,661.3**	**364,408**	**689,219**	**62,812**
Canada	**2,214,950**	**406,461**	**27,244**	**369,228**	**18,316**	**99,604**	**55,603**	**755.5**	**14,417**	**17,282**	**980**
Europe	**8,014,336**	**1,332,880**	**136,004**	**2,487,374**	**84,278**	**633,814**	**388,749**	**4,720.0**	**199,385**	**312,076**	**43,413**
Belgium	203,215	25,509	1,621	34,833	-1,023	9,360	4,852	63.2	3,413	6,260	273
Denmark	34,803	8,977	1,215	27,910	963	6,196	3,810	41.7	1,419	12,125	499
Finland	24,650	6,817	492	22,280	-3,616	6,765	4,616	37.2	2,344	4,065	(D)
France	1,172,358	110,885	7,994	298,217	12,416	87,872	54,588	744.4	24,443	26,682	4,072
Germany	1,416,345	273,080	40,704	492,649	26,271	114,108	69,319	815.8	40,764	82,942	9,122
Ireland	518,519	53,375	4,476	141,164	6,588	48,659	34,234	319.0	10,426	7,257	5,262
Italy	79,528	36,863	2,577	40,735	1,866	10,370	5,715	86.7	1,619	5,502	208
Netherlands	834,463	112,668	14,181	352,371	18,405	63,930	39,568	557.2	42,657	62,231	5,571
Spain	369,618	69,581	4,881	57,739	507	12,600	9,067	90.2	1,241	1,264	162
Sweden	178,327	20,907	1,911	73,379	2,914	20,725	13,803	221.8	6,928	9,748	669
Switzerland	1,094,603	86,283	6,953	242,784	9,022	74,127	49,188	457.5	16,783	12,352	9,422
United Kingdom	1,923,134	416,616	37,029	628,927	8,656	165,212	94,319	1,214.7	44,559	63,647	6,659
Other	164,773	111,320	11,968	74,387	1,310	13,890	5,670	70.6	2,788	18,002	(D)
Latin America and Other Western Hemisphere	**536,458**	**107,173**	**10,583**	**307,538**	**7,047**	**48,692**	**31,394**	**373.0**	**33,371**	**24,146**	**1,546**
South and Central America	217,096	58,979	4,528	126,820	4,703	23,568	13,262	197.2	10,003	13,375	91
Brazil	96,735	21,536	1,593	52,180	2,125	10,814	5,728	91.8	4,362	3,456	27
Mexico	52,570	18,614	1,349	39,935	2,602	8,349	5,443	83.3	1,101	4,081	(D)
Venezuela	22,277	(D)	290	(D)	265	(D)	(D)	I	(D)	(D)	0
Other	45,514	(D)	1,296	(D)	-290	(D)	(D)	J	(D)	(D)	(D)
Other Western Hemisphere	319,362	48,194	6,055	180,717	2,344	25,124	18,132	175.8	23,368	10,771	1,455
Bermuda	222,954	19,443	(D)	91,646	1,633	11,945	8,894	61.8	(D)	3,941	(D)
United Kingdom Islands, Caribbean	52,794	(D)	2,488	47,592	342	7,917	6,008	85.4	4,315	(D)	(D)
Other	43,614	(D)	(D)	41,479	368	5,262	3,230	28.6	(D)	(D)	(D)
Africa	**21,791**	**(D)**	**(D)**	**5,094**	**396**	**1,547**	**702**	**6.4**	**(D)**	**(D)**	**(D)**
South Africa	7,377	(D)	(D)	4,237	359	1,309	497	4.2	(D)	(D)	(D)
Other	14,413	162	16	858	37	238	205	2.2	0	0	(D)
Middle East	**196,913**	**47,201**	**3,790**	**64,161**	**-14,308**	**13,276**	**6,652**	**69.0**	**3,697**	**16,079**	**1,936**
Israel	107,014	7,861	702	24,157	(D)	5,949	3,042	28.9	839	5,611	1,097
Saudi Arabia	26,501	17,660	630	(D)	(D)	3,806	1,581	9.1	2,103	(D)	(D)

United Arab Emirates	48,537	14,068	(D)	9,942	2,013	1,548	1,045	12.0	(D)	(D)	(D)
Other	14,860	7,612	(D)	(D)	51	1,973	984	19.1	(D)	204	6
Asia and Pacific	**3,181,875**	**663,191**	**85,751**	**1,270,249**	**23,107**	**216,100**	**119,531**	**1,410.8**	**109,455**	**315,035**	**14,025**
Australia	262,000	77,508	4,648	49,934	-1,491	14,165	7,835	81.3	2,732	2,646	(D)
China	249,534	51,456	5,520	74,805	-2,088	14,216	9,021	142.4	5,235	10,093	1,422
Hong Kong	36,365	17,108	1,749	31,934	325	3,766	2,288	27.3	917	10,020	634
India	59,226	10,710	1,015	33,794	102	7,924	6,244	65.5	2,028	4,784	213
Japan	2,280,036	418,229	64,600	840,334	24,227	155,642	80,436	922.4	80,581	180,493	9,403
Korea, Republic of	137,201	60,567	5,719	161,073	1,668	9,827	6,222	66.7	14,193	94,941	1,557
Singapore	73,548	9,894	1,128	20,136	-100	3,269	3,041	45.5	1,237	1,057	403
Taiwan	48,019	5,950	434	38,911	86	2,470	1,435	16.1	1,051	8,225	87
Other	35,946	11,767	936	19,329	379	4,821	3,010	43.7	1,479	2,775	(D)
United States	**309,263**	**(D)**	**(D)**	**60,774**	**1,888**	**21,687**	**18,419**	**326.5**	**(D)**	**(D)**	**(D)**
Addenda:											
European Union (28)	6,832,625	1,198,938	124,532	2,218,297	74,570	553,999	337,489	4,242.9	181,427	296,725	33,909
OPEC	111,674	46,911	3,193	63,067	3,312	8,651	3,809	29.6	6,383	14,410	833

Appendix-Table 3 *U.S. Direct Investment Abroad, All Majority-owned Foreign Affiliates (data for 2009 and forward), US Bureau of Economic Analysis*

	Research and Development Expenditures								
	2009	2010	2011	2012	2013	2014	2015	2016	2017
All Countries Total	39205	39887	44684	44983	49221	55278	56096	54307	56598
Canada	2920	2765	2964	2864	3160	3558	3447	3443	3513
Europe	25044	23902	27396	26742	29835	32435	32646	32556	32877
Austria	296	278	289	257	283	580	536	548	533
Belgium	2378	2031	2431	2547	2588	1198	1121	1726	1368
Czech Republic	81	56	60	75	63	105	88	75	127
Denmark	185	199	185	237	510	515	587	621	660
Finland	145	221	224	191	195	433	1089	525	268
France	1943	2021	2109	2031	2373	2469	2231	1856	2009
Germany	7528	6717	7230	8027	8248	8373	8768	9133	8177
Greece	32	27	26	21	18	45	43	29	40
Hungary	45	65	77	75	89	104	99	105	108
Ireland	1046	1431	1419	1465	1874	2797	3113	3065	3350
Italy	788	596	939	683	796	890	840	772	849
Luxembourg	(D)	(D)	(D)	302	(D)	237	147	177	172
Netherlands	1022	1282	1422	1489	1495	1238	1230	1230	1377
Norway	53	136	146	299	279	297	358	312	287
Poland	140	135	197	207	201	248	245	278	371
Portugal	36	56	58	52	52	53	54	52	55
Russia	68	65	163	130	147	213	169	176	201
Spain	570	361	398	272	285	439	379	364	421
Sweden	1133	400	544	572	644	822	706	713	844
Switzerland	1436	1588	2306	2364	3749	4441	4223	4410	4735
Turkey	39	54	61	(D)	(D)	61	85	89	87
United Kingdom	5792	5788	6604	5206	5364	6540	6176	5902	6415
Other	(D)	(D)	(D)	(D)	(D)	336	360	399	423
Albania	0	0	0	0	0	0	0	0	0
Andorra	0	0	0	0	0	n.s.	n.s.	n.s.	n.s.
Armenia	0	0	0	0	0	0	0	0	0
Azerbaijan	0	0	0	0	0	0	0	0	0
Belarus	0	0	0	0	0	1	1	1	1
Bosnia and Herzegovina	0	0	(*)	(*)	0	0	0	0	0
Bulgaria	(*)	(*)	(*)	1	1	17	16	16	18
Croatia	2	2	2	2	2	7	7	17	18
Cyprus	0	0	0	0	0	5	5	(D)	(D)
Estonia	4	5	6	28	(D)	(D)	(D)	(D)	(D)
Georgia	0	0	0	0	0	2	2	2	2
Gibraltar	0	0	0	0	0	0	0	0	0
Greenland	0	0	0	0	0	0	0	0	0
Iceland	0	(*)	1	(D)	(D)	(D)	(D)	(D)	(D)
Kazakhstan	0	0	0	0	0	(*)	(*)	(*)	1
Kosovo	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0	0
Kyrgyzstan	0	0	0	0	0	0	0	0	0
Latvia	2	2	2	(D)	2	4	4	4	4
Liechtenstein	0	0	0	0	0	0	0	0	0
Lithuania	3	3	3	(D)	3	4	(D)	(D)	(D)
Macedonia	0	0	0	0	0	0	0	0	0
Malta	5	(D)	(D)	(D)	2	(D)	(D)	(D)	(D)

Moldova	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Monaco	0	1	1	0	0	1	1	1	1
Montenegro	0	0	0	0	0	0	0	0	0
Romania	21	84	128	31	50	45	57	60	64
San Marino	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Serbia	3	3	3	3	2	(*)	(*)	(*)	(*)
Slovakia	(D)	17	19	16	35	64	61	64	66
Slovenia	4	4	4	3	3	4	4	4	5
Tajikistan	0	n.s.	n.s.	n.s.	n.s.	0	0	0	0
Turkmenistan	0	0	0	0	0	0	0	0	0
Ukraine	(D)	8	8	8	8	(D)	(D)	(D)	(D)
Uzbekistan	0	0	0	0	0	0	0	0	0
Vatican City	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Latin America and Other Western Hemisphere	1465	2553	2536	2747	2785	2610	2383	1917	2234
South America	1144	(D)	1575	1569	1543	1561	1267	1125	1269
Argentina	92	117	136	161	162	156	151	130	130
Brazil	955	1389	1325	1285	1220	1212	884	793	886
Chile	20	21	21	23	25	29	32	35	52
Colombia	26	(D)	32	37	63	62	64	64	73
Ecuador	1	1	2	2	1	2	(D)	1	4
Peru	22	8	8	9	30	44	90	79	107
Venezuela	25	27	47	48	38	55	42	21	15
Other	3	(D)	3	3	3	1	(D)	2	2
Bolivia	0	0	0	0	0	0	(*)	(*)	1
French Guiana	0	0	0	0	0	0	0	0	0
Guyana	1	1	1	1	1	0	0	0	0
Paraguay	0	0	0	0	0	(*)	(*)	(*)	(*)
Suriname	1	(D)	1	1	1	(*)	(D)	1	(*)
Uruguay	1	1	1	1	1	1	1	1	1
Central America	314	365	(D)	(D)	(D)	796	769	519	633
Costa Rica	8	20	(D)	(D)	80	40	77	84	104
Honduras	(D)	3	3	4	4	4	5	5	4
Mexico	281	337	332	405	418	722	671	412	504
Panama	2	2	2	5	(D)	22	10	13	14
Other	(D)	2	(D)	(D)	(D)	7	7	6	7
Belize	0	0	0	0	0	0	0	0	0
El Salvador	1	2	(D)	(D)	(D)	3	3	3	3
Guatemala	(D)	(*)	(*)	(*)	1	4	3	3	4
Nicaragua	0	0	0	0	(*)	(*)	(*)	(*)	(*)
Other Western Hemisphere	8	(D)	(D)	(D)	(D)	253	347	272	332
Barbados	(*)	(*)	1	(D)	(D)	0	1	3	1
Bermuda	5	(D)	(D)	(D)	(D)	9	67	53	77
Dominican Republic	2	2	1	1	1	1	3	3	2
United Kingdom Islands, Caribbean	1	2	1	(*)	(*)	(D)	(D)	(D)	(D)
Other	1	1	1	1	1	(D)	(D)	(D)	(D)
Anguilla	0	0	0	0	0	0	0	0	0
Antigua and Barbuda	0	0	0	0	0	0	0	0	0
Aruba	0	0	0	0	0	0	0	0	0
Bahamas	0	0	0	0	0	(D)	(D)	(D)	(D)
Cuba	0	0	0	0	0	n.s.	n.s.	n.s.	n.s.
Curacao	n.s.	n.s.	0	0	0	0	0	0	0
Dominica	0	(*)	(*)	(*)	0	(*)	(*)	(*)	(*)
French Islands, Caribbean	0	0	0	0	0	0	0	0	0

Grenada	0	0	0	0	0	0	0	0	0
Haiti	0	0	0	0	0	0	0	0	0
Jamaica	1	1	1	1	1	0	0	0	0
Netherlands Antilles	0	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Netherlands Islands, Caribbean	n.s.	n.s.	0	0	0	0	0	0	0
Sint Maarten	n.s.	n.s.	0	0	0	0	0	0	0
St. Kitts and Nevis	0	0	0	0	0	0	0	0	0
St. Lucia	0	0	0	0	0	0	0	0	0
St. Pierre and Miquelon	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
St. Vincent and the Grenadines	0	0	0	0	0	0	0	0	0
Trinidad and Tobago	0	0	0	0	0	0	(*)	(*)	(*)
United Kingdom Islands, Atlantic (OWH)	0	0	0	0	0	0	0	0	0
Africa	94	86	102	129	133	114	149	114	116
Egypt	6	6	2	2	3	19	43	23	20
Nigeria	(*)	3	3	(D)	(D)	1	(D)	(D)	(D)
South Africa	83	71	90	102	99	68	42	58	62
Other	5	6	7	(D)	(D)	26	(D)	(D)	(D)
Algeria	0	1	1	0	0	0	1	(D)	(D)
Angola	(*)	(*)	(*)	(*)	(*)	0	0	0	0
Benin	0	0	0	0	0	(D)	1	1	1
Botswana	0	0	0	0	0	0	0	0	0
Burkina Faso	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burundi	0	0	0	0	0	0	0	0	0
Cameroon	0	0	0	0	0	0	0	0	0
Cape Verde	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Central African Republic	0	0	0	0	0	0	0	0	0
Chad	0	0	0	0	0	0	0	0	0
Comoros	0	n.s.	n.s.	n.s.	n.s.	0	0	0	0
Congo (Brazzaville)	0	0	0	0	0	0	(*)	(*)	(*)
Congo (Kinshasa)	0	0	0	0	0	0	0	0	0
Cote D'Ivoire	0	0	0	0	0	0	0	0	0
Djibouti	0	0	0	0	0	0	0	0	0
Equatorial Guinea	0	0	0	0	0	0	0	0	0
Eritrea	0	0	0	0	0	0	0	0	0
Ethiopia	0	0	0	0	0	(D)	(*)	(*)	(*)
Gabon	0	(*)	(*)	0	0	0	(*)	(*)	(*)
Gambia	0	0	0	0	0	n.s.	n.s.	n.s.	n.s.
Ghana	1	1	1	1	1	2	2	2	3
Guinea	0	0	0	0	0	0	0	0	0
Guinea-Bissau	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Kenya	(*)	(*)	(*)	1	1	(D)	(*)	(*)	(*)
Lesotho	0	0	0	0	0	0	0	0	0
Liberia	0	0	0	0	0	0	0	0	0
Libya	0	(*)	(*)	(*)	(*)	(D)	(*)	(*)	(*)
Madagascar	0	0	0	0	0	0	0	0	0
Malawi	0	0	0	0	0	0	0	0	0
Mali	0	0	0	0	0	0	0	0	0
Mauritania	0	0	0	0	0	0	0	0	0
Mauritius	(*)	0	0	0	0	(D)	(D)	4	4
Morocco	1	(*)	(*)	(*)	(*)	1	2	1	1
Mozambique	0	0	0	0	0	0	0	0	0
Namibia	0	0	0	0	0	0	0	0	0

Niger	0	0	0	0	0	n.s.	n.s.	n.s.	n.s.
Rwanda	0	0	0	0	0	0	0	0	0
Sao Tome and Principe	(*)	0	0	0	0	0	0	0	0
Senegal	0	0	0	(*)	(*)	(D)	2	(*)	1
Seychelles	0	0	0	0	0	0	0	0	0
Sierra Leone	0	0	0	0	0	0	0	0	0
Somalia	0	0	0	0	0	n.s.	n.s.	n.s.	n.s.
South Sudan	n.s.	n.s.	n.s.	n.s.	n.s.	0	0	0	0
Sudan	0	0	0	0	0	n.s.	n.s.	n.s.	n.s.
Swaziland	0	0	0	0	0	(*)	(*)	(D)	(*)
Tanzania	0	0	0	0	0	0	0	0	0
Togo	0	0	0	0	0	0	0	0	0
Tunisia	3	4	4	(D)	(D)	0	0	0	0
Uganda	0	0	0	0	0	0	0	0	0
United Kingdom Islands, Atlantic (Africa)	0	0	0	0	0	0	0	0	0
Western Sahara	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Zambia	0	0	0	0	0	0	0	0	0
Zimbabwe	0	0	0	0	0	0	0	0	0
Middle East	1856	2016	2060	2033	2182	2856	3150	2668	2832
Israel	1845	2000	2045	2012	2148	2645	2955	2518	2621
Saudi Arabia	(*)	1	1	7	(D)	(D)	16	15	15
United Arab Emirates	11	15	13	(D)	(D)	(D)	177	132	194
Other	1	1	1	(D)	1	(D)	2	2	2
Bahrain	0	0	0	0	0	(D)	(D)	(*)	(*)
Iran	0	0	0	0	0	n.s.	n.s.	n.s.	n.s.
Iraq	0	0	0	0	0	0	0	0	0
Jordan	(*)	(*)	0	0	0	0	0	0	0
Kuwait	0	0	0	0	0	0	0	0	0
Lebanon	0	0	0	0	0	0	(*)	(*)	(*)
Oman	0	0	0	0	0	0	1	1	1
Qatar	1	1	1	(D)	1	1	(D)	1	1
Syria	0	0	0	0	0	0	0	0	0
Yemen	0	0	0	0	0	0	0	0	0
Asia and Pacific	7826	8564	9626	10470	11128	13704	14321	13610	15026
Australia	751	982	1081	1153	1113	1271	1053	869	940
China	1579	1535	1653	2012	2201	3048	3423	3280	3650
Hong Kong	70	148	164	154	151	172	150	156	197
India	1377	1716	2075	2289	2557	2905	3171	3289	3586
Indonesia	23	28	17	18	(D)	20	19	21	29
Japan	1835	1812	2169	2314	2392	2674	2504	2788	2875
Korea, Republic of	746	824	854	898	912	996	985	915	1014
Malaysia	376	348	390	655	517	437	597	528	612
New Zealand	21	21	37	37	33	30	27	30	34
Philippines	51	54	60	67	53	72	75	84	102
Singapore	706	738	772	509	717	1521	1788	1157	1421
Taiwan	196	278	242	274	269	443	423	383	441
Thailand	93	75	111	89	104	108	97	98	111
Other	2	2	1	2	(D)	6	8	14	14
Afghanistan	0	0	0	0	0	0	0	0	0
Bangladesh	0	0	0	0	(*)	0	(*)	(*)	(*)
Bhutan	0	0	0	0	0	0	0	0	0
Brunei	0	0	0	0	0	0	0	0	0
Burma	0	0	0	0	0	0	0	0	0

Cambodia	0	0	0	0	0	0	(*)	(*)	(*)
East Timor	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Fiji	0	0	0	0	0	0	0	0	0
French Islands, Indian Ocean	0	0	0	0	0	0	0	0	0
French Islands, Pacific	0	0	0	0	0	0	0	0	0
Kiribati	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Laos	0	0	0	n.s.	n.s.	0	0	0	0
Macau	2	2	0	0	0	0	0	4	5
Maldives	0	0	0	0	0	0	0	0	0
Marshall Islands	0	0	0	0	0	0	0	0	0
Micronesia	0	0	0	0	0	0	0	0	0
Mongolia	0	0	0	0	0	0	0	0	0
Nauru	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Nepal	0	0	0	0	0	0	0	0	0
North Korea	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Pakistan	(*)	(*)	(*)	1	1	1	1	1	2
Palau	0	0	0	0	0	0	0	0	0
Papua New Guinea	0	0	0	0	0	0	0	0	0
Samoa	0	0	0	0	0	0	0	0	0
Solomon Islands	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Sri Lanka	0	0	0	0	0	(*)	(*)	(*)	(*)
Timor-Leste	n.s.	0	0	0	0	n.s.	n.s.	n.s.	n.s.
Tonga	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Tuvalu	0	0	0	0	0	n.s.	n.s.	n.s.	n.s.
United Kingdom Islands, Indian Ocean	0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
United Kingdom Islands, Pacific	0	0	0	0	0	0	0	0	0
Vanuatu	0	0	0	0	0	0	0	0	0
Vietnam	(*)	(*)	(*)	1	(D)	5	6	7	6
Addenda:									
European Union	23435	22046	24706	23837	25509	27295	27665	27401	27385
OPEC	37	49	69	89	98	270	268	217	255

Appendix-Table 4 *Japan Inward activity of multinationals by investing country total manufacturing - ISIC Rev 3, https://stats.oecd.org*

Variables	R&D expenditures							
Country	Japan	-	-	-	-	-	-	-
Sources	Source 1							
Year	2000	2001	2002	2003	2004	2005	2006	2007
Partner Countries								
World	386,954	373,622	403,450	483,682	584,329	632,617	701,963	687,059
OECD	..	..	..	480,672	579,941	630,088	697,339	681,209
United States	114,357	75,860	70,365	36,242	62,306	64,828	69,878	75,010
Canada	..	..	..	991	925	1,022	0	..
Mexico	..	..	..	0	0	0	0	0
Japan	..	..	..	..	..	..	..	..
Korea	..	..	..	21	0	1	2	4,060
Australia	..	..	..	..	..	..	..	..
New Zealand	..	..	..	0	0	0	0	0
Europe	..	..	..	442,818	516,272	563,778	626,907	601,506
European Union (27)	..	..	..	..	..	..	..	599,366
European Union (25)	..	..	..	..	..	560,733	625,086	599,366
European Union (15)	245,540	287,357	318,591	438,323	510,301	560,733	625,086	599,366
Austria	..	..	..	2	1	1	1	0
Belgium	..	..	..	541	0	2,186	5,738	6,563
Denmark	..	..	..	295	538	390	143	97
Finland	..	..	..	0	0	0	0	..
France	184,211	216,847	246,207	287,920	359,878	389,174	403,812	406,135
Germany	16,175	18,241	16,013	49,227	50,057	44,428	46,620	39,968
Greece	..	..	..	0	0	0	0	0
Ireland	..	..	..	..	..	..	22,680	..
Italy	..	..	..	1,115	319	276	0	0
Luxembourg	..	..	..	..	947	..	2,132	2,562
Netherlands	19,604	17,659	35,910	57,418	56,992	60,375	103,437	91,010

Portugal		..	..	..	0	0	0	0	0
Spain		..	..	..	0	..	..	..	..
Sweden		..	..	..	186	162	19,629	21,847	14,309
United Kingdom		10,332	15,861	16,749	17,437	16,131	16,699	17,142	13,834
Czech Republic		..	..	..	0	0	0	0	0
Hungary		..	..	..	0	0	0	0	0
Iceland		..	..	..	0	0	0	0	0
Norway		..	..	..	0	0	0	0	0
Poland		..	..	..	0	0	0	0	0
Slovak Republic		..	..	..	0	0	0	0	0
Switzerland		3,936	4,677	4,162	4,495	5,964	3,013	1,795	2,140
Turkey		..	..	..	0	0	0	0	0
Other European countries		..	..	..	0	7	..	..	..
Baltic countries		..	..	..	0	0	0	0	0
Estonia		..	..	..	0	0	0	0	0
Latvia		..	..	..	0	0	0	0	0
Lithuania		..	..	..	0	0	0	0	0
Bulgaria		..	..	..	0	0	0	0	0
Croatia		..	..	..	0	0	0	0	0
Romania		..	..	..	0	0	0	0	0
Russia		..	..	..	0	0	0	0	0
Serbia		..	..	..	..	..	0	0	0
Slovenia		..	..	..	0	0	0	0	0
Ukraine		..	..	..	0	0	0	0	0
Non-OECD Asia		306	584	1,760	1,717	1,582	1,097	730	1,143
China		..	..	..	4	7	7	123	56
Hong-Kong, China		..	..	..	27	227	383	304	451
India		..	..	..	0	0	0	0	..
Indonesia		..	..	..	0	0	0	0	0
Malaysia		..	..	..	0	0	0	0	..

Philippines		..	..	..	0	0	0	0	0
Singapore		..	..	..	121	161	8	97	..
Chinese Taipei		..	..	..	1,565	1,187	680	206	353
Thailand		..	..	..	0	0	..	0	0
Middle East		..	..	..	63	31	14	31	260
Israel		..	..	..	..	..	0	0	0
Africa		..	..	..	0	0	0	0	0
Morocco		..	..	..	0	0	0	0	0
South Africa		..	..	..	0	0	0	0	0
Latin America		4,002	5,065	6,690	1,230	2,768	1,360	3,784	..
Argentina		..	..	..	..	..	..	0	..
Brazil		..	..	..	0	0	0	0	0
Chile		..	..	..	0	0	0	0	..

Appendix-Table 5 *Japan Outward activity of multinationals by country of location - ISIC Rev 3, https://stats.oecd.org*

Country		Japan										
ISIC3		Total Business Enterprise										
Variables		R&D expenditures										
Year		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Partner Countries												
Africa		..	..	..	..	..	..	..	..	..	..	..
Argentina		..	..	..	..	..	..	..	..	..	..	..
Non-OECD Asia		10,398	..	22,448	19,841	32,434	29,997	36,818	73,188	49,780	51,445	62,405
Australia		..	..	..	..	..	..	..	..	..	..	..
Austria		..	..	..	..	..	..	..	..	..	..	..
Baltic countries		..	..	..	..	..	..	..	..	..	..	..
Belgium		..	..	..	..	..	..	..	..	..	..	..
Bulgaria		..	..	..	..	..	..	..	..	..	..	..
Brazil		..	..	..	..	..	..	..	..	..	..	..
Canada		..	..	..	..	..	..	..	..	..	..	..
Switzerland		..	..	..	..	..	..	..	..	..	..	..
Chile		..	..	..	..	..	..	..	..	..	..	..
China		..	..	..	..	..	..	..	..	..	..	..
Czech Republic		..	..	..	..	..	..	..	..	..	..	..
Germany		16,770	..	17,774	16,076	12,860	16,837	20,883	14,270	14,033	21,665	22,283
Denmark		..	..	..	..	..	..	..	..	..	..	..
Spain		..	..	..	..	..	..	..	..	..	..	..
Estonia		..	..	..	..	..	..	..	..	..	..	..
European Union (15)		58,357	..	65,151	67,787	93,316	103,440	121,636	97,519	115,537	114,212	105,247
European Union (25)		..	..	..	..	..	..	..	..	..	..	..
European Union (27)		..	..	..	..	..	..	..	..	..	..	..
Europe		..	..	..	..	..	..	..	..	..	..	..
Finland		..	..	..	..	..	..	..	..	..	..	..

France		5,661	..	8,155	10,106	12,392	8,929	..	9,272	8,666	9,217	7,300
United Kingdom		20,523	..	15,731	19,433	41,801	33,773	35,192	37,514	29,635	26,106	29,972
Greece		..	..	..	..	..	..	..	..	..	..	..
Hong-Kong, China		..	..	..	..	..	..	..	..	..	..	..
Croatia		..	..	..	..	..	..	..	..	..	..	..
Hungary		..	..	..	..	..	..	..	..	..	..	..
Indonesia		..	..	..	..	..	..	..	..	..	..	..
India		..	..	..	..	..	..	..	..	..	..	..
Ireland		..	..	..	..	..	..	..	..	..	..	..
Iceland		..	..	..	..	..	..	..	..	..	..	..
Israel		..	..	..	..	..	..	..	..	..	..	..
Italy		..	..	..	..	..	..	..	..	..	..	..
Japan		..	..	..	..	..	..	..	..	..	..	..
Korea		..	..	..	..	..	..	..	..	..	..	..
Latin America		486	..	935	726	1,349	..	..	..	..	..	..
Lithuania		..	..	..	..	..	..	..	..	..	..	..
Luxembourg		..	..	..	..	..	..	..	..	..	..	..
Latvia		..	..	..	..	..	..	..	..	..	..	..
Morocco		..	..	..	..	..	..	..	..	..	..	..
Mexico		..	..	..	..	..	..	..	..	..	..	..
Middle East		..	..	..	..	..	..	..	..	..	..	..
Malaysia		..	..	..	..	..	..	..	..	..	..	..
Netherlands		..	..	..	..	..	..	..	..	..	..	..
Norway		..	..	..	..	..	..	..	..	..	..	..
New Zealand		..	..	..	..	..	..	..	..	..	..	..
OECD		..	..	..	..	..	..	..	..	..	..	..
Other European countries		..	..	..	..	..	..	..	..	..	..	..
Philippines		..	..	..	..	..	..	..	..	..	..	..
Poland		..	..	..	..	..	..	..	..	..	..	..
Portugal		..	..	..	..	..	..	..	..	..	..	..
Romania		..	..	..	..	..	..	..	..	..	..	..

Russia		..	..	..	..	..	..	..	..	..	..	..
Singapore		..	..	..	..	..	..	..	..	..	..	..
Serbia		..	..	..	..	..	..	..	..	..	..	..
Slovak Republic		..	..	..	..	..	..	..	..	..	..	..
Slovenia		..	..	..	..	..	..	..	..	..	..	..
Sweden		..	..	..	..	..	..	..	..	..	..	..
Thailand		..	..	..	..	..	..	..	..	..	..	..
Turkey		..	..	..	..	..	..	..	..	..	..	..
Chinese Taipei		..	..	..	..	..	..	..	..	..	..	..
Ukraine		..	..	..	..	..	..	..	..	..	..	..
United States		151,568	..	199,987	204,782	154,084	208,652	165,607	148,426	161,812	195,058	195,515
Western and Eastern Europe		490	..	..	70	..	707	1,178	8,497	5,332	5,084	2,577
World		223,707	..	294,614	298,525	286,010	353,816	337,447	347,870	349,949	387,301	387,963
South Africa		..	..	..	..	..	..	..	..	..	..	..

Data extracted on 01 Jan 2020 19:39 UTC (GMT) from OECD.Stat

Appendix-Table 6 *Exchange Rates to USD, https://data.worldbank.org*

Country Name	Country Code	Indicator Name	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Aruba	ABW	LCU per US$	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79
Afghanistan	AFG	LCU per US$	47.35757473	47.50001452	47.263	48.76275358	47.8453125	49.4945975	49.92533083	49.96201777	50.24961474	50.325	46.452461	46.74700774	50.9214	55.3775	57.2475	61.14346154	67.86608577	68.02690408	72.08324718
Angola	AGO	LCU per US$	10.04054417	22.05786167	43.53020667	74.60630083	83.5413625	87.15914167	80.36807206	76.70614275	75.03335417	79.32816667	91.90572034	93.93475	95.46795542	96.51827948	98.30241686	120.0607017	163.6564341	165.9159507	252.8557477
Albania	ALB	LCU per US$	143.7094167	143.4848333	140.1545159	121.86325	102.7800512	99.87025448	98.10337709	90.42789383	83.8946041	94.97811982	103.9366667	100.8958333	108.1841667	105.6691667	105.48	125.9616667	124.1425	119.1	107.9891667
United Arab Emirates	ARE	LCU per US$	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725	3.6725
Argentina	ARG	LCU per US$	0.9995	0.9995	3.063256667	2.900629167	2.923300819	2.9036575	3.054313333	3.095648849	3.14416456	3.710106831	3.896295154	4.110139576	4.53693436	5.459352665	8.075275993	9.233185525	14.75817509	16.56270693	28.09499167
Armenia	ARM	LCU per US$	539.5258333	555.0782583	573.3533333	578.7629545	533.4508333	457.6869406	416.0403697	342.0791162	305.9694003	363.2832856	373.6604667	372.5008824	401.7639756	409.6257493	415.9197892	477.9183066	480.4881508	482.7163938	482.9879466
Antigua and Barbuda	ATG	LCU per US$	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Australia	AUS	LCU per US$	1.724826667	1.9334425	1.8405625	1.541914167	1.3597525	1.309473333	1.327973441	1.1950725	1.192178333	1.28218881	1.090159486	0.969463201	0.965801031	1.035843097	1.109363293	1.331090262	1.345213976	1.304758077	1.338412146
Azerbaijan	AZE	LCU per US$	0.89483075	0.931316667	0.972164167	0.982146	0.9826955	0.945421	0.893445	0.858123808	0.821619579	0.803783333	0.80265	0.789686389	0.785645349	0.784541075	0.7843475	1.024563819	1.595721573	1.721154802	1.700016667
Burundi	BDI	LCU per US$	720.6733333	830.3533333	930.7491667	1082.62	1100.9	1081.577167	1028.683553	1081.869683	1185.690833	1230.179167	1230.748333	1261.073333	1442.505625	1555.090833	1546.686667	1571.898333	1654.626667	1729.055	1782.876875
Benin	BEN	LCU per US$	710.207977	732.3976933	693.7132265	579.8974262	527.3380323	527.2583626	522.4256249	478.6337185	446.0000414	470.2934233	494.7942622	471.2486257	510.5563385	493.8996239	493.7573299	591.211698	592.6056151	580.6567496	555.4464584
Burkina Faso	BFA	LCU per US$	711.9762744	733.0385071	696.9882036	581.2003139	528.2848093	527.4681428	522.8901096	479.2667826	447.8052556	472.1862908	495.2770216	471.8661141	510.5271359	494.0400374	494.4149529	591.4495075	593.0081704	582.0945501	555.7178304
Bangladesh	BGD	LCU per US$	52.14166667	55.80666667	57.888	58.15004	59.51265833	64.327475	68.93323333	68.874875	68.598275	69.03906667	69.64929167	74.1524	81.86265833	78.103235	77.64140833	77.94690833	78.46809167	80.43754167	83.46620192
Bulgaria	BGR	LCU per US$	2.123275	2.184708333	2.076975	1.732701667	1.575108917	1.574133333	1.559266667	1.42905	1.337116667	1.406691667	1.477391667	1.406458333	1.52205	1.473566667	1.474183333	1.7644	1.768041667	1.735458333	1.657041667
Bahrain	BHR	LCU per US$	0.376	0.376	0.376	0.376	0.376	0.376	0.376	0.376	0.376	0.376	0.376	0.376	0.376	0.376	0.376	0.376	0.376	0.376	0.376
Bahamas, The	BHS	LCU per US$	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bosnia and Herzegovina	BIH	LCU per US$	2.122859512	2.185659583	2.078170426	1.732932204	1.575157028	1.57272202	1.559071956	1.429002742	1.335195680	1.407891238	1.476739568	1.406936586	1.522209974	1.473051323	1.474169187	1.763491647	1.768139024	1.735352713	1.656985441
Belarus	BLR	LCU per US$	0.087675	0.139	0.179091667	0.205127083	0.216025750	0.215382	0.214456417	0.214607833	0.213630975	0.279304922	0.297851	0.497463333	0.833689833	0.888005250	1.022410250	1.592598833	1.989562833	1.932341667	2.037608333
Belize	BLZ	LCU per US$	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bermuda	BMU	LCU per US$	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bolivia	BOL	LCU per US$	6.183541667	6.606916667	7.17	7.659166667	7.936266667	8.0660625	8.011616667	7.851245161	7.238320699	7.02	7.016666667	6.9369625	6.91	6.91	6.91	6.91	6.91	6.91	6.91
Brazil	BRA	LCU per US$	1.829423122	2.349631709	2.920363018	3.077475118	2.925119450	2.434390036	2.175326667	1.947058333	1.833766667	1.999428173	1.759226711	1.672828755	1.953068611	2.156089151	2.352951963	3.326904383	3.491313422	3.191389446	3.653825361
Barbados	BRB	LCU per US$	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Brunei Darussalam	BRN	LCU per US$	1.723963333	1.7917225	1.790588333	1.742183333	1.690228333	1.6643975	1.588933333	1.507101667	1.417166667	1.454569273	1.363509474	1.257913020	1.249567016	1.251165670	1.267040123	1.374910845	1.381346877	1.380891164	1.348918565
Bhutan	BTN	LCU per US$	44.941605	47.18641417	48.61031917	46.58328417	45.31646667	44.0999375	45.30700833	41.34853333	43.50518333	48.40526667	45.72581212	46.67046667	53.43723333	58.59784542	61.02951446	64.15194446	67.19531281	65.12156865	68.38946709
Botswana	BWA	LCU per US$	5.102241667	5.841416667	6.327791667	4.949666667	4.693833333	5.11675	5.8303	6.139408333	6.826858333	7.155141667	6.793625	6.838233333	6.838233333	8.398908333	8.976083333	10.12899167	10.90115833	10.34741667	10.199975
Central African Republic	CAF	LCU per US$	711.9762744	733.0385071	696.9882036	581.2003139	528.2848093	527.4681428	522.8901096	479.2667826	447.8052556	472.1862908	495.2770216	471.8661141	510.5271359	494.0400374	494.4149529	591.4495075	593.0081704	582.0945501	555.7178304
Canada	CAN	LCU per US$	1.485394095	1.548839955	1.570342834	1.401014548	1.301281595	1.211405134	1.134344726	1.074045622	1.067086918	1.141535406	1.030112735	0.989258159	0.999364744	1.030137364	1.104747132	1.278786204	1.325615164	1.297935846	1.295817928
Switzerland	CHE	LCU per US$	1.6888425	1.687615	1.5586075	1.346650833	1.243495833	1.245176667	1.253843333	1.200365833	1.08309	1.088141696	1.042905646	0.888042028	0.937684481	0.926903548	0.916151047	0.962381328	0.985394394	0.984691667	0.977883333
Chile	CHL	LCU per US$	539.5875	634.9383333	688.9366667	691.3975	609.5291667	559.7675	530.275	522.4641667	522.4610358	560.8598948	510.2491667	483.6675	486.4713034	495.2728776	570.3482161	654.1240843	676.957736	648.8337926	641.2768131
China	CHN	LCU per US$	8.278504167	8.277068333	8.2769575	8.277036667	8.276800833	8.194316667	7.973438333	7.6075325	6.948655	6.831416052	6.770269029	6.461461327	6.312332827	6.195758346	6.143434094	6.227488673	6.644477829	6.758755086	6.615957177

Cote d'Ivoire	CIV	LCU per US$	711.9762744	733.0385071	696.9882036	581.2003139	528.2848093	527.4681428	522.8901096	479.2667826	447.8052556	472.1862908	495.2770216	471.8661141	510.5271359	494.0400374	494.4149529	591.4495075	593.0081704	582.0945501	555.7178304
Cameroon	CMR	LCU per US$	711.9762744	733.0385071	696.9882036	581.2003139	528.2848093	527.4681428	522.8901096	479.2667826	447.8052556	472.1862908	495.2770216	471.8661141	510.5271359	494.0400374	494.4149529	591.4495075	593.0081704	582.0945501	555.7178304
Congo, Dem. Rep.	COD	LCU per US$	21.81833333	206.6174999	346.4849999	405.1781832	399.4757917	473.9080083	468.278825	516.7498917	559.2925083	809.7858333	905.9134583	919.4913	919.7550167	919.5659074	925.2262825	925.9849613	1010.302757	1464.417932	1622.523502
Congo, Rep.	COG	LCU per US$	711.9762744	733.0385071	696.9882036	581.2003139	528.2848093	527.4681428	522.8901096	479.2667826	447.8052556	472.1862908	495.2770216	471.8661141	510.5271359	494.0400374	494.4149529	591.4495075	593.0081704	582.0945501	555.7178304
Colombia	COL	LCU per US$	2087.903842	2299.633156	2504.241331	2877.652458	2628.612903	2320.834177	2361.139408	2078.291837	1967.711309	2158.255903	1898.569636	1848.13947	1796.895912	1868.785327	2001.781048	2741.880855	3054.121673	2951.327402	2955.70397
Comoros	COM	LCU per US$	532.6559828	549.2982699	520.2849199	434.9230696	395.5035242	395.443772	391.8192187	358.9752889	334.5000311	352.7200675	371.0956967	353.4364693	382.9172538	370.4247179	370.3179974	443.4087735	444.4542113	435.4925622	416.5848438
Cabo Verde	CPV	LCU per US$	115.8765516	123.2133333	117.2558333	97.7875	88.7479249	88.64616853	87.92606491	80.61502716	75.33600384	80.03541773	83.27868938	79.27688148	86.31895418	83.0725	83.0345	99.38569354	99.68811364	97.80693777	93.41357891
Costa Rica	CRI	LCU per US$	308.1866667	328.8708333	359.8175269	398.6622222	437.935	477.7867415	511.3018179	516.6173902	526.2355134	573.2879567	525.8292007	505.6642399	502.901462	499.7668326	538.3172003	534.56577	544.7393672	567.5130903	576.9725012
Curacao	CUW	LCU per US$												1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79
Cayman Islands	CYM	LCU per US$	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333	0.83333
Czech Republic	CZE	LCU per US$	38.59841667	38.03532833	32.73851833	28.209	25.69975	23.95741667	22.59558333	20.29366667	17.07166667	19.063	19.09825	17.69591667	19.5775	19.57058333	20.7575	24.59875	24.43991667	23.37633333	21.72991667
Djibouti	DJI	LCU per US$	177.721	177.721	177.721	177.721	177.721	177.721	177.721	177.721	177.721	177.721	177.721	177.721	177.721	177.721	177.7208333	177.72	177.72	177.72	177.72
Dominica	DMA	LCU per US$	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Denmark	DNK	LCU per US$	8.083144167	8.3228175	7.894714167	6.587673333	5.991056667	5.99691	5.946778333	5.443700833	5.098130833	5.360866667	5.624075	5.368711535	5.792475537	5.616311686	5.612466667	6.727906831	6.731718257	6.602893466	6.314618787
Dominican Republic	DOM	LCU per US$	16.18145768	16.69096152	17.59304369	29.36999962	41.93031457	30.28280818	33.3000352	33.17187058	34.52936096	35.97186555	36.82129187	38.08758487	39.32030084	41.79450343	43.54967262	45.04549907	46.06444394	47.5343582	49.50999286
Algeria	DZA	LCU per US$	75.25979167	77.2152083	79.6819	77.394975	72.06065	73.27630833	72.64661667	69.2924	64.5828	72.64741667	74.38598333	72.93788333	77.53596667	79.3684	80.57901667	100.6914333	109.4430667	110.9730167	116.5937917
Ecuador	ECU	LCU per US$	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Egypt, Arab Rep.	EGY	LCU per US$	3.47205	3.973	4.499666667	5.850875	6.196241667	5.778833333	5.733166667	5.635433333	5.4325	5.544553309	5.621942918	5.932827652	6.056058333	6.870325	7.077608561	7.691258333	10.02540079	17.78253352	17.76729042
Euro area	EMU	LCU per US$	1.082705081	1.116533086	1.057558996	0.884047927	0.803921648	0.803800192	0.796432731	0.7296724	0.67992268	0.716957702	0.75430899	0.718413899	0.77833812	0.752945123	0.752728197	0.901296423	0.903421436	0.885205508	0.846772667
Eritrea	ERI	LCU per US$	9.625	11.30945208	13.95819417	13.87789058	13.7875	15.36791667	15.375	15.375	15.375	15.375	15.375	15.375	15.375	15.375	15.375	15.375	15.35	15.075	15.075
Ethiopia	ETH	LCU per US$	8.217258333	8.457491667	8.56775	8.599683333	8.635583333	8.666441667	8.698615833	8.96595	9.599741667	11.77759967	14.40958981	16.89922576	17.70476138	18.62662896	19.58578991	20.57684875	21.73154722	23.86610446	27.42938659
Fiji	FJI	LCU per US$	2.128625	2.276633333	2.186691667	1.8956	1.73295	1.690966667	1.731183333	1.610283333	1.593708333	1.955708333	1.918308333	1.793194258	1.789893922	1.841387986	1.887349723	2.097623233	2.094683036	2.066883333	2.087382441
Faroe Islands	FRO	LCU per US$	8.083144167	8.3228175	7.894714167	6.587673333	5.991056667	5.99691	5.946778333	5.443700833	5.098130833	5.360866667	5.624075	5.368711535	5.792475537	5.616311686	5.612466667	6.727906831	6.731718257		
Gabon	GAB	LCU per US$	711.9762744	733.0385071	696.9882036	581.2003139	528.2848093	527.4681428	522.8901096	479.2667826	447.8052556	472.1862908	495.2770216	471.8661141	510.5271359	494.0400374	494.4149529	591.4495075	593.0081704	582.0945501	555.7178304
United Kingdom	GBR	LCU per US$	0.660930833	0.694655	0.667223333	0.6124725	0.54618	0.549998333	0.543486667	0.499771667	0.54396625	0.641919263	0.647179346	0.624140836	0.633046989	0.639660578	0.607729627	0.654545479	0.740634464	0.776976682	0.74953154
Georgia	GEO	LCU per US$	1.976166667	2.073016667	2.195675	2.14565	1.91665	1.812675	1.780433333	1.670491667	1.490791667	1.670487097	1.782341667	1.68649543	1.651258333	1.66335	1.765666667	2.269341667	2.366725	2.509541667	2.534110833
Ghana	GHA	LCU per US$	0.544919176	0.716305158	0.792417084	0.866764327	0.899494854	0.90627897	0.916451773	0.935247846	1.057858333	1.4088	1.431025	1.51185	1.795816667	1.95405	2.899775	3.668025	3.9098	4.356741667	4.586816667
Gibraltar	GIB	LCU per US$	0.660930833	0.694655	0.667223333	0.6124725	0.54618	0.549998333	0.543486667	0.499771667	0.54396625	0.641919263	0.647179346	0.624140836	0.633046989	0.639660578	0.607729627	0.654545479	0.740634464	0.776976682	0.74953154
Guinea	GIN	LCU per US$	1746.869917	1950.558333	1975.84375	1984.93125	2243.93125	3644.333333	5148.75	4197.752004	4601.691004	4801.083238	5726.071021	6658.031258	6985.829026	6907.87807	7014.118777	7485.516742	8959.716125	9088.319508	9011.134179
Gambia, The	GMB	LCU per US$	12.7876251	15.68715833	19.917825	28.53050833	30.03008333	28.57543333	28.065725	24.87343333	22.19235	26.6443612	28.01195366	29.46152006	32.07713389	35.95758683	41.73296165	42.50620809	43.88463359	46.60752712	48.15134559
Guinea-Bissau	GNB	LCU per US$	711.9762744	733.0385071	696.9882036	581.2003139	528.2848093	527.4681428	522.8901096	479.2667826	447.8052556	472.1862908	495.2770216	471.8661141	510.5271359	494.0400374	494.4149529	591.4495075	593.0081704	582.0945501	555.7178304
Equatorial Guinea	GNQ	LCU per US$	711.9762744	733.0385071	696.9882036	581.2003139	528.2848093	527.4681428	522.8901096	479.2667826	447.8052556	472.1862908	495.2770216	471.8661141	510.5271359	494.0400374	494.4149529	591.4495075	593.0081704	582.0945501	555.7178304
Grenada	GRD	LCU per US$	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Greenland	GRL	LCU per US$	8.083144167	8.3228175	7.894714167	6.587673333	5.991056667	5.99691	5.946778333	5.443700833	5.098130833	5.360866667	5.624075	5.368711535	5.792475537	5.616311686	5.612466667	6.727906831	6.731718257		

Guatemala	GTM	LCU per US$	7.76315 9167	7.85859 25	7.82164 5	7.94084 6667	7.94649 5833	7.63394 4167	7.60263 0833	7.67330 4167	7.56002 8333	8.16155 5417	8.05777 0833	7.78541 8333	7.83360 5417	7.85681 375	7.73223 3333	7.65481 5	7.59993 7083	7.34793 875	7.51916 4583
Guyana	GUY	LCU per US$	182.43	187.320 8333	190.665	193.878 3333	198.307 5	199.875	200.188 3333	202.346 6667	203.633 3333	203.95	203.635 8333	204.017 5	204.358 3333	205.394 1667	206.449 1667	206.5	206.5	206.5	207.716 6667
Hong Kong SAR, China	HKG	LCU per US$	7.79116 6667	7.79875	7.79891 6667	7.78675	7.788	7.77733 3333	7.76783 3333	7.80141 6667	7.78683 3333	7.75175	7.76916 6667	7.784	7.75641 6667	7.756	7.75408 3333	7.75175	7.76225	7.79325	7.8385
Honduras	HND	LCU per US$	14.8406 25	15.4768 25	16.4370 5833	17.3524 9167	18.2097 25	18.8323 4167	18.8952 0833	18.8951	18.9037 5833	18.8951	18.8951	18.9171 4167	19.5022 4951	20.3537 7917	20.9871 5833	21.9451 75	22.8350 1839	23.4870 8394	23.9027 2829
Croatia	HRV	LCU per US$	8.27766 6417	8.34154 1	7.87168 25	6.70496 8833	6.03434 0667	5.94923 6917	5.83779 325	5.36453 5667	4.93503 975	5.28394 6417	5.49801 0583	5.34386 975	5.85029 1833	5.70488 0167	5.74816 5417	6.85830 375	6.80599 0167	6.62383 1	6.27902 525
Haiti	HTI	LCU per US$	21.1706 6667	24.4290 8333	29.2504 8333	42.3667 5833	38.3520 3333	40.4485 5	40.4085 1667	36.8614 1667	39.1075 9167	41.1976 0833	39.7974	40.5228 2194	41.9497 2295	43.4627 8333	45.2159 8089	50.7064 2667	63.3358 1837	64.7696 8028	68.0317 5398
Hungary	HUN	LCU per US$	282.179 1667	286.49	257.886 6667	224.306 6667	202.745 8333	199.582 5	210.39	183.625 8333	172.113 3333	202.341 6667	207.944 1667	201.055	225.104 1667	223.695	232.601 6667	279.332 5	281.523 3333	274.433 3333	270.211 6667
Indonesia	IDN	LCU per US$	8421.77 5	10260.8 5	9311.19 1667	8577.13 3333	8938.85	9704.74 1667	9159.31 6667	9141	9698.96 25	10389.9 375	9090.43 3333	8770.43 3333	9386.62 9167	10461.2 4	11865.2 113	13389.4 1294	13308.3 268	13380.8 3388	14236.9 3877
Isle of Man	IMN	LCU per US$	0.66093 0833	0.69465 5	0.66722 3333	0.61247 25	0.54618	0.54999 8333	0.54348 6667	0.49977 1667	0.54396 625	0.64191 9263	0.64717 9346	0.62414 0836	0.63304 6989	0.63966 0578	0.60772 9627	0.65454 5479	0.74063 4464	0.77697 6682	0.74953 154
India	IND	LCU per US$	44.9416 05	47.1864 1417	48.6103 1917	46.5832 8417	45.3164 6667	44.0999 75	45.3070 0833	41.3485 3333	43.5051 8333	48.4052 6667	45.7258 1212	46.6704 6667	53.4372 3333	58.5978 4542	61.0295 1446	64.1519 4446	67.1953 1281	65.1215 6865	68.3894 6709
Iran, Islamic Rep.	IRN	LCU per US$	1764.85 6069	1753.98 5685	6907.03 4456	8193.88 7519	8613.98 9421	8963.95 8907	9170.94 2878	9281.15 1828	9428.52 8261	9864.30 2456	10254.1 7647	10616.3 0664	12175.5 4722	18414.4 4801	25941.6 6414	29011.4 9138	30914.8 5244	33226.2 9815	40864.3 2901
Iceland	ISL	LCU per US$	78.6159 4667	97.4246 0333	91.6616 6667	76.7089 825	70.1916 6667	62.9816 6667	70.18	64.055	87.9479 1667	123.638 3814	122.241 8112	115.954 0398	125.082 787	122.179 1213	116.767 3525	131.918 7084	120.811 5481	106.839 572	108.300 1763
Israel	ISR	LCU per US$	4.07733 3333	4.20565	4.73782 5	4.55413 3333	4.48198 3333	4.4877	4.45580 8333	4.10808 2949	3.58802 1194	3.93233 5478	3.73897 5	3.57812 9306	3.85592 1825	3.61075 8333	3.57792 5	3.88683 3333	3.84056 6667	3.59955 5548	3.59055 8127
Jamaica	JAM	LCU per US$	42.9857	45.9962 5	48.4159 4167	57.7408 7375	61.1972	62.2807 1494	65.7438 5754	69.1921 6185	72.7562 0341	87.8941 1981	87.1961 4633	85.8934 632	88.7498 0239	100.397 8832	110.934 5278	116.969 7766	125.095 0346	127.964 5442	128.871 5191
Jordan	JOR	LCU per US$	0.709	0.70898 3174	0.70899 9833	0.709	0.709	0.709	0.709	0.70899 9767	0.70966 655	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Japan	JPN	LCU per US$	107.765 4983	121.528 9475	125.388 0192	115.933 4642	108.192 5692	110.218 2117	116.299 3117	117.753 5292	103.359 494	93.5700 8909	87.7798 75	79.8070 1983	79.7904 5542	97.5956 5828	105.944 781	121.044 0257	108.792 9	112.166 1411	110.423 1793
Kazakhstan	KAZ	LCU per US$	142.133 3333	146.735 8333	153.279 1667	149.575 8333	136.035	132.88	126.089 4306	122.554 1667	120.299 1667	147.496 6667	147.355	146.620 8333	149.112 5	152.129 1667	179.191 6667	221.728 3333	342.16	326.001 0227	344.705 8333
Kenya	KEN	LCU per US$	76.1755 4167	78.5631 95	78.7491 4167	75.9355 6944	79.1738 7606	75.5541 0945	72.1008 3502	67.3166 6667	69.1758 3333	77.3508 3333	79.2333 3333	88.8116 6667	84.53	86.1233 3333	87.9225	98.1791 6667	101.504 1667	103.410 4462	101.301 574
Kyrgyz Republic	KGZ	LCU per US$	47.7038 3333	48.3779 5833	46.9370 6667	43.6483 75	42.6499 4167	41.0118 2051	40.1528 9995	37.3162 5681	36.5745 9167	42.9041 0833	45.9642 614	46.1439 0132	47.0044 7914	48.4380 5901	53.6540 5831	64.4621 0827	69.9140 6583	68.8666 6786	68.8403 2033
Cambodia	KHM	LCU per US$	3840.75	3916.33 3333	3912.08 3333	3973.33 3333	4016.25	4092.5	4103.25	4056.16 6667	4054.16 6667	4139.33 3333	4184.91 6667	4058.5	4033	4027.25	4037.5	4067.75	4058.69 4579	4050.57 9986	4051.16 69
Kiribati	KIR	LCU per US$	1.72482 6667	1.93344 25	1.84056 25	1.54191 4167	1.35975 25	1.30947 3333	1.32797 3441	1.19507 25	1.19217 8333	1.28218 881	1.09015 9486	0.96946 3201	0.96580 1031	1.03584 3097	1.10936 3293	1.33109 0262	1.34521 3976	1.30475 8077	1.33841 2146
St. Kitts and Nevis	KNA	LCU per US$	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Korea, Rep.	KOR	LCU per US$	1130.95 75	1290.99 4583	1251.08 8333	1191.61 4167	1145.31 9167	1024.11 6667	954.790 5158	929.257 2617	1102.04 6667	1276.93	1156.06 0988	1108.29 2125	1126.47 0826	1094.85 2917	1052.96 0833	1131.15 75	1160.43 3435	1130.42 4621	1100.5
Kuwait	KWT	LCU per US$	0.30675 1583	0.30668 1667	0.30391 4252	0.29801 1521	0.2947	0.292	0.29017 6225	0.28421 3958	0.26882 8367	0.28778 5417	0.28660 6592	0.27597 8944	0.27993 5558	0.28358 9442	0.28456 7142	0.30085 2025	0.30213 7441	0.30334 9758	0.30195 6494
Lao PDR	LAO	LCU per US$	7887.64 3333	8954.58 3333	10056.3 3333	10569.0 375	10585.3 75	10655.1 6667	10159.9 3917	9603.16 0306	8744.22 4088	8516.05 2615	8258.77 0086	8030.05 5	8007.75 75	7860.13 75	8048.96 0333	8147.90 7956	8179.26 8333	8351.52 6075	8489.23 9909
Lebanon	LBN	LCU per US$	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5
Liberia	LBR	LCU per US$	40.9025	48.5919 0899	61.7541 6667	59.3788 3333	54.9058 3333	57.0958 3333	58.0133 3333	61.2722 2222	63.2075	68.2866 6667	71.4033 3333	72.2266 6667	73.5147 7208	77.52	83.8925	86.1883 6657	94.4272 4359	112.706 6667	144.055 5758
Libya	LBY	LCU per US$	0.51218 9613	0.60506 4254	1.27067 9174	1.29294 4128	1.30496 6144	1.30838 4824	1.31357 1625	1.26264 4868	1.22356 2393	1.25353 4489	1.26678 941	1.22415 2495	1.26165 9638	1.27169 1821	1.27240 2067	1.38120 986	1.39036 8679	1.39382 0011	1.36496 6667
St. Lucia	LCA	LCU per US$	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Sri Lanka	LKA	LCU per US$	77.0051 1667	89.3830 1333	95.6620 65	96.5209 5083	101.194 4575	100.498 0517	103.914 4458	110.623 2333	108.333 7627	114.944 7833	113.064 4804	110.565 2079	127.603 3535	129.069 0309	130.564 6852	135.856 9128	145.581 6675	152.446 4139	162.464 8587
Lesotho	LSO	LCU per US$	6.93982 8333	8.60918 0833	10.5407 4667	7.56474 9167	6.45969 25	6.35932 8333	6.77154 9167	7.04536 5	8.26122 3333	8.47367 4158	7.32122 1961	7.26113 2132	8.20996 8627	9.65505 6069	10.8526 5557	12.7589 3088	14.7096 1089	13.3337 8146	13.2409 1113
Macao SAR, China	MAC	LCU per US$	8.0259	8.0335	8.03343 3333	8.02124 1167	8.02217 1083	8.01106 4583	8.00142 6167	8.03585 3917	8.02010 9917	7.98428 3333	8.00221 6667	8.01820 8333	7.98986 35	7.98925 5333	7.98712 9	7.98496 0417	7.99506 425	8.02600 1	8.07250 7417
Morocco	MAR	LCU per US$	10.6256 3617	11.3029 75	11.0205 8333	9.57438 3333	8.86801 6667	8.86500 8333	8.79558 3333	8.19233 3333	7.75032 5	8.0571	8.41715 8333	8.08987 5	8.62844 4583	8.40550 3917	8.40633 6688	9.76434 828	9.80747 6032	9.69199 7889	9.38610 2421
Moldova	MDA	LCU per US$	12.4342 1667	12.8651 4167	13.5704 975	13.9448 8333	12.3297 1667	12.5996 25	13.1310 5833	12.1399 4497	10.3920 4368	11.1095 7543	12.3692 6096	11.7386 1249	12.1114 3682	12.5867 5623	14.0356 3005	18.8184 7515	19.9238 2756	18.4990 3489	16.8020 5172
Madagascar	MDG	LCU per US$	1353.49 6167	1317.69 8833	1366.39 1167	1238.32 7667	1868.85 7833	2003.02 5833	2142.30 1667	1873.87 6667	1708.37 0833	1956.20 5833	2089.95	2025.11 75	2194.96 6667	2206.91 4167	2414.81 1667	2933.50 8333	3176.53 9167	3116.11	3334.75 2255

Maldives	MDV	LCU per US$	11.77	12.24208333	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	14.6020084	15.36483532	15.36671003	15.38039352	15.36633122	15.36840768	15.38696851	15.39083727
Mexico	MEX	LCU per US$	9.455558333	9.342341667	9.655958333	10.78901917	11.28596667	10.89789167	10.89924167	10.92819167	11.12971667	13.513475	12.63600833	12.423325	13.16945833	12.77199167	13.29245	15.84826667	18.66405833	18.92651667	19.24434167
North Macedonia	MKD	LCU per US$	65.90386667	68.03713333	64.34979167	54.32225833	49.40993333	49.28368333	48.80176667	44.72981667	41.86768333	44.100575	46.48539167	44.230825	47.89025	46.39534167	46.43713083	55.537075	55.731725	54.66545833	52.10710833
Mali	MLI	LCU per US$	711.9762744	733.0385071	696.9882036	581.2003139	528.2848093	527.4681428	522.8901096	479.2667826	447.8052556	472.1862908	495.2770216	471.8661141	510.5271359	494.0400374	494.4149529	591.4495075	593.0081704	582.0945501	555.7178304
Myanmar	MMR	LCU per US$	6.516725	6.748908333	6.642083333	6.138925	5.805833333	5.818166667	5.842941667	5.616883333	5.44145	5.576366667	5.634883333	5.444108333	640.6534167	933.5704564	984.3457476	1162.615329	1234.869517	1360.358707	1429.807975
Montenegro	MNE	LCU per US$	1.085400833	1.11751	1.062551667	0.886034167	0.805365	0.80412	0.797140833	0.7306375	0.682674711	0.71984336	0.755044952	0.719355254	0.778293601	0.753159182	0.753730737	0.901658962	0.904035128	0.887397421	0.847186371
Mongolia	MNG	LCU per US$	1076.666667	1097.6975	1110.31	1146.5425	1185.2975	1205.246667	1179.699167	1170.400833	1165.804167	1437.795	1357.064167	1265.515833	1357.58	1523.9275	1817.938708	1970.309167	2140.290864	2439.777201	2472.484051
Mozambique	MOZ	LCU per US$	15.22725	20.70364083	23.67795667	23.7822675	22.5813425	23.060965	25.40077917	25.84034145	24.30064247	27.51829996	33.9600988	29.06759993	28.37298448	30.10411109	31.3526877	39.98247415	63.05623273	63.58432291	60.32620764
Mauritania	MRT	LCU per US$	23.89233333	25.56291667	27.17391667	26.303		26.55283333	26.86	25.85866667	23.82033333	26.23658333	27.58941667	28.11183333	29.662	30.06816667	30.2725	32.46716667	35.23708333	35.79441667	35.6775
Mauritius	MUS	LCU per US$	26.24955833	29.12925833	29.962	27.901475	27.49851667	29.49623333	31.70806667	31.31365625	28.4528375	31.9598	30.7844	28.70595	30.04997167	30.70135833	30.62161667	35.0567	35.54188333	34.48140833	33.93445
Malawi	MWI	LCU per US$	59.54380833	72.19733333	76.68660833	97.432475	108.8975083	118.42	136.0125	139.9575	140.5216667	141.1683333	150.4858333	156.5158333	249.1066667	364.4058333	424.8966667	499.6058333	718.005	730.2725	732.3333333
Malaysia	MYS	LCU per US$	3.8	3.8	3.8	3.8	3.8	3.787091667	3.668176958	3.437569382	3.335833333	3.524502911	3.221086915	3.060003011	3.088800867	3.15090855	3.272859746	3.905500263	4.148300663	4.300440878	4.035130137
Namibia	NAM	LCU per US$	6.939828333	8.609180833	10.54074667	7.564749167	6.4596925	6.377116667	6.76715	7.054391667	8.251741667	8.522819833	7.33025	7.300025	8.193770833	9.750075	10.8428875	12.88192083	14.70876667	13.3129	13.23394167
New Caledonia	NCL	LCU per US$	129.5227266	133.3543681	126.7960967	105.7319634	96.10557457	95.9570066	95.12417078	87.18821496	81.46473384	85.90013186	90.1007977	85.84188532	92.87509856	89.87576554	89.94397015	107.5964967	107.8800487	105.8946428	101.0961899
Niger	NER	LCU per US$	711.9762744	733.0385071	696.9882036	581.2003139	528.2848093	527.4681428	522.8901096	479.2667826	447.8052556	472.1862908	495.2770216	471.8661141	510.5271359	494.0400374	494.4149529	591.4495075	593.0081704	582.0945501	555.7178304
Nigeria	NGA	LCU per US$	101.6973333	111.23125	120.5781583	129.22235	132.888025	131.2743333	128.6516667	125.8081083	118.5460167	148.9017417	150.298025	153.8616083	157.4994258	157.311225	158.5526417	192.4403333	253.492	305.7901092	306.0836882
Nicaragua	NIC	LCU per US$	12.68439167	13.37194167	14.25132525	15.10464333	15.93724732	16.73332953	17.56999843	18.44850616	19.37189641	20.33948187	21.35644868	22.42427062	23.54666353	24.72276417	25.95890037	27.25684494	28.62096241	30.05094134	31.55321233
Norway	NOR	LCU per US$	8.801841667	8.991654167	7.983778833	7.080216667	6.740833333	6.4425	6.413333333	5.861666667	5.64	6.288333333	6.044166667	5.604607307	5.8175	5.875	6.301666667	8.064166667	8.4	8.271666667	8.1325
Nepal	NPL	LCU per US$	71.09379583	74.94925	77.87661917	76.1414475	73.67359667	71.3675	72.75560583	66.4150275	69.761695	77.57343074	73.26235902	74.02	85.22575599	93.08439381	97.55484216	102.4051343	107.3838152	104.5118852	108.9301341
Nauru	NRU	LCU per US$	1.724826667	1.9334425	1.8405625	1.541914167	1.3597525	1.309473333	1.327973441	1.1950725	1.192178333	1.28218881	1.090159486	0.969463201	0.965801031	1.035843097	1.109363293	1.331090262	1.345213976	1.304758077	1.338412146
New Zealand	NZL	LCU per US$	2.201149167	2.378750833	2.162190833	1.722099146	1.508681271	1.420273457	1.542055757	1.360675229	1.42272681	1.600877295	1.387833828	1.265810697	1.234283655	1.219407974	1.205433333	1.433975	1.436525	1.407408333	1.445258333
Oman	OMN	LCU per US$	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845	0.3845
Pakistan	PAK	LCU per US$	53.6481865	61.92716167	59.72378167	57.75199667	58.25786333	59.514475	60.271335	60.73851583	70.40803333	81.71289167	85.19381633	86.34338333	93.39519722	101.6288992	101.1000884	102.7692716	104.769117	105.4551621	121.8240689
Panama	PAN	LCU per US$	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Peru	PER	LCU per US$	3.49	3.506833333	3.5165	3.478467	3.413175	3.295841667	3.274032503	3.128044577	2.924408333	3.011508333	2.825125	2.7541	2.637586418	2.701899026	2.839044138	3.184439242	3.375061587	3.260488491	3.286602698
Philippines	PHL	LCU per US$	44.19225	50.99265	51.60356667	54.20333333	56.03991667	55.08549167	51.3142725	46.14839118	44.32328761	47.67968845	45.10966418	43.31313692	42.22879473	42.44618483	44.3951543	45.50283994	47.49246386	50.40371979	52.66142995
Papua New Guinea	PNG	LCU per US$	2.782156667	3.388715065	3.895220802	3.563452875	3.222540104	3.1019498	3.056734787	2.965345833	2.700088333	2.755143333	2.719294167	2.370969949	2.083648339	2.24451	2.461385	2.768411667	3.133029302	3.188788383	3.279036634
Poland	POL	LCU per US$	4.346075	4.0939	4.080033333	3.889075	3.657641667	3.235483333	3.103158333	2.76795	2.409241667	3.120141667	3.0153	2.962847778	3.256541667	3.160616667	3.154541667	3.7695	3.942783333	3.779333333	3.611716667
Paraguay	PRY	LCU per US$	3486.353333	4105.925	5716.258333	6424.339167	5974.5775	6177.934947	5635.093939	5032.711576	4363.291608	4966.682297	4758.430129	4193.802308	4421.659286	4303.882566	4462.185288	5204.920808	5670.540898	5618.933452	5732.104556
French Polynesia	PYF	LCU per US$	129.5227266	133.3543681	126.7960967	105.7319634	96.10557457	95.9570066	95.12417078	87.18821496	81.46473384	85.90013186	90.1007977	85.84188532	92.87509856	89.87576554	89.94397015	107.5964967	107.8800487	105.8946428	101.0961899
Qatar	QAT	LCU per US$	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64
Romania	ROU	LCU per US$	2.170872083	2.906079167	3.305543	3.320007083	3.263656833	2.913653167	2.808983333	2.43825	2.518858333	3.049325	3.1779	3.048608333	3.4682	3.327916667	3.349175	4.005666667	4.059183333	4.052491667	3.941616667
Russian Federation	RUS	LCU per US$	28.12916667	29.168525	31.34848333	30.692025	28.81374167	28.28444167	27.19095833	25.58084537	24.852875	31.74035833	30.36791534	29.38234137	30.83983135	31.83714364	38.37820714	60.93765011	67.05593333	58.34280119	62.66813333
Rwanda	RWA	LCU per US$	389.6962167	442.9918917	475.3652417	537.6549848	577.4489746	557.8226408	551.7103333	546.955	546.8486532	568.2813268	583.1309066	600.3065198	614.2951424	646.6359745	681.861719	720.975109	787.2515218	831.5307869	861.0934122

Saudi Arabia	SAU	LCU per US$	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75
Sudan	SDN	LCU per US$	2.571225	2.587021042	2.633058333	2.609834333	2.57905	2.436058333	2.171533333	2.0161	2.090162829	2.301533333	2.30600092	2.666619622	3.572958333	4.756760547	5.736866667	6.025732598	6.211713646	6.68336	24.3289109
Senegal	SEN	LCU per US$	711.9762744	733.0385071	696.9882036	581.2003139	528.2848093	527.4681428	522.8901096	479.2667826	447.8052556	472.1862908	495.2770216	471.8661141	510.5271359	494.0400374	494.4149529	591.4495075	593.0081704	582.0945501	555.7178304
Singapore	SGP	LCU per US$	1.723963333	1.7917225	1.790588333	1.742183333	1.690228333	1.6643975	1.588933333	1.507101667	1.414860833	1.454514713	1.363508333	1.257775877	1.249676204	1.2513	1.26705	1.374825	1.381546364	1.380925	1.348841667
Solomon Islands	SLB	LCU per US$	5.088930833	5.277984953	6.748772103	7.505943749	7.484743906	7.529873025	7.609458333	7.652	7.747916667	8.055041667	8.064501344	7.64125903	7.355202847	7.3021351	7.375345354	7.914688977	7.948152938	7.887390369	7.952504861
Sierra Leone	SLE	LCU per US$	2092.125	1986.154167	2099.033866	2347.941667	2701.296667	2889.5875	2961.909167	2985.185833	2981.514658	3385.65	3978.087527	4349.162135	4344.037642	4332.499099	4524.157882	5080.747136	6289.940085	7384.432222	7931.63175
El Salvador	SLV	LCU per US$	8.755	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
San Marino	SMR	LCU per US$	1.085400833	1.11751	1.062551667	0.886034167	0.805365	0.80412	0.797140833	0.7306375	0.682674711	0.71984336	0.755044952	0.719355254	0.778293601	0.753159182	0.753730737	0.901658962	0.904035128	0.887397421	0.847186371
Somalia	SOM	LCU per US$										31558.90548	31269.66257	29966.83544	22516.0003	19283.79995	20230.92913	22254.23568	23061.78431	23097.98732	
Serbia	SRB	LCU per US$	63.1659	66.91366	64.39825127	57.585425	58.3814	66.71380833	67.14581667	58.453525	55.72348333	67.5806	77.72893333	73.3334	87.9733	85.15885	88.40530833	108.811425	111.27785	107.75885	100.175075
South Sudan	SSD	LCU per US$												2.98895	2.95	2.95	2.95	3.604166667	46.72916667	113.6475	141.3858333
Sao Tome and Principe	STP	LCU per US$	7.978171667	8.842109167	9.088325	9.347583333	9.902324167	10.55797033	12.4486425	13.536755	14.69520167	16.20845125	18.49860132	17.62293501	19.06841681	18.44995262	18.46640305	22.09064456	22.14886063	21.74113836	20.75085924
Suriname	SUR	LCU per US$	1.322490515	2.178182254	2.34675	2.601333333	2.733582976	2.731666665	2.74375	2.745	2.745	2.745	2.745416667	3.268	3.3	3.3	3.3	3.416666667	6.228630278	7.487661125	7.462511198
Sweden	SWE	LCU per US$	9.162244167	10.32913583	9.737123333	8.086304167	7.348886667	7.473088333	7.378249167	6.75877	6.591099167	7.653819167	7.207524167	6.493543333	6.775015833	6.513971667	6.860785	8.434840833	8.561991667	8.548860833	8.692518333
Eswatini	SWZ	LCU per US$	6.939828333	8.609180833	10.54074667	7.564749167	6.4596925	6.359328333	6.771549167	7.045365	8.261223333	8.473674158	7.321221961	7.261132132	8.209968627	9.655056069	10.85265557	12.75893088	14.70961089	13.33378146	13.24091113
Sint Maarten (Dutch part)	SXM	LCU per US$												1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79
Seychelles	SYC	LCU per US$	5.713816667	5.857541667	5.480033333	5.400716667	5.5	5.5	5.519691667	6.701059538	9.457243283	13.60994045	12.06775664	12.38103191	13.70403121	12.05831667	12.74703333	13.313925	13.31911667	13.64784167	13.91111667
Syrian Arab Republic	SYR	LCU per US$	11.225	11.225	11.225	11.225	11.225	11.225	11.225	11.225	11.225	11.225	11.225	48.33666667	64.58083333	108.7333333	154.13	237.0291667	460.2758333	492.6108333	
Chad	TCD	LCU per US$	711.9762744	733.0385071	696.9882036	581.2003139	528.2848093	527.4681428	522.8901096	479.2667826	447.8052556	472.1862908	495.2770216	471.8661141	510.5271359	494.0400374	494.4149529	591.4495075	593.0081704	582.0945501	555.7178304
Togo	TGO	LCU per US$	711.9762744	733.0385071	696.9882036	581.2003139	528.2848093	527.4681428	522.8901096	479.2667826	447.8052556	472.1862908	495.2770216	471.8661141	510.5271359	494.0400374	494.4149529	591.4495075	593.0081704	582.0945501	555.7178304
Thailand	THA	LCU per US$	40.11180333	44.4319	42.96008333	41.48461667	40.22241492	40.22013021	37.88198322	34.51818059	33.31330064	34.28577412	31.685705	30.49173333	31.08309167	30.72596667	32.47983333	34.24771667	35.29638333	33.93981106	32.31022574
Tajikistan	TJK	LCU per US$	2.07625	2.372191667	2.764133333	3.061366667	2.970508333	3.116566667	3.298408333	3.442483333	3.430725	4.142708333	4.378966667	4.610183333	4.737708333	4.764233333	4.937566667	6.163116667	7.835675	8.549741667	9.151216667
Timor-Leste	TLS	LCU per US$	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tonga	TON	LCU per US$	1.758502604	2.123574169	2.195187335	2.145892252	1.971562793	1.943036217	2.025880795	1.970933657	1.942444257	2.034493613	1.905987842	1.72895071	1.719507016	1.773713119	1.846773685	2.105763257	2.215661104	2.205972697	2.236571476
Trinidad and Tobago	TTO	LCU per US$	6.299796667	6.233216667	6.248683333	6.2951	6.298991667	6.299558333	6.312283333	6.328033333	6.289433333	6.324908333	6.375508333	6.409300706	6.429602656	6.442629398	6.409094578	6.377441667	6.668966667	6.779525	6.770750898
Tunisia	TUN	LCU per US$	1.370683333	1.4387125	1.421733333	1.288458333	1.245466667	1.297433333	1.331025	1.281358333	1.232141667	1.350275	1.4314	1.407783333	1.561891667	1.624658333	1.697675	1.961625	2.148033333	2.419425	2.646866667
Turkey	TUR	LCU per US$	0.6252185	1.225588083	1.507226417	1.500885209	1.425537250	1.343583108	1.428453413	1.302930905	1.301521703	1.549959776	1.502848630	1.674954552	1.796000944	1.903768242	2.188542418	2.720008528	3.020134748	3.648132635	4.828370147
Tanzania	TZA	LCU per US$	800.4085167	876.4116667	966.5827843	1038.419007	1089.334771	1128.934179	1251.899973	1245.035464	1196.310709	1320.312061	1395.624943	1557.433373	1571.697999	1597.555751	1653.232013	1991.390964	2177.085954	2228.857629	2263.780634
Uganda	UGA	LCU per US$	1644.475333	1755.65875	1797.5505	1963.720083	1810.304714	1780.540261	1831.451851	1723.491587	1720.443879	2030.488074	2177.557507	2522.802033	2504.563078	2586.889569	2599.788201	3240.64542	3420.098007	3611.224458	3727.068995
Ukraine	UKR	LCU per US$	5.440233333	5.372158333	5.326625	5.332688333	5.319180667	5.124729	5.05	5.05	5.267221417	7.791240333	7.935639417	7.967562833	7.991029333	7.993	11.88665942	21.84469777	25.55133412	26.5966063	27.20049233
Uruguay	URY	LCU per US$	12.09959167	13.31911667	21.25696667	28.20868333	28.70373333	24.4786	24.07335833	23.471025	20.94931667	22.56798333	20.059275	19.31420833	20.310575	20.48160833	23.246025	27.32736667	30.1626	28.6764	30.72525833
United States	USA	LCU per US$	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Uzbekistan	UZB	LCU per US$	236.6083333													2094.988465	2310.948159	2567.987213	2965.253499	5113.878946	8069.606237
St. Vincent and the Grenadines	VCT	LCU per US$	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Vietnam	VNM	LCU per US$	14167.75	14725.16667	15279.5	15509.58333	15746	15858.91667	15994.25	16105.125	16302.25	17065.08333	18612.91667	20509.75	20828	20933.41667	21148	21697.5675	21935.00083	22370.08667	22602.05

Vanuatu	VUT	LCU per US$	137.6433333	145.3125	139.1983333	122.1891667	111.79	109.2458333	110.6408333	102.4375	101.3341667	106.7408333	96.90583333	89.46916667	92.6375	94.5425	97.07166667	108.9891667	108.475	107.8208333	110.1683333
Samoa	WSM	LCU per US$	3.286361525	3.478040072	3.376258103	2.973237658	2.780723431	2.710336734	2.779294045	2.616572472	2.64417628	2.73077851	2.484656585	2.317472012	2.29231195	2.310900035	2.331768846	2.560873688	2.564929673	2.554377116	2.587279951
Kosovo	XKX	LCU per US$			1.062551667	0.886034167	0.805365	0.80412	0.797140833	0.7306375	0.682674711	0.71984336	0.755044952	0.719355254	0.778293601	0.753159182	0.753730737	0.901658962	0.904035128	0.887397421	0.847186371
Yemen, Rep.	YEM	LCU per US$	161.7183333	168.6716667	175.625	183.4483333	184.7758333	191.5091667	197.0491667	198.9533333	199.7641667	202.8466667	219.59	213.8	214.3508333	214.89	214.89	214.89	214.89	214.89	214.89
South Africa	ZAF	LCU per US$	6.939828333	8.609180833	10.54074667	7.564749167	6.4596925	6.359328333	6.771549167	7.045365	8.261223333	8.473674158	7.321221961	7.261132132	8.209968627	9.655056069	10.85265557	12.75893088	14.70961089	13.32380142	13.23392647
Zambia	ZMB	LCU per US$	3.110844167	3.610935	4.398595	4.733271046	4.778875386	4.463503311	3.603072043	4.002522665	3.74566069	5.046109245	4.797136875	4.860665532	5.147252665	5.395887068	6.152816248	8.632355962	10.31305323	9.51950142	10.45814322

Appendix-Table 7 *Test Statistics One-Way ANOVA with Bonferroni correction for Patents in Pharmaceutical Industry, all years, OECD (2020a, 2020f, 2020h)*

Analysis of Variance					
Source	SS	df	MS	F	Prob > F
Between groups	1.68439791	3	0.561465971	54.27	0.0000
Within groups	1059.94754	102457	0.010345292		
Total	1061.63194	102460	0.010361428		

Bartlett's test for equal variances: chi2(3) = 33.2884 Prob>chi2 = 0.000

Comparison of Groups (Bonferroni)			
Row Mean – Col Mean	0	1	2
1	0.015343 0.000		
2	0.011167 0.000	-0.004176 0.228	
3	0.004419 0.017	-0.0077 0.008	-0.006749 0.005

Appendix-Table 8 *Outward Host-Country Patents, https://stats.oecd.org*

Reference Date	Priority date
Patent office	Patent applications filed under the PCT
Type of International Cooperation in Patenting	Domestic ownership of inventions made abroad
Unit	Number

	Time	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Country	**Partner Country**																		
Germany	Total Patents	13,678.0	13,893.0	14,205.0	14,973.0	15,863.0	16,774.0	17,794.0	18,687.0	17,125.0	17,508.0	18,851.0	19,022.0	18,285.0	17,857.0	17,857.0	18,161.0	18,868.0	19,063.0
	Total co-operation with abroad	2,275.0	2,417.0	2,362.0	2,445.0	2,542.0	2,964.0	3,249.0	3,377.0	3,189.0	3,347.0	3,613.0	3,667.0	3,606.0	3,442.0	3,325.0	3,445.0	3,648.0	3,616.0
	Australia	21.0	31.0	21.0	23.0	15.0	26.0	39.0	37.0	23.0	25.0	26.0	31.0	15.0	16.0	28.0	20.0	17.0	22.0
	Austria	256.0	275.0	286.0	253.0	242.0	316.0	333.0	300.0	246.0	265.0	277.0	243.0	297.0	232.0	247.0	294.0	338.0	299.0
	Belgium	109.0	100.0	102.0	88.0	118.0	116.0	130.0	110.0	131.0	133.0	140.0	156.0	96.0	120.0	101.0	75.0	94.0	108.0
	Canada	34.0	34.0	43.0	51.0	59.0	53.0	54.0	63.0	45.0	65.0	54.0	55.0	51.0	43.0	51.0	55.0	52.0	57.0
	Chile	3.0	2.0	1.0	1.0	4.0	5.0	3.0	11.0	3.0	1.0	0.0	3.0	2.0	2.0	1.0	4.0	0.0	4.0
	Czech Republic	9.0	12.0	13.0	10.0	19.0	18.0	22.0	34.0	21.0	21.0	14.0	23.0	26.0	40.0	43.0	39.0	43.0	47.0
	Denmark	27.0	16.0	27.0	32.0	24.0	27.0	37.0	37.0	39.0	62.0	87.0	56.0	62.0	36.0	39.0	40.0	57.0	45.0
	Estonia	3.0	0.0	2.0	0.0	0.0	1.0	0.0	3.0	3.0	3.0	2.0	2.0	1.0	4.0	3.0	1.0	0.0	..
	Finland	15.0	14.0	12.0	8.0	11.0	10.0	15.0	24.0	28.0	23.0	24.0	16.0	16.0	25.0	25.0	11.0	11.0	10.0
	France	227.0	258.0	244.0	265.0	256.0	276.0	271.0	295.0	333.0	349.0	406.0	405.0	361.0	337.0	348.0	376.0	360.0	365.0
	Germany	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Greece	5.0	6.0	5.0	7.0	4.0	5.0	5.0	8.0	4.0	5.0	3.0	4.0	8.0	12.0	7.0	2.0	5.0	6.0
	Hungary	15.0	12.0	15.0	22.0	16.0	23.0	15.0	29.0	33.0	31.0	27.0	27.0	34.0	48.0	66.0	70.0	77.0	68.0
	Iceland	0.0	1.0	3.0	5.0	0.0	2.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ireland	6.0	3.0	7.0	9.0	6.0	5.0	14.0	9.0	20.0	16.0	9.0	16.0	17.0	24.0	16.0	17.0	18.0	20.0
	Israel	13.0	10.0	8.0	12.0	25.0	18.0	15.0	32.0	22.0	17.0	16.0	11.0	15.0	6.0	11.0	20.0	15.0	25.0
	Italy	68.0	56.0	68.0	80.0	75.0	91.0	83.0	102.0	98.0	120.0	82.0	81.0	121.0	112.0	117.0	117.0	149.0	114.0
	Japan	102.0	95.0	120.0	117.0	105.0	88.0	116.0	113.0	103.0	123.0	151.0	128.0	115.0	98.0	114.0	128.0	122.0	182.0
	Korea	3.0	7.0	5.0	19.0	17.0	14.0	13.0	20.0	25.0	32.0	32.0	34.0	26.0	22.0	25.0	40.0	24.0	37.0
	Luxembourg	5.0	1.0	2.0	1.0	4.0	6.0	4.0	2.0	7.0	7.0	13.0	11.0	7.0	7.0	3.0	2.0	2.0	5.0
	Mexico	4.0	1.0	1.0	5.0	5.0	11.0	8.0	8.0	4.0	7.0	5.0	6.0	6.0	4.0	11.0	12.0	4.0	8.0
	Netherlands	112.0	187.0	134.0	135.0	180.0	258.0	474.0	466.0	447.0	458.0	351.0	381.0	313.0	224.0	168.0	109.0	144.0	105.0
	New Zealand	1.0	2.0	5.0	4.0	3.0	1.0	5.0	3.0	6.0	3.0	4.0	3.0	4.0	2.0	5.0	3.0	4.0	3.0
	Norway	13.0	19.0	22.0	7.0	12.0	21.0	25.0	14.0	13.0	22.0	29.0	24.0	23.0	29.0	33.0	24.0	16.0	20.0
	Poland	9.0	5.0	12.0	9.0	12.0	7.0	16.0	13.0	18.0	23.0	22.0	31.0	27.0	23.0	23.0	29.0	28.0	27.0
	Portugal	1.0	2.0	5.0	2.0	10.0	21.0	27.0	8.0	12.0	5.0	15.0	9.0	9.0	7.0	8.0	4.0	11.0	24.0
	Slovak Republic	5.0	6.0	10.0	11.0	4.0	11.0	11.0	15.0	12.0	6.0	9.0	10.0	7.0	14.0	11.0	16.0	19.0	16.0
	Slovenia	28.0	19.0	18.0	5.0	10.0	24.0	25.0	16.0	17.0	13.0	18.0	7.0	8.0	9.0	16.0	13.0	13.0	24.0

	Spain	61.0	62.0	58.0	90.0	75.0	75.0	86.0	121.0	111.0	94.0	96.0	93.0	82.0	54.0	91.0	88.0	113.0	99.0
	Sweden	62.0	51.0	64.0	65.0	45.0	63.0	64.0	55.0	54.0	55.0	57.0	49.0	55.0	62.0	60.0	49.0	63.0	60.0
	Switzerland	183.0	205.0	192.0	227.0	273.0	322.0	282.0	337.0	285.0	252.0	275.0	302.0	264.0	212.0	220.0	267.0	305.0	234.0
	Turkey	10.0	5.0	4.0	7.0	12.0	12.0	9.0	11.0	16.0	18.0	17.0	26.0	22.0	20.0	23.0	34.0	11.0	10.0
	United Kingdom	135.0	175.0	212.0	195.0	227.0	199.0	247.0	203.0	228.0	279.0	386.0	277.0	271.0	280.0	276.0	250.0	234.0	184.0
	United States	801.0	786.0	741.0	764.0	697.0	789.0	789.0	841.0	736.0	756.0	843.0	924.0	1,020.0	1,077.0	919.0	1,067.0	1,089.0	1,001.0
	European Union (28 countries)	1,098.0	1,220.0	1,244.0	1,215.0	1,284.0	1,488.0	1,801.0	1,773.0	1,779.0	1,903.0	1,944.0	1,834.0	1,761.0	1,603.0	1,604.0	1,572.0	1,717.0	1,610.0
	Algeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0
	Andorra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Argentina	2.0	2.0	1.0	3.0	4.0	4.0	3.0	2.0	3.0	8.0	3.0	0.0	8.0	2.0	1.0	0.0	1.0	0.0
	Armenia	0.0	0.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Belarus	1.0	2.0	2.0	3.0	1.0	0.0	0.0	3.0	2.0	3.0	3.0	0.0	0.0	1.0	2.0	0.0	3.0	1.0
	Bermuda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Bosnia and Herzegovina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	1.0	0.0	2.0	2.0	0.0	1.0	1.0
	Brazil	5.0	15.0	9.0	16.0	32.0	27.0	34.0	29.0	35.0	37.0	30.0	39.0	45.0	66.0	41.0	32.0	52.0	41.0
	Bulgaria	0.0	1.0	2.0	0.0	1.0	8.0	8.0	4.0	7.0	3.0	3.0	3.0	6.0	3.0	1.0	5.0	3.0	0.0
	Cayman Islands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	China	22.0	20.0	21.0	40.0	40.0	71.0	92.0	128.0	157.0	177.0	227.0	318.0	278.0	248.0	262.0	241.0	282.0	367.0
	Chinese Taipei	6.0	4.0	18.0	22.0	7.0	9.0	14.0	15.0	11.0	10.0	18.0	19.0	8.0	16.0	14.0	16.0	11.0	13.0
	Colombia	1.0	0.0	1.0	1.0	0.0	0.0	0.0	3.0	7.0	6.0	2.0	1.0	3.0	2.0	3.0	1.0	1.0	2.0
	Costa Rica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	2.0
	Croatia	0.0	0.0	0.0	2.0	3.0	8.0	7.0	2.0	2.0	0.0	1.0	0.0	3.0	3.0	6.0	3.0	2.0	4.0
	Cuba	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Cyprus	0.0	0.0	0.0	2.0	1.0	2.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
	Democratic People's Republic of Korea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Djibouti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ecuador	0.0	0.0	0.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0
	Egypt	1.0	0.0	2.0	2.0	1.0	1.0	1.0	1.0	0.0	2.0	0.0	2.0	6.0	4.0	2.0	1.0	2.0	3.0
	El Salvador	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Serbia and Montenegro	1.0	0.0	0.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	North Macedonia	0.0	0.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
	Georgia	0.0	0.0	0.0	1.0	2.0	0.0	0.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	3.0	0.0	0.0	0.0
	Guatemala	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hong Kong - China	8.0	5.0	3.0	6.0	13.0	21.0	23.0	8.0	10.0	14.0	19.0	9.0	12.0	9.0	20.0	13.0	22.0	10.0
	India	17.0	9.0	16.0	27.0	19.0	29.0	31.0	34.0	31.0	52.0	71.0	70.0	85.0	84.0	97.0	81.0	66.0	95.0
	Indonesia	1.0	3.0	0.0	1.0	1.0	3.0	3.0	1.0	1.0	5.0	2.0	1.0	2.0	2.0	2.0	1.0	3.0	1.0

Iran (Islamic Republic of)	2.0	1.0	1.0	1.0	0.0	2.0	0.0	1.0	1.0	1.0	1.0	0.0	1.0	2.0	6.0	0.0	2.0	0.0
Jamaica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jordan	1.0	0.0	0.0	0.0	0.0	5.0	16.0	3.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	2.0	..
Kazakhstan	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0
Kenya	0.0	0.0	2.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Kuwait	0.0	0.0	2.0	2.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Latvia	3.0	2.0	1.0	4.0	2.0	7.0	8.0	2.0	5.0	5.0	5.0	4.0	0.0	0.0	0.0	0.0	0.0	3.0
Lebanon	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	0.0	2.0	2.0
Liechtenstein	2.0	0.0	2.0	1.0	5.0	2.0	4.0	2.0	1.0	0.0	3.0	2.0	10.0	7.0	19.0	22.0	32.0	18.0
Lithuania	1.0	2.0	0.0	1.0	0.0	2.0	0.0	0.0	3.0	0.0	1.0	1.0	5.0	4.0	1.0	1.0	4.0	0.0
Malaysia	8.0	7.0	5.0	12.0	9.0	21.0	12.0	17.0	15.0	22.0	26.0	17.0	16.0	21.0	21.0	38.0	42.0	59.0
Malta	0.0	1.0	0.0	2.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	1.0	1.0	2.0
Monaco	2.0	0.0	0.0	0.0	3.0	3.0	3.0	6.0	2.0	2.0	0.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0
Mongolia	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Morocco	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Nigeria	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Pakistan	0.0	0.0	0.0	0.0	0.0	1.0	0.0	2.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	2.0	1.0
Panama	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peru	0.0	0.0	0.0	0.0	2.0	1.0	2.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Philippines	0.0	1.0	2.0	0.0	2.0	1.0	1.0	2.0	4.0	11.0	3.0	0.0	3.0	1.0	2.0	0.0	3.0	1.0
Puerto Rico	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Republic of Moldova	0.0	0.0	1.0	0.0	2.0	2.0	2.0	4.0	1.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Romania	2.0	1.0	2.0	5.0	2.0	1.0	4.0	5.0	6.0	4.0	5.0	18.0	16.0	26.0	18.0	29.0	22.0	44.0
Russian Fed-eration	31.0	38.0	33.0	31.0	33.0	37.0	37.0	26.0	33.0	34.0	34.0	38.0	64.0	53.0	29.0	33.0	25.0	33.0
Saudi Arabia	0.0	0.0	0.0	0.0	5.0	17.0	2.0	6.0	5.0	5.0	1.0	9.0	3.0	5.0	2.0	7.0	5.0	2.0
Seychelles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Singapore	17.0	28.0	41.0	21.0	39.0	43.0	30.0	45.0	50.0	30.0	43.0	38.0	37.0	63.0	47.0	33.0	40.0	34.0
South Africa	2.0	7.0	6.0	2.0	9.0	9.0	5.0	12.0	2.0	2.0	6.0	8.0	7.0	2.0	8.0	10.0	5.0	4.0
Sri Lanka	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0
Thailand	6.0	4.0	3.0	7.0	6.0	1.0	1.0	3.0	6.0	3.0	4.0	4.0	1.0	1.0	4.0	2.0	8.0	3.0
Trinidad and Tobago	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Tunisia	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	1.0	..
Ukraine	4.0	3.0	4.0	4.0	4.0	3.0	3.0	2.0	2.0	6.0	4.0	1.0	2.0	3.0	3.0	4.0	2.0	3.0
United Arab Emirates	0.0	0.0	0.0	1.0	0.0	7.0	6.0	0.0	3.0	2.0	6.0	2.0	2.0	6.0	3.0	8.0	5.0	0.0
Uruguay	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uzbekistan	0.0	0.0	0.0	1.0	2.0	1.0	1.0	2.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0
Venezuela	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Zimbabwe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Japan	Total Patents	10,774.0	12,268.0	14,887.0	19,418.0	24,412.0	26,434.0	26,901.0	29,097.0	28,220.0	31,189.0	37,412.0	42,046.0	43,737.0	42,275.0	43,253.0	44,357.0	47,034.0	47,867.0
	Total co-operation with abroad	599.0	595.0	785.0	954.0	1,052.0	1,105.0	1,058.0	1,014.0	928.0	1,018.0	1,136.0	1,310.0	1,269.0	1,543.0	1,601.0	1,657.0	1,893.0	1,960.0
	Australia	10.0	6.0	8.0	14.0	11.0	20.0	17.0	16.0	11.0	11.0	6.0	12.0	24.0	30.0	19.0	15.0	20.0	22.0
	Austria	2.0	2.0	6.0	1.0	4.0	0.0	7.0	4.0	0.0	2.0	5.0	2.0	1.0	5.0	4.0	4.0	9.0	4.0
	Belgium	6.0	5.0	11.0	7.0	10.0	6.0	9.0	12.0	15.0	39.0	37.0	28.0	26.0	30.0	24.0	18.0	27.0	24.0
	Canada	13.0	16.0	18.0	17.0	15.0	8.0	17.0	8.0	15.0	8.0	9.0	15.0	24.0	22.0	25.0	14.0	18.0	20.0
	Chile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Czech Republic	1.0	0.0	0.0	0.0	1.0	2.0	0.0	0.0	0.0	2.0	0.0	2.0	4.0	1.0	2.0	1.0	3.0	2.0
	Denmark	1.0	4.0	2.0	0.0	1.0	1.0	0.0	4.0	2.0	0.0	9.0	7.0	3.0	0.0	8.0	16.0	8.0	5.0
	Estonia	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
	Finland	1.0	3.0	4.0	5.0	1.0	0.0	2.0	2.0	2.0	3.0	7.0	41.0	24.0	18.0	20.0	14.0	4.0	2.0
	France	22.0	17.0	18.0	32.0	31.0	41.0	48.0	55.0	37.0	44.0	43.0	62.0	41.0	65.0	60.0	67.0	102.0	112.0
	Germany	47.0	55.0	91.0	109.0	131.0	80.0	96.0	120.0	89.0	118.0	103.0	118.0	119.0	146.0	107.0	96.0	148.0	194.0
	Greece	0.0	0.0	0.0	0.0	0.0	1.0	0.0	4.0	0.0	6.0	0.0	0.0	2.0	1.0	1.0	0.0	0.0	0.0
	Hungary	0.0	1.0	2.0	1.0	0.0	3.0	11.0	4.0	1.0	1.0	2.0	0.0	2.0	3.0	4.0	0.0	2.0	2.0
	Iceland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ireland	0.0	3.0	1.0	0.0	1.0	2.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	1.0	3.0
	Israel	1.0	1.0	5.0	2.0	2.0	2.0	4.0	3.0	2.0	3.0	1.0	2.0	1.0	0.0	2.0	2.0	1.0	6.0
	Italy	3.0	1.0	13.0	3.0	9.0	3.0	8.0	12.0	13.0	16.0	19.0	29.0	22.0	24.0	26.0	24.0	44.0	20.0
	Japan	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Korea	8.0	14.0	30.0	33.0	33.0	47.0	43.0	25.0	56.0	28.0	65.0	63.0	55.0	37.0	49.0	71.0	55.0	73.0
	Luxembourg	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	1.0	2.0	2.0	1.0	0.0	3.0	0.0
	Mexico	2.0	0.0	0.0	0.0	2.0	0.0	2.0	1.0	2.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	2.0	0.0
	Netherlands	9.0	19.0	19.0	6.0	6.0	14.0	5.0	5.0	11.0	13.0	15.0	21.0	10.0	14.0	15.0	27.0	23.0	25.0
	New Zealand	1.0	0.0	1.0	0.0	1.0	1.0	0.0	1.0	2.0	0.0	0.0	0.0	3.0	1.0	0.0	1.0	0.0	0.0
	Norway	3.0	1.0	2.0	1.0	2.0	0.0	3.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0	5.0	0.0	0.0
	Poland	1.0	6.0	10.0	0.0	3.0	0.0	0.0	1.0	1.0	1.0	5.0	6.0	5.0	1.0	2.0	9.0	0.0	1.0
	Portugal	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	0.0	2.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0
	Slovak Republic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	6.0	3.0	4.0	1.0	1.0	1.0	1.0	0.0	1.0
	Slovenia	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Spain	5.0	4.0	6.0	2.0	5.0	3.0	2.0	4.0	3.0	5.0	7.0	6.0	6.0	4.0	2.0	2.0	7.0	6.0
	Sweden	23.0	2.0	2.0	4.0	1.0	3.0	10.0	10.0	12.0	16.0	20.0	11.0	18.0	81.0	180.0	120.0	92.0	97.0
	Switzerland	4.0	7.0	8.0	12.0	4.0	6.0	11.0	16.0	8.0	9.0	16.0	10.0	4.0	17.0	20.0	32.0	26.0	27.0
	Turkey	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	3.0	1.0	0.0	0.0	2.0	2.0	1.0	3.0	6.0	7.0
	United Kingdom	51.0	35.0	48.0	55.0	62.0	91.0	79.0	87.0	96.0	111.0	120.0	144.0	152.0	170.0	168.0	159.0	174.0	185.0
	United States	381.0	374.0	458.0	610.0	648.0	709.0	613.0	529.0	474.0	483.0	491.0	505.0	519.0	612.0	526.0	540.0	637.0	605.0
	European Union (28 countries)	166.0	154.0	216.0	216.0	257.0	237.0	265.0	316.0	280.0	354.0	353.0	438.0	419.0	536.0	593.0	538.0	616.0	644.0
	Algeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Andorra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Argentina	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
	Armenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Belarus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
	Bermuda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Bosnia and Herzegovina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Brazil	1.0	0.0	0.0	0.0	1.0	1.0	0.0	2.0	2.0	3.0	4.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0
	Bulgaria	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	1.0	3.0	5.0	0.0
	Cayman Islands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	China	14.0	14.0	22.0	30.0	27.0	41.0	39.0	42.0	38.0	83.0	145.0	224.0	198.0	216.0	272.0	337.0	413.0	481.0
	Chinese Taipei	6.0	5.0	15.0	19.0	14.0	6.0	3.0	8.0	6.0	21.0	12.0	9.0	11.0	14.0	23.0	33.0	32.0	33.0
	Colombia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Costa Rica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Croatia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Cuba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Cyprus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0
	Democratic People’s Republic of Korea	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
	Djibouti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ecuador	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Egypt	0.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	1.0	0.0
	El Salvador	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Serbia and Montenegro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	North Macedonia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Georgia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
	Guatemala	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hong Kong - China	0.0	1.0	0.0	0.0	6.0	4.0	2.0	4.0	0.0	3.0	10.0	5.0	7.0	3.0	9.0	1.0	5.0	4.0
	India	1.0	0.0	2.0	6.0	2.0	3.0	4.0	0.0	3.0	2.0	3.0	7.0	11.0	14.0	13.0	28.0	21.0	27.0
	Indonesia	3.0	0.0	0.0	0.0	9.0	0.0	1.0	1.0	1.0	2.0	3.0	1.0	5.0	6.0	1.0	3.0	4.0	3.0
	Iran (Islamic Republic of)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Jamaica	0.0	0.0	0.0	0.0	2.0	1.0	1.0	0.0	2.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0
	Jordan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Kazakhstan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Kenya	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Kuwait	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Latvia	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Lebanon	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0

	Liechtenstein	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Lithuania	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Malaysia	0.0	0.0	1.0	0.0	2.0	1.0	2.0	0.0	5.0	2.0	6.0	5.0	4.0	3.0	10.0	7.0	9.0	5.0
	Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Monaco	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	..
	Mongolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
	Morocco	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nigeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pakistan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	1.0	0.0
	Panama	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Peru	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Philippines	1.0	2.0	0.0	0.0	1.0	0.0	2.0	0.0	2.0	0.0	0.0	1.0	2.0	2.0	4.0	1.0	3.0	1.0
	Puerto Rico	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Republic of Moldova	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Romania	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0
	Russian Federation	6.0	5.0	13.0	17.0	15.0	20.0	34.0	13.0	12.0	8.0	14.0	6.0	4.0	6.0	3.0	2.0	4.0	3.0
	Saudi Arabia	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	2.0	2.0	2.0	1.0	1.0	2.0	1.0	1.0	6.0	..
	Seychelles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Singapore	2.0	15.0	32.0	21.0	39.0	35.0	35.0	42.0	18.0	36.0	23.0	39.0	26.0	37.0	39.0	32.0	34.0	42.0
	South Africa	1.0	2.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
	Sri Lanka	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Thailand	0.0	1.0	3.0	6.0	7.0	4.0	9.0	12.0	13.0	12.0	9.0	13.0	14.0	39.0	41.0	50.0	36.0	23.0
	Trinidad and Tobago	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Tunisia	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
	Ukraine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0
	United Arab Emirates	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Uruguay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Uzbekistan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Venezuela	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Zimbabwe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
United States	Total Patents	41,935.0	40,930.0	40,279.0	42,629.0	46,341.0	50,705.0	53,221.0	51,020.0	45,565.0	43,664.0	46,172.0	51,078.0	54,635.0	61,213.0	56,022.0	55,452.0	55,930.0	54,485.0
	Total co-operation with abroad	5,388.0	5,498.0	5,544.0	6,041.0	6,729.0	7,456.0	7,954.0	7,845.0	7,030.0	6,839.0	7,367.0	8,631.0	9,101.0	9,822.0	9,496.0	9,296.0	9,297.0	8,650.0
	Australia	146.0	160.0	192.0	203.0	215.0	205.0	223.0	193.0	198.0	168.0	139.0	162.0	240.0	249.0	230.0	225.0	177.0	156.0
	Austria	49.0	16.0	47.0	24.0	39.0	36.0	54.0	80.0	58.0	64.0	60.0	76.0	66.0	63.0	58.0	58.0	65.0	53.0
	Belgium	243.0	239.0	235.0	248.0	250.0	271.0	340.0	296.0	268.0	281.0	281.0	305.0	315.0	300.0	299.0	307.0	298.0	258.0
	Canada	611.0	611.0	606.0	625.0	702.0	780.0	802.0	897.0	790.0	771.0	811.0	812.0	888.0	840.0	752.0	697.0	685.0	616.0
	Chile	7.0	1.0	8.0	6.0	9.0	8.0	10.0	13.0	5.0	4.0	9.0	10.0	11.0	9.0	7.0	11.0	9.0	6.0
	Czech Republic	8.0	10.0	14.0	10.0	14.0	28.0	18.0	22.0	31.0	27.0	18.0	18.0	31.0	28.0	38.0	24.0	11.0	32.0

Denmark	59.0	75.0	83.0	112.0	122.0	113.0	117.0	126.0	99.0	91.0	83.0	103.0	84.0	92.0	53.0	49.0	76.0	72.0
Estonia	2.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0	0.0	3.0	0.0	2.0	3.0	4.0	2.0	4.0	2.0
Finland	66.0	56.0	40.0	44.0	66.0	66.0	70.0	54.0	44.0	31.0	44.0	71.0	109.0	71.0	84.0	66.0	77.0	49.0
France	428.0	433.0	482.0	506.0	559.0	601.0	659.0	604.0	523.0	468.0	496.0	520.0	514.0	566.0	502.0	566.0	475.0	497.0
Germany	790.0	751.0	791.0	785.0	894.0	1,016.0	1,110.0	1,082.0	994.0	973.0	1,018.0	1,100.0	1,106.0	1,275.0	1,183.0	1,220.0	1,218.0	1,157.0
Greece	13.0	12.0	12.0	14.0	9.0	16.0	15.0	24.0	16.0	18.0	19.0	14.0	19.0	19.0	16.0	11.0	17.0	20.0
Hungary	26.0	6.0	13.0	21.0	19.0	21.0	23.0	31.0	27.0	16.0	34.0	42.0	20.0	27.0	21.0	13.0	19.0	21.0
Iceland	8.0	7.0	3.0	6.0	2.0	6.0	4.0	3.0	4.0	0.0	3.0	12.0	4.0	3.0	0.0	4.0	2.0	4.0
Ireland	39.0	62.0	72.0	77.0	75.0	87.0	96.0	133.0	120.0	99.0	111.0	147.0	119.0	128.0	139.0	177.0	186.0	163.0
Israel	339.0	313.0	293.0	315.0	285.0	377.0	444.0	343.0	328.0	309.0	335.0	548.0	560.0	603.0	542.0	523.0	542.0	425.0
Italy	186.0	196.0	165.0	165.0	212.0	231.0	264.0	261.0	194.0	220.0	217.0	237.0	183.0	210.0	242.0	185.0	193.0	212.0
Japan	467.0	463.0	423.0	500.0	615.0	642.0	614.0	601.0	555.0	493.0	503.0	618.0	698.0	632.0	476.0	394.0	471.0	548.0
Korea	69.0	71.0	99.0	122.0	155.0	126.0	153.0	156.0	114.0	123.0	130.0	175.0	227.0	199.0	162.0	197.0	246.0	178.0
Luxembourg	5.0	5.0	17.0	5.0	18.0	4.0	11.0	7.0	11.0	7.0	8.0	8.0	11.0	6.0	6.0	11.0	13.0	2.0
Mexico	26.0	26.0	20.0	34.0	42.0	40.0	35.0	31.0	32.0	47.0	50.0	64.0	69.0	64.0	78.0	83.0	82.0	81.0
Netherlands	208.0	213.0	212.0	246.0	234.0	254.0	276.0	228.0	263.0	189.0	212.0	232.0	196.0	242.0	267.0	240.0	208.0	214.0
New Zealand	35.0	22.0	34.0	48.0	36.0	35.0	50.0	54.0	44.0	43.0	40.0	50.0	51.0	52.0	48.0	32.0	43.0	34.0
Norway	31.0	28.0	42.0	30.0	34.0	40.0	43.0	62.0	52.0	37.0	53.0	50.0	85.0	93.0	70.0	41.0	52.0	48.0
Poland	16.0	15.0	17.0	15.0	18.0	25.0	22.0	32.0	22.0	35.0	30.0	40.0	31.0	48.0	68.0	67.0	79.0	47.0
Portugal	8.0	9.0	4.0	4.0	3.0	13.0	15.0	15.0	13.0	11.0	11.0	10.0	12.0	9.0	14.0	22.0	18.0	11.0
Slovak Re-public	4.0	0.0	2.0	1.0	0.0	2.0	2.0	0.0	2.0	2.0	2.0	3.0	3.0	10.0	5.0	0.0	8.0	5.0
Slovenia	3.0	1.0	4.0	2.0	1.0	3.0	1.0	4.0	4.0	3.0	8.0	4.0	10.0	10.0	12.0	3.0	7.0	12.0
Spain	72.0	85.0	73.0	77.0	98.0	117.0	119.0	117.0	97.0	99.0	122.0	157.0	162.0	171.0	274.0	310.0	318.0	249.0
Sweden	140.0	114.0	98.0	95.0	134.0	142.0	160.0	172.0	144.0	143.0	108.0	116.0	138.0	128.0	98.0	119.0	144.0	111.0
Switzerland	154.0	195.0	185.0	180.0	215.0	203.0	235.0	230.0	252.0	230.0	294.0	278.0	316.0	307.0	230.0	257.0	294.0	275.0
Turkey	6.0	8.0	11.0	17.0	19.0	23.0	21.0	11.0	12.0	24.0	17.0	16.0	28.0	23.0	28.0	15.0	30.0	24.0
United King-dom	1,042.0	1,114.0	1,041.0	1,137.0	1,249.0	1,228.0	1,257.0	1,253.0	1,098.0	1,009.0	1,063.0	1,175.0	1,049.0	1,225.0	1,185.0	1,096.0	1,085.0	1,008.0
United States	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
European Un-ion (28 coun-tries)	3,163.0	3,204.0	3,166.0	3,362.0	3,750.0	3,990.0	4,309.0	4,176.0	3,707.0	3,475.0	3,621.0	4,003.0	3,898.0	4,302.0	4,172.0	4,202.0	4,088.0	3,855.0
Algeria	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Andorra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Argentina	16.0	14.0	23.0	23.0	19.0	41.0	33.0	63.0	19.0	23.0	28.0	34.0	27.0	34.0	35.0	58.0	26.0	24.0
Armenia	1.0	2.0	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0	3.0	13.0	1.0	8.0	4.0	5.0	9.0	6.0
Belarus	2.0	3.0	1.0	1.0	3.0	3.0	0.0	2.0	1.0	3.0	3.0	2.0	0.0	4.0	1.0	0.0	2.0	2.0
Bermuda	3.0	1.0	0.0	2.0	2.0	4.0	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Bosnia and Herzegovina	0.0	2.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	1.0	1.0	2.0	0.0	1.0	2.0	0.0	0.0	..
Brazil	20.0	46.0	31.0	33.0	47.0	53.0	43.0	72.0	49.0	49.0	100.0	63.0	78.0	105.0	105.0	131.0	125.0	124.0
Bulgaria	1.0	3.0	2.0	3.0	2.0	1.0	2.0	7.0	1.0	3.0	2.0	4.0	8.0	11.0	9.0	3.0	7.0	2.0

	Cayman Islands	2.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	3.0	1.0	2.0	2.0	2.0	4.0
	China	124.0	125.0	170.0	234.0	206.0	328.0	444.0	451.0	434.0	527.0	648.0	982.0	1,157.0	1,336.0	1,541.0	1,275.0	1,408.0	1,251.0
	Chinese Taipei	40.0	56.0	64.0	67.0	98.0	110.0	122.0	110.0	80.0	104.0	92.0	111.0	132.0	165.0	210.0	248.0	245.0	327.0
	Colombia	4.0	5.0	3.0	6.0	3.0	1.0	4.0	5.0	6.0	8.0	5.0	12.0	18.0	17.0	15.0	16.0	23.0	15.0
	Costa Rica	2.0	1.0	4.0	1.0	1.0	6.0	0.0	3.0	7.0	5.0	7.0	3.0	5.0	11.0	6.0	25.0	11.0	10.0
	Croatia	3.0	8.0	2.0	7.0	2.0	4.0	0.0	2.0	1.0	8.0	2.0	0.0	3.0	1.0	4.0	2.0	7.0	2.0
	Cuba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
	Cyprus	0.0	5.0	1.0	5.0	1.0	3.0	3.0	2.0	0.0	1.0	2.0	1.0	1.0	5.0	2.0	4.0	2.0	2.0
	Democratic People's Republic of Korea	1.0	0.0	2.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	4.0	1.0	0.0	1.0	0.0
	Djibouti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ecuador	1.0	1.0	0.0	0.0	3.0	0.0	0.0	2.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0	0.0	2.0	2.0
	Egypt	3.0	4.0	11.0	6.0	3.0	11.0	8.0	6.0	8.0	15.0	9.0	13.0	13.0	21.0	22.0	11.0	12.0	9.0
	El Salvador	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0
	Serbia and Montenegro	3.0	2.0	0.0	4.0	2.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	North Macedonia	0.0	0.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	2.0	0.0	0.0
	Georgia	6.0	1.0	2.0	2.0	4.0	6.0	2.0	2.0	3.0	0.0	2.0	0.0	0.0	0.0	1.0	2.0	4.0	0.0
	Guatemala	0.0	1.0	0.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	2.0	1.0	0.0	0.0	3.0	3.0	2.0
	Hong Kong - China	29.0	30.0	54.0	54.0	64.0	60.0	80.0	70.0	53.0	64.0	89.0	68.0	48.0	52.0	60.0	47.0	44.0	33.0
	India	66.0	90.0	107.0	166.0	229.0	315.0	306.0	321.0	300.0	347.0	459.0	606.0	651.0	815.0	804.0	806.0	736.0	706.0
	Indonesia	5.0	3.0	2.0	1.0	7.0	1.0	4.0	6.0	1.0	4.0	4.0	1.0	7.0	5.0	1.0	3.0	1.0	4.0
	Iran (Islamic Republic of)	0.0	2.0	3.0	3.0	0.0	1.0	2.0	3.0	1.0	1.0	2.0	1.0	0.0	5.0	4.0	4.0	4.0	1.0
	Jamaica	0.0	1.0	1.0	0.0	1.0	0.0	0.0	3.0	1.0	0.0	1.0	0.0	0.0	2.0	0.0	3.0	2.0	1.0
	Jordan	0.0	0.0	1.0	0.0	1.0	3.0	3.0	18.0	19.0	0.0	1.0	1.0	0.0	1.0	1.0	0.0	1.0	0.0
	Kazakhstan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	3.0	1.0	1.0	2.0	0.0	2.0
	Kenya	0.0	2.0	4.0	3.0	2.0	5.0	2.0	0.0	3.0	0.0	3.0	1.0	0.0	2.0	3.0	4.0	2.0	1.0
	Kuwait	1.0	0.0	2.0	1.0	0.0	1.0	0.0	2.0	2.0	0.0	1.0	0.0	2.0	0.0	4.0	1.0	4.0	5.0
	Latvia	1.0	0.0	0.0	0.0	0.0	2.0	1.0	2.0	0.0	0.0	0.0	2.0	1.0	1.0	1.0	1.0	0.0	2.0
	Lebanon	0.0	1.0	0.0	0.0	4.0	0.0	4.0	3.0	1.0	1.0	3.0	2.0	0.0	1.0	5.0	5.0	2.0	8.0
	Liechtenstein	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0
	Lithuania	1.0	1.0	1.0	1.0	1.0	3.0	3.0	1.0	6.0	0.0	2.0	0.0	1.0	0.0	1.0	2.0	4.0	4.0
	Malaysia	23.0	11.0	21.0	16.0	21.0	36.0	29.0	27.0	37.0	29.0	36.0	68.0	63.0	49.0	40.0	90.0	132.0	56.0
	Malta	0.0	1.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0	0.0	0.0	3.0
	Monaco	1.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	3.0	1.0	1.0	0.0	..
	Mongolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
	Morocco	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	2.0
	Nigeria	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	1.0	0.0	0.0	2.0	0.0	2.0	3.0
	Pakistan	3.0	2.0	0.0	2.0	1.0	3.0	1.0	5.0	1.0	1.0	4.0	7.0	4.0	2.0	6.0	3.0	0.0	4.0
	Panama	0.0	1.0	2.0	1.0	1.0	0.0	0.0	1.0	2.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0

	Peru	0.0	0.0	0.0	1.0	0.0	2.0	5.0	0.0	4.0	0.0	2.0	3.0	0.0	1.0	2.0	0.0	2.0	1.0
	Philippines	11.0	3.0	13.0	4.0	20.0	22.0	16.0	15.0	14.0	5.0	17.0	9.0	9.0	5.0	17.0	14.0	8.0	8.0
	Puerto Rico	0.0	4.0	3.0	5.0	9.0	11.0	4.0	3.0	4.0	5.0	4.0	10.0	7.0	11.0	4.0	9.0	11.0	11.0
	Republic of Moldova	0.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0
	Romania	6.0	4.0	8.0	7.0	20.0	13.0	23.0	10.0	24.0	14.0	10.0	14.0	26.0	24.0	28.0	21.0	12.0	9.0
	Russian Federation	88.0	98.0	78.0	93.0	98.0	135.0	125.0	113.0	88.0	96.0	94.0	168.0	203.0	204.0	144.0	174.0	227.0	201.0
	Saudi Arabia	4.0	4.0	9.0	13.0	11.0	14.0	14.0	23.0	18.0	31.0	30.0	39.0	22.0	23.0	18.0	25.0	16.0	18.0
	Seychelles	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Singapore	49.0	53.0	44.0	67.0	66.0	89.0	108.0	98.0	118.0	111.0	124.0	161.0	138.0	186.0	249.0	238.0	227.0	228.0
	South Africa	17.0	15.0	15.0	25.0	21.0	8.0	24.0	27.0	33.0	20.0	21.0	24.0	33.0	37.0	24.0	33.0	26.0	15.0
	Sri Lanka	0.0	0.0	2.0	1.0	1.0	2.0	4.0	2.0	4.0	3.0	2.0	1.0	4.0	0.0	2.0	1.0	5.0	4.0
	Thailand	21.0	16.0	10.0	10.0	14.0	34.0	13.0	23.0	8.0	13.0	19.0	17.0	16.0	17.0	14.0	14.0	11.0	12.0
	Trinidad and Tobago	0.0	1.0	2.0	0.0	0.0	1.0	0.0	0.0	2.0	4.0	4.0	3.0	0.0	0.0	0.0	2.0	0.0	0.0
	Tunisia	0.0	1.0	0.0	1.0	2.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0
	Ukraine	15.0	15.0	14.0	14.0	9.0	17.0	16.0	39.0	17.0	18.0	13.0	16.0	33.0	22.0	20.0	21.0	21.0	18.0
	United Arab Emirates	3.0	4.0	3.0	4.0	2.0	1.0	4.0	4.0	14.0	7.0	10.0	14.0	13.0	20.0	18.0	21.0	23.0	12.0
	Uruguay	2.0	3.0	3.0	4.0	4.0	2.0	5.0	4.0	1.0	0.0	2.0	7.0	4.0	11.0	2.0	5.0	5.0	4.0
	Uzbekistan	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0
	Venezuela	6.0	8.0	5.0	2.0	3.0	1.0	8.0	10.0	1.0	3.0	2.0	0.0	9.0	5.0	6.0	2.0	1.0	3.0
	Zimbabwe	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0
World	Total Patents	102,746.0	104,710.0	108,587.0	118,594.0	132,449.0	144,892.0	154,406.0	159,880.0	150,262.0	156,622.0	172,190.0	188,385.0	196,348.0	206,948.0	207,806.0	218,227.0	232,490.0	235,071.0
	Total co-operation with abroad	16,026.0	16,902.0	18,483.0	20,006.0	21,679.0	23,773.0	25,231.0	26,481.0	24,638.0	24,591.0	26,247.0	28,101.0	29,525.0	30,695.0	30,623.0	31,048.0	31,288.0	30,014.0
	Australia	335.0	344.0	377.0	395.0	445.0	458.0	473.0	443.0	465.0	442.0	399.0	437.0	511.0	487.0	488.0	452.0	400.0	388.0
	Austria	399.0	410.0	489.0	476.0	512.0	597.0	691.0	717.0	541.0	472.0	506.0	533.0	577.0	562.0	567.0	619.0	694.0	600.0
	Belgium	555.0	540.0	576.0	587.0	655.0	713.0	776.0	765.0	758.0	813.0	843.0	892.0	839.0	762.0	784.0	759.0	716.0	705.0
	Canada	911.0	920.0	906.0	978.0	1,087.0	1,214.0	1,370.0	1,394.0	1,233.0	1,236.0	1,368.0	1,344.0	1,548.0	1,587.0	1,525.0	1,595.0	1,553.0	1,316.0
	Chile	14.0	11.0	12.0	11.0	25.0	25.0	19.0	34.0	26.0	22.0	29.0	41.0	36.0	34.0	31.0	40.0	27.0	19.0
	Czech Republic	42.0	52.0	46.0	49.0	44.0	77.0	68.0	113.0	96.0	85.0	71.0	90.0	113.0	132.0	162.0	134.0	118.0	149.0
	Denmark	213.0	253.0	248.0	281.0	295.0	318.0	353.0	346.0	324.0	317.0	362.0	346.0	337.0	325.0	251.0	286.0	307.0	289.0
	Estonia	8.0	5.0	5.0	10.0	5.0	7.0	13.0	27.0	33.0	15.0	35.0	12.0	6.0	22.0	20.0	16.0	16.0	11.0
	Finland	214.0	195.0	157.0	148.0	188.0	212.0	249.0	246.0	261.0	216.0	245.0	258.0	326.0	299.0	330.0	308.0	346.0	392.0
	France	1,364.0	1,450.0	1,665.0	1,849.0	1,985.0	2,024.0	2,077.0	2,117.0	2,001.0	1,994.0	2,112.0	2,213.0	2,127.0	2,131.0	2,025.0	2,103.0	1,912.0	1,891.0
	Germany	2,020.0	2,151.0	2,592.0	2,932.0	3,111.0	3,337.0	3,348.0	3,948.0	3,479.0	3,497.0	3,636.0	3,664.0	3,872.0	3,782.0	3,704.0	3,819.0	4,020.0	3,906.0
	Greece	33.0	31.0	48.0	39.0	30.0	45.0	33.0	59.0	36.0	61.0	53.0	40.0	57.0	61.0	57.0	34.0	65.0	66.0
	Hungary	97.0	61.0	62.0	97.0	86.0	97.0	108.0	140.0	147.0	140.0	184.0	181.0	169.0	165.0	194.0	195.0	193.0	154.0
	Iceland	12.0	10.0	13.0	13.0	5.0	18.0	9.0	5.0	7.0	6.0	10.0	15.0	7.0	9.0	3.0	8.0	3.0	7.0
	Ireland	108.0	114.0	145.0	130.0	156.0	164.0	164.0	213.0	225.0	199.0	195.0	250.0	217.0	257.0	252.0	273.0	318.0	282.0

	Israel	469.0	446.0	384.0	412.0	468.0	564.0	610.0	539.0	472.0	453.0	492.0	714.0	760.0	750.0	692.0	750.0	752.0	691.0
	Italy	576.0	617.0	522.0	629.0	678.0	717.0	807.0	900.0	825.0	829.0	858.0	917.0	955.0	912.0	944.0	910.0	957.0	843.0
	Japan	806.0	791.0	841.0	906.0	1,055.0	1,140.0	1,078.0	1,204.0	1,036.0	1,054.0	1,093.0	1,228.0	1,421.0	1,321.0	1,231.0	1,122.0	1,309.0	1,357.0
	Korea	100.0	106.0	170.0	210.0	249.0	283.0	273.0	263.0	269.0	249.0	371.0	453.0	461.0	414.0	407.0	476.0	451.0	394.0
	Luxembourg	33.0	13.0	27.0	15.0	31.0	18.0	24.0	25.0	27.0	29.0	43.0	30.0	37.0	30.0	18.0	33.0	36.0	23.0
	Mexico	46.0	40.0	41.0	59.0	66.0	77.0	66.0	77.0	61.0	74.0	75.0	86.0	101.0	93.0	112.0	122.0	117.0	104.0
	Netherlands	685.0	839.0	702.0	803.0	839.0	1,012.0	1,176.0	1,159.0	1,148.0	1,047.0	965.0	1,038.0	959.0	954.0	834.0	707.0	701.0	582.0
	New Zealand	77.0	62.0	69.0	101.0	90.0	81.0	110.0	101.0	104.0	80.0	81.0	104.0	104.0	107.0	107.0	84.0	80.0	67.0
	Norway	167.0	140.0	174.0	124.0	154.0	173.0	226.0	240.0	202.0	189.0	199.0	173.0	225.0	238.0	209.0	179.0	168.0	150.0
	Poland	40.0	60.0	67.0	50.0	57.0	59.0	75.0	86.0	103.0	141.0	162.0	180.0	165.0	175.0	190.0	216.0	200.0	198.0
	Portugal	18.0	23.0	16.0	21.0	23.0	46.0	66.0	54.0	59.0	56.0	66.0	54.0	46.0	50.0	51.0	76.0	71.0	71.0
	Slovak Re-public	18.0	18.0	29.0	23.0	16.0	24.0	32.0	38.0	37.0	30.0	27.0	48.0	35.0	52.0	54.0	49.0	62.0	48.0
	Slovenia	41.0	26.0	36.0	19.0	22.0	40.0	40.0	31.0	32.0	38.0	37.0	36.0	34.0	48.0	66.0	44.0	43.0	49.0
	Spain	248.0	278.0	260.0	281.0	331.0	357.0	422.0	447.0	409.0	401.0	453.0	457.0	482.0	478.0	656.0	703.0	731.0	647.0
	Sweden	514.0	477.0	441.0	455.0	534.0	598.0	693.0	721.0	675.0	748.0	767.0	688.0	769.0	809.0	901.0	881.0	899.0	821.0
	Switzerland	590.0	678.0	702.0	732.0	797.0	879.0	852.0	1,272.0	961.0	873.0	898.0	963.0	1,041.0	1,018.0	880.0	993.0	972.0	941.0
	Turkey	19.0	16.0	22.0	34.0	40.0	44.0	36.0	30.0	46.0	50.0	50.0	54.0	73.0	74.0	79.0	77.0	71.0	58.0
	United King-dom	2,106.0	2,213.0	2,495.0	2,563.0	2,767.0	2,738.0	2,906.0	2,896.0	2,861.0	2,665.0	2,892.0	2,925.0	2,701.0	3,074.0	2,985.0	2,852.0	2,652.0	2,608.0
	United States	4,368.0	4,555.0	5,209.0	5,541.0	5,831.0	6,278.0	6,679.0	6,846.0	6,153.0	6,242.0	6,579.0	6,804.0	7,302.0	7,521.0	7,172.0	7,444.0	7,450.0	7,358.0
	European Un-ion (28 coun-tries)	8,514.0	9,057.0	9,751.0	10,511.0	11,376.0	12,160.0	12,978.0	13,719.0	12,831.0	12,556.0	13,114.0	13,499.0	13,556.0	13,804.0	13,730.0	13,716.0	13,682.0	13,083.0
	Algeria	2.0	2.0	1.0	0.0	3.0	1.0	3.0	1.0	4.0	1.0	3.0	3.0	3.0	3.0	4.0	2.0	3.0	3.0
	Andorra	0.0	0.0	1.0	0.0	1.0	3.0	0.0	0.0	1.0	1.0	1.0	3.0	2.0	0.0	4.0	5.0	4.0	6.0
	Argentina	43.0	33.0	46.0	64.0	48.0	75.0	63.0	106.0	46.0	51.0	59.0	56.0	59.0	51.0	54.0	84.0	54.0	50.0
	Armenia	1.0	4.0	6.0	3.0	4.0	5.0	2.0	2.0	1.0	3.0	5.0	15.0	3.0	8.0	5.0	11.0	11.0	9.0
	Belarus	11.0	12.0	8.0	14.0	13.0	9.0	4.0	10.0	9.0	14.0	14.0	14.0	5.0	19.0	14.0	14.0	21.0	22.0
	Bermuda	3.0	1.0	0.0	2.0	2.0	4.0	1.0	1.0	2.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	2.0	1.0
	Bosnia and Herzegovina	0.0	6.0	0.0	1.0	0.0	1.0	2.0	1.0	3.0	1.0	2.0	3.0	1.0	5.0	5.0	1.0	6.0	2.0
	Brazil	42.0	90.0	80.0	100.0	108.0	109.0	111.0	158.0	141.0	143.0	189.0	186.0	233.0	276.0	245.0	259.0	275.0	259.0
	Bulgaria	8.0	16.0	9.0	9.0	7.0	16.0	20.0	17.0	15.0	14.0	19.0	14.0	20.0	21.0	25.0	18.0	22.0	10.0
	Cayman Is-lands	3.0	1.0	2.0	1.0	1.0	2.0	0.0	0.0	0.0	1.0	0.0	0.0	3.0	1.0	3.0	2.0	3.0	5.0
	China	239.0	259.0	408.0	554.0	612.0	870.0	1,046.0	1,241.0	1,371.0	1,673.0	1,986.0	2,556.0	2,954.0	3,374.0	3,771.0	3,870.0	4,043.0	4,044.0
	Chinese Tai-pei	62.0	78.0	102.0	125.0	139.0	154.0	203.0	194.0	164.0	219.0	222.0	259.0	277.0	343.0	406.0	436.0	414.0	588.0
	Colombia	8.0	8.0	4.0	11.0	7.0	5.0	8.0	14.0	17.0	24.0	20.0	24.0	28.0	33.0	25.0	30.0	31.0	27.0
	Costa Rica	3.0	2.0	5.0	2.0	4.0	8.0	4.0	4.0	9.0	7.0	11.0	4.0	9.0	15.0	10.0	27.0	15.0	15.0
	Croatia	5.0	15.0	10.0	18.0	12.0	18.0	20.0	17.0	20.0	18.0	24.0	17.0	12.0	18.0	25.0	15.0	24.0	19.0
	Cuba	0.0	0.0	5.0	3.0	1.0	5.0	1.0	1.0	2.0	0.0	3.0	2.0	2.0	4.0	1.0	1.0	1.0	2.0
	Cyprus	4.0	11.0	7.0	9.0	2.0	11.0	6.0	7.0	1.0	8.0	4.0	9.0	4.0	11.0	11.0	8.0	8.0	2.0
	Democratic People’s	1.0	0.0	3.0	3.0	1.0	1.0	0.0	4.0	1.0	5.0	2.0	2.0	2.0	9.0	3.0	4.0	3.0	0.0

	Republic of Korea																		
	Djibouti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ecuador	1.0	3.0	1.0	2.0	5.0	0.0	1.0	4.0	2.0	1.0	5.0	3.0	6.0	3.0	3.0	3.0	6.0	5.0
	Egypt	7.0	10.0	17.0	9.0	8.0	19.0	17.0	16.0	21.0	26.0	19.0	24.0	26.0	29.0	39.0	18.0	19.0	17.0
	El Salvador	4.0	1.0	4.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	2.0	2.0	0.0	0.0	1.0	0.0
	Serbia and Montenegro	5.0	8.0	1.0	6.0	6.0	5.0	1.0	2.0	2.0	0.0	3.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0
	North Mace-donia	0.0	0.0	2.0	0.0	5.0	2.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	3.0	1.0	3.0	2.0	0.0
	Georgia	7.0	5.0	5.0	4.0	8.0	7.0	4.0	8.0	6.0	0.0	6.0	3.0	5.0	2.0	5.0	4.0	5.0	5.0
	Guatemala	0.0	2.0	0.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	2.0	1.0	0.0	0.0	3.0	3.0	2.0
	Hong Kong - China	54.0	58.0	83.0	94.0	128.0	149.0	158.0	135.0	130.0	152.0	205.0	183.0	174.0	193.0	210.0	194.0	268.0	173.0
	India	125.0	162.0	200.0	299.0	358.0	474.0	526.0	632.0	624.0	698.0	942.0	1,093.0	1,199.0	1,386.0	1,402.0	1,466.0	1,365.0	1,439.0
	Indonesia	17.0	10.0	10.0	11.0	23.0	15.0	20.0	17.0	16.0	20.0	20.0	15.0	34.0	32.0	14.0	20.0	20.0	17.0
	Iran (Islamic Republic of)	4.0	9.0	7.0	5.0	4.0	6.0	12.0	5.0	11.0	5.0	9.0	5.0	10.0	12.0	18.0	8.0	9.0	12.0
	Jamaica	0.0	1.0	2.0	0.0	3.0	2.0	1.0	3.0	3.0	1.0	1.0	1.0	0.0	3.0	0.0	3.0	2.0	1.0
	Jordan	1.0	3.0	1.0	0.0	1.0	10.0	20.0	23.0	21.0	0.0	4.0	4.0	7.0	3.0	2.0	1.0	5.0	5.0
	Kazakhstan	2.0	2.0	2.0	3.0	2.0	3.0	2.0	4.0	2.0	9.0	8.0	6.0	7.0	4.0	2.0	6.0	11.0	7.0
	Kenya	1.0	4.0	6.0	3.0	2.0	6.0	5.0	3.0	4.0	0.0	7.0	6.0	8.0	5.0	5.0	8.0	4.0	2.0
	Kuwait	1.0	0.0	3.0	5.0	0.0	2.0	2.0	4.0	2.0	1.0	1.0	0.0	4.0	0.0	4.0	3.0	5.0	5.0
	Latvia	16.0	7.0	7.0	12.0	8.0	27.0	15.0	13.0	9.0	14.0	12.0	7.0	7.0	4.0	2.0	7.0	8.0	13.0
	Lebanon	2.0	3.0	2.0	7.0	6.0	4.0	10.0	7.0	12.0	6.0	15.0	13.0	14.0	13.0	21.0	15.0	14.0	24.0
	Liechtenstein	3.0	5.0	10.0	4.0	10.0	8.0	11.0	20.0	11.0	8.0	22.0	10.0	22.0	19.0	29.0	38.0	50.0	30.0
	Lithuania	9.0	6.0	3.0	3.0	8.0	11.0	7.0	7.0	11.0	2.0	5.0	5.0	11.0	5.0	6.0	7.0	16.0	13.0
	Malaysia	60.0	40.0	57.0	66.0	63.0	93.0	87.0	79.0	103.0	96.0	101.0	127.0	120.0	118.0	114.0	188.0	222.0	149.0
	Malta	0.0	3.0	1.0	2.0	5.0	5.0	4.0	6.0	3.0	3.0	1.0	2.0	4.0	5.0	7.0	6.0	3.0	11.0
	Monaco	16.0	14.0	16.0	17.0	13.0	17.0	15.0	17.0	14.0	13.0	11.0	14.0	13.0	12.0	16.0	12.0	11.0	17.0
	Mongolia	1.0	0.0	0.0	1.0	0.0	0.0	0.0	2.0	2.0	0.0	2.0	0.0	0.0	1.0	0.0	1.0	2.0	2.0
	Morocco	7.0	6.0	9.0	9.0	2.0	3.0	5.0	18.0	5.0	8.0	2.0	6.0	9.0	9.0	2.0	6.0	3.0	11.0
	Nigeria	0.0	1.0	0.0	2.0	1.0	1.0	3.0	1.0	2.0	1.0	1.0	2.0	1.0	1.0	4.0	3.0	5.0	4.0
	Pakistan	5.0	2.0	1.0	3.0	4.0	4.0	5.0	10.0	4.0	8.0	7.0	11.0	11.0	8.0	18.0	10.0	13.0	11.0
	Panama	1.0	1.0	2.0	2.0	1.0	3.0	0.0	1.0	2.0	1.0	3.0	5.0	7.0	6.0	1.0	2.0	2.0	2.0
	Peru	0.0	0.0	2.0	3.0	5.0	4.0	9.0	4.0	10.0	2.0	5.0	8.0	3.0	2.0	4.0	3.0	6.0	32.0
	Philippines	22.0	11.0	17.0	14.0	35.0	37.0	32.0	25.0	29.0	24.0	26.0	29.0	28.0	18.0	31.0	24.0	25.0	20.0
	Puerto Rico	1.0	4.0	3.0	5.0	10.0	13.0	5.0	4.0	4.0	6.0	4.0	11.0	7.0	13.0	5.0	10.0	11.0	11.0
	Republic of Moldova	2.0	2.0	3.0	2.0	3.0	5.0	3.0	7.0	2.0	2.0	0.0	2.0	4.0	1.0	1.0	3.0	3.0	2.0
	Romania	12.0	9.0	12.0	21.0	27.0	24.0	42.0	44.0	50.0	30.0	36.0	47.0	70.0	74.0	86.0	79.0	66.0	64.0
	Russian Fed-eration	245.0	273.0	217.0	276.0	245.0	347.0	343.0	318.0	277.0	302.0	297.0	403.0	444.0	413.0	424.0	393.0	401.0	352.0
	Saudi Arabia	6.0	8.0	13.0	16.0	18.0	34.0	21.0	34.0	36.0	49.0	56.0	74.0	51.0	59.0	128.0	178.0	141.0	167.0
	Seychelles	1.0	0.0	0.0	1.0	2.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0

	Singapore	99.0	133.0	163.0	162.0	203.0	224.0	249.0	254.0	279.0	268.0	292.0	345.0	320.0	424.0	460.0	438.0	416.0	426.0
	South Africa	73.0	61.0	54.0	51.0	77.0	56.0	78.0	81.0	70.0	54.0	81.0	80.0	86.0	67.0	62.0	79.0	67.0	43.0
	Sri Lanka	3.0	3.0	4.0	3.0	2.0	2.0	6.0	5.0	11.0	5.0	7.0	7.0	8.0	3.0	2.0	9.0	17.0	22.0
	Thailand	45.0	33.0	29.0	39.0	43.0	52.0	51.0	62.0	48.0	58.0	58.0	60.0	64.0	82.0	80.0	85.0	75.0	65.0
	Trinidad and Tobago	0.0	1.0	2.0	4.0	3.0	4.0	6.0	5.0	3.0	4.0	4.0	3.0	1.0	0.0	1.0	4.0	2.0	0.0
	Tunisia	3.0	7.0	3.0	9.0	4.0	6.0	8.0	6.0	4.0	11.0	8.0	12.0	16.0	9.0	13.0	3.0	13.0	4.0
	Ukraine	44.0	53.0	50.0	42.0	41.0	47.0	49.0	73.0	48.0	47.0	77.0	55.0	87.0	56.0	62.0	81.0	61.0	54.0
	United Arab Emirates	7.0	8.0	10.0	15.0	8.0	12.0	21.0	16.0	41.0	24.0	47.0	38.0	49.0	80.0	50.0	58.0	75.0	60.0
	Uruguay	4.0	5.0	7.0	9.0	9.0	7.0	24.0	13.0	9.0	5.0	5.0	13.0	17.0	14.0	7.0	10.0	10.0	7.0
	Uzbekistan	2.0	1.0	0.0	2.0	5.0	2.0	3.0	4.0	0.0	2.0	2.0	2.0	4.0	1.0	0.0	0.0	3.0	3.0
	Venezuela	6.0	10.0	6.0	5.0	5.0	6.0	12.0	15.0	2.0	8.0	4.0	6.0	12.0	14.0	8.0	6.0	4.0	7.0
	Zimbabwe	1.0	2.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	..

Data extracted on 26 Apr 2020 11:26 UTC (GMT) from OECD.Stat

Appendix-Table 9 *Inward Host-Country Patents, https://stats.oecd.org*

Patent office		Patent applications filed under the PCT																	
Reference Date		Priority date																	
Type of International Cooperation in Patenting		Foreign ownership of domestic inventions																	
Unit		Number																	
	Time	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Country	**Partner Country**																		
Germany	Total Patents	14,368.0	14,659.0	15,293.0	16,239.0	17,305.0	18,223.0	19,145.0	20,518.0	18,647.0	18,901.0	20,121.0	20,249.0	19,647.0	19,353.0	19,569.0	19,805.0	20,543.0	20,489.0
	Total co-operation with abroad	2,020.0	2,151.0	2,592.0	2,932.0	3,111.0	3,337.0	3,348.0	3,948.0	3,479.0	3,497.0	3,636.0	3,664.0	3,872.0	3,782.0	3,704.0	3,819.0	4,020.0	3,906.0
	Australia	13.0	4.0	25.0	22.0	14.0	16.0	20.0	16.0	15.0	7.0	13.0	15.0	9.0	16.0	14.0	5.0	5.0	6.0
	Austria	89.0	106.0	117.0	157.0	133.0	121.0	148.0	119.0	121.0	134.0	149.0	134.0	175.0	150.0	157.0	170.0	165.0	129.0
	Belgium	38.0	32.0	27.0	35.0	49.0	61.0	61.0	70.0	60.0	71.0	84.0	84.0	69.0	77.0	67.0	51.0	123.0	102.0
	Canada	46.0	32.0	20.0	23.0	26.0	13.0	21.0	38.0	34.0	44.0	42.0	25.0	34.0	38.0	26.0	26.0	22.0	17.0
	Chile	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0	2.0	1.0	1.0	0.0	0.0	1.0
	Czech Republic	1.0	4.0	0.0	2.0	16.0	7.0	2.0	3.0	2.0	4.0	5.0	5.0	12.0	8.0	4.0	10.0	9.0	4.0
	Denmark	24.0	20.0	36.0	20.0	33.0	40.0	27.0	35.0	48.0	55.0	89.0	54.0	37.0	43.0	45.0	47.0	59.0	44.0
	Estonia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	3.0	0.0
	Finland	43.0	72.0	78.0	71.0	105.0	64.0	60.0	188.0	202.0	167.0	152.0	152.0	172.0	130.0	121.0	117.0	128.0	140.0
	France	130.0	167.0	135.0	191.0	208.0	256.0	291.0	270.0	327.0	264.0	282.0	312.0	291.0	280.0	257.0	262.0	267.0	263.0
	Germany	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Greece	0.0	1.0	1.0	0.0	1.0	1.0	0.0	2.0	0.0	1.0	0.0	1.0	1.0	3.0	0.0	1.0	0.0	..
	Hungary	4.0	4.0	2.0	4.0	8.0	6.0	5.0	4.0	7.0	4.0	5.0	4.0	4.0	5.0	2.0	1.0	5.0	3.0
	Iceland	0.0	10.0	2.0	3.0	1.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0
	Ireland	17.0	16.0	17.0	11.0	11.0	17.0	12.0	27.0	25.0	16.0	21.0	24.0	27.0	29.0	32.0	27.0	38.0	21.0
	Israel	8.0	10.0	14.0	12.0	8.0	6.0	9.0	10.0	8.0	9.0	22.0	17.0	9.0	8.0	12.0	11.0	10.0	18.0
	Italy	31.0	26.0	31.0	44.0	29.0	37.0	30.0	39.0	43.0	51.0	34.0	44.0	35.0	45.0	29.0	31.0	39.0	35.0
	Japan	47.0	55.0	91.0	109.0	131.0	80.0	96.0	120.0	89.0	118.0	103.0	118.0	119.0	146.0	107.0	96.0	148.0	194.0
	Korea	2.0	9.0	2.0	9.0	10.0	33.0	13.0	8.0	5.0	53.0	100.0	89.0	103.0	50.0	28.0	12.0	8.0	18.0
	Luxembourg	22.0	12.0	20.0	33.0	34.0	55.0	66.0	96.0	62.0	88.0	96.0	115.0	122.0	117.0	99.0	111.0	131.0	67.0
	Mexico	0.0	0.0	1.0	1.0	1.0	0.0	2.0	0.0	1.0	0.0	1.0	0.0	1.0	2.0	6.0	4.0	3.0	3.0
	Netherlands	111.0	84.0	458.0	544.0	483.0	552.0	257.0	257.0	237.0	223.0	193.0	153.0	187.0	184.0	160.0	242.0	226.0	135.0
	New Zealand	1.0	1.0	0.0	2.0	3.0	4.0	2.0	0.0	2.0	1.0	0.0	1.0	1.0	1.0	1.0	6.0	2.0	3.0
	Norway	6.0	10.0	17.0	4.0	8.0	6.0	9.0	15.0	9.0	6.0	11.0	9.0	14.0	21.0	17.0	7.0	25.0	16.0
	Poland	0.0	3.0	4.0	5.0	7.0	2.0	1.0	0.0	2.0	6.0	4.0	4.0	10.0	4.0	5.0	7.0	4.0	10.0
	Portugal	2.0	2.0	0.0	0.0	1.0	1.0	2.0	1.0	5.0	1.0	3.0	2.0	2.0	1.0	0.0	0.0	1.0	0.0
	Slovak Republic	0.0	0.0	0.0	1.0	0.0	0.0	2.0	1.0	3.0	2.0	1.0	2.0	0.0	3.0	2.0	1.0	1.0	0.0
	Slovenia	0.0	2.0	0.0	0.0	0.0	4.0	0.0	1.0	2.0	5.0	0.0	3.0	2.0	1.0	1.0	4.0	2.0	1.0
	Spain	4.0	4.0	14.0	7.0	11.0	9.0	11.0	19.0	17.0	23.0	15.0	21.0	18.0	22.0	15.0	14.0	18.0	23.0
	Sweden	127.0	133.0	135.0	159.0	140.0	143.0	160.0	179.0	213.0	192.0	232.0	235.0	204.0	192.0	242.0	215.0	212.0	218.0

Switzerland	413.0	466.0	512.0	639.0	669.0	671.0	763.0	825.0	713.0	769.0	750.0	761.0	832.0	638.0	702.0	729.0	754.0	738.0
Turkey	3.0	3.0	2.0	5.0	0.0	0.0	1.0	2.0	3.0	2.0	1.0	0.0	9.0	4.0	12.0	4.0	3.0	5.0
United Kingdom	71.0	110.0	80.0	80.0	89.0	79.0	90.0	105.0	94.0	91.0	89.0	80.0	99.0	102.0	119.0	107.0	112.0	159.0
United States	790.0	751.0	791.0	785.0	894.0	1,016.0	1,110.0	1,082.0	994.0	973.0	1,018.0	1,100.0	1,106.0	1,275.0	1,183.0	1,220.0	1,218.0	1,157.0
European Union (28 countries)	698.0	790.0	1,136.0	1,344.0	1,332.0	1,447.0	1,214.0	1,404.0	1,462.0	1,389.0	1,437.0	1,415.0	1,439.0	1,372.0	1,348.0	1,401.0	1,514.0	1,340.0
Algeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Andorra	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Argentina	0.0	0.0	0.0	1.0	1.0	0.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
Armenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Belarus	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bermuda	1.0	2.0	3.0	3.0	2.0	1.0	6.0	9.0	2.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Bosnia and Herze-govina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brazil	0.0	5.0	3.0	3.0	3.0	2.0	2.0	1.0	1.0	6.0	0.0	2.0	10.0	7.0	3.0	5.0	5.0	4.0
Bulgaria	0.0	0.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	2.0	0.0	1.0	0.0	0.0	3.0	0.0	1.0
Cayman Islands	3.0	2.0	19.0	4.0	6.0	3.0	7.0	15.0	21.0	11.0	0.0	2.0	2.0	1.0	0.0	0.0	0.0	5.0
China	2.0	0.0	0.0	2.0	6.0	9.0	7.0	12.0	19.0	26.0	57.0	65.0	75.0	87.0	102.0	187.0	241.0	298.0
Chinese Taipei	1.0	7.0	4.0	16.0	7.0	1.0	4.0	2.0	1.0	3.0	4.0	0.0	0.0	3.0	0.0	0.0	0.0	..
Colombia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Costa Rica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Croatia	0.0	0.0	0.0	0.0	1.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Cuba	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyprus	3.0	2.0	3.0	0.0	2.0	2.0	1.0	3.0	2.0	2.0	3.0	3.0	2.0	0.0	0.0	1.0	0.0	1.0
Democratic People’s Republic of Korea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Djibouti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ecuador	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
Egypt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
El Salvador	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Serbia and Montene-gro	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
North Macedonia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Georgia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guatemala	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hong Kong - China	1.0	1.0	0.0	1.0	4.0	2.0	6.0	7.0	8.0	1.0	5.0	7.0	5.0	2.0	7.0	6.0	7.0	4.0
India	0.0	0.0	4.0	6.0	4.0	5.0	4.0	1.0	7.0	9.0	4.0	8.0	5.0	7.0	5.0	2.0	8.0	16.0
Indonesia	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0
Iran (Islamic Repub-lic of)	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Jamaica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jordan	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kazakhstan	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Kenya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Kuwait	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Latvia	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0
	Lebanon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	..
	Liechtenstein	18.0	13.0	6.0	7.0	18.0	14.0	10.0	319.0	19.0	35.0	43.0	31.0	94.0	111.0	125.0	123.0	111.0	119.0
	Lithuania	1.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	0.0
	Malaysia	0.0	1.0	0.0	1.0	2.0	7.0	5.0	7.0	2.0	6.0	1.0	3.0	3.0	2.0	3.0	1.0	2.0	0.0
	Malta	1.0	1.0	0.0	2.0	1.0	4.0	5.0	0.0	4.0	4.0	4.0	5.0	5.0	2.0	7.0	5.0	5.0	3.0
	Monaco	0.0	1.0	0.0	2.0	0.0	0.0	2.0	1.0	1.0	0.0	3.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
	Mongolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Morocco	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nigeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pakistan	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Panama	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
	Peru	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Philippines	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
	Puerto Rico	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	1.0	0.0	..
	Republic of Moldova	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Romania	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	2.0	0.0	0.0	1.0
	Russian Federation	9.0	5.0	13.0	6.0	7.0	1.0	5.0	5.0	4.0	5.0	5.0	5.0	10.0	7.0	9.0	4.0	4.0	5.0
	Saudi Arabia	1.0	0.0	0.0	1.0	3.0	17.0	2.0	7.0	3.0	5.0	2.0	6.0	7.0	9.0	10.0	3.0	2.0	2.0
	Seychelles	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Singapore	1.0	10.0	9.0	5.0	7.0	10.0	26.0	18.0	29.0	29.0	47.0	17.0	32.0	19.0	24.0	25.0	25.0	33.0
	South Africa	5.0	2.0	1.0	1.0	1.0	3.0	1.0	9.0	2.0	2.0	0.0	9.0	5.0	1.0	4.0	8.0	1.0	3.0
	Sri Lanka	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
	Thailand	0.0	1.0	1.0	0.0	2.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	1.0
	Trinidad and Tobago	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Tunisia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
	Ukraine	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	0.0	1.0	1.0	1.0	0.0	1.0
	United Arab Emirates	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	1.0	2.0	2.0	3.0	2.0	0.0	0.0	1.0	3.0
	Uruguay	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Uzbekistan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Venezuela	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
	Zimbabwe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Japan	Total Patents	11,047.0	12,573.0	15,106.0	18,468.0	22,709.0	23,983.0	24,650.0	29,400.0	28,462.0	31,396.0	37,554.0	42,161.0	44,095.0	41,929.0	40,495.0	41,736.0	44,199.0	44,363.0
	Total co-operation with abroad	806.0	791.0	841.0	906.0	1,055.0	1,140.0	1,078.0	1,204.0	1,036.0	1,054.0	1,093.0	1,228.0	1,421.0	1,321.0	1,231.0	1,122.0	1,309.0	1,357.0
	Australia	5.0	3.0	3.0	8.0	2.0	2.0	6.0	3.0	4.0	7.0	2.0	5.0	2.0	7.0	1.0	2.0	3.0	4.0
	Austria	1.0	6.0	5.0	8.0	5.0	6.0	1.0	4.0	1.0	1.0	0.0	4.0	7.0	0.0	3.0	1.0	7.0	5.0
	Belgium	2.0	6.0	3.0	2.0	1.0	4.0	4.0	7.0	3.0	10.0	12.0	14.0	23.0	14.0	12.0	13.0	17.0	23.0
	Canada	15.0	12.0	9.0	11.0	18.0	13.0	11.0	25.0	19.0	21.0	17.0	22.0	14.0	10.0	3.0	11.0	14.0	6.0

Chile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Czech Republic	0.0	0.0	2.0	0.0	1.0	3.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
Denmark	8.0	7.0	6.0	3.0	4.0	2.0	5.0	18.0	11.0	11.0	24.0	18.0	14.0	6.0	8.0	3.0	11.0	10.0
Estonia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
Finland	12.0	8.0	21.0	23.0	18.0	27.0	39.0	52.0	10.0	18.0	31.0	27.0	18.0	14.0	32.0	30.0	16.0	22.0
France	36.0	36.0	39.0	38.0	56.0	63.0	57.0	94.0	58.0	107.0	77.0	89.0	106.0	115.0	105.0	96.0	134.0	181.0
Germany	102.0	95.0	120.0	117.0	105.0	88.0	116.0	113.0	103.0	123.0	151.0	128.0	115.0	98.0	114.0	128.0	122.0	182.0
Greece	0.0	0.0	0.0	0.0	0.0	1.0	0.0	3.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hungary	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	1.0	1.0	0.0	1.0	0.0	2.0	0.0
Iceland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ireland	1.0	1.0	4.0	4.0	6.0	10.0	5.0	8.0	4.0	15.0	29.0	38.0	7.0	0.0	6.0	2.0	0.0	0.0
Israel	2.0	1.0	2.0	4.0	1.0	2.0	3.0	0.0	2.0	1.0	4.0	3.0	1.0	2.0	1.0	1.0	3.0	3.0
Italy	4.0	3.0	5.0	2.0	4.0	6.0	1.0	5.0	4.0	4.0	6.0	9.0	3.0	6.0	7.0	5.0	8.0	3.0
Japan	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Korea	12.0	14.0	26.0	22.0	40.0	37.0	23.0	25.0	29.0	36.0	50.0	63.0	57.0	65.0	73.0	84.0	70.0	79.0
Luxembourg	2.0	1.0	5.0	3.0	10.0	5.0	5.0	9.0	10.0	2.0	4.0	2.0	78.0	103.0	20.0	14.0	22.0	0.0
Mexico	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	40.0	35.0	73.0	36.0	55.0	88.0	46.0	73.0	39.0	46.0	33.0	30.0	35.0	48.0	25.0	38.0	23.0	13.0
New Zealand	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	2.0	1.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0
Norway	1.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	5.0	1.0	1.0	0.0
Poland	2.0	8.0	9.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0
Portugal	0.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Slovak Republic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Slovenia	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spain	2.0	0.0	4.0	3.0	0.0	1.0	0.0	2.0	3.0	1.0	3.0	0.0	7.0	2.0	3.0	1.0	2.0	2.0
Sweden	29.0	11.0	9.0	27.0	22.0	24.0	23.0	52.0	48.0	56.0	54.0	39.0	60.0	48.0	45.0	44.0	29.0	31.0
Switzerland	47.0	46.0	45.0	52.0	41.0	38.0	43.0	46.0	38.0	43.0	40.0	41.0	49.0	57.0	79.0	60.0	32.0	40.0
Turkey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	2.0	0.0	1.0	2.0
United Kingdom	23.0	23.0	23.0	36.0	44.0	39.0	18.0	18.0	24.0	13.0	17.0	28.0	23.0	14.0	18.0	30.0	24.0	22.0
United States	467.0	463.0	423.0	500.0	615.0	642.0	614.0	601.0	555.0	493.0	503.0	618.0	698.0	632.0	476.0	394.0	471.0	548.0
European Union (28 countries)	257.0	234.0	319.0	291.0	320.0	352.0	304.0	428.0	301.0	390.0	428.0	417.0	485.0	440.0	391.0	391.0	415.0	493.0
Algeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Andorra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Argentina	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Armenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Belarus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bermuda	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bosnia and Herze-govina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brazil	0.0	0.0	0.0	1.0	1.0	0.0	0.0	2.0	1.0	0.0	2.0	1.0	1.0	0.0	1.0	0.0	3.0	2.0
Bulgaria	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Cayman Islands	0.0	2.0	1.0	0.0	0.0	2.0	1.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0	1.0	3.0	0.0	0.0
	China	3.0	5.0	6.0	4.0	4.0	16.0	8.0	30.0	25.0	15.0	34.0	35.0	55.0	31.0	88.0	92.0	172.0	117.0
	Chinese Taipei	0.0	6.0	2.0	2.0	3.0	1.0	6.0	7.0	4.0	7.0	4.0	6.0	6.0	2.0	10.0	17.0	17.0	5.0
	Colombia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Costa Rica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Croatia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Cuba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Cyprus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Democratic People’s Republic of Korea	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Djibouti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ecuador	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Egypt	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Salvador	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Serbia and Montene-gro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	North Macedonia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Georgia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Guatemala	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hong Kong - China	2.0	0.0	11.0	15.0	13.0	22.0	41.0	36.0	17.0	25.0	7.0	12.0	17.0	7.0	27.0	13.0	72.0	25.0
	India	1.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	1.0	2.0	1.0	2.0	3.0	2.0	3.0	7.0	4.0	5.0
	Indonesia	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	2.0	3.0	2.0	3.0	0.0	0.0	2.0	3.0	1.0
	Iran (Islamic Repub-lic of)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Jamaica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Jordan	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Kazakhstan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Kenya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Kuwait	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Latvia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Lebanon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Liechtenstein	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	1.0	2.0	0.0	0.0	1.0	1.0	0.0	0.0
	Lithuania	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Malaysia	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	2.0	3.0	4.0	2.0	3.0	3.0	6.0	3.0	2.0	3.0
	Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Monaco	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
	Mongolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Morocco	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nigeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pakistan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Panama	0.0	0.0	1.0	4.0	4.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
	Peru	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Philippines	2.0	0.0	0.0	2.0	0.0	3.0	2.0	0.0	1.0	0.0	1.0	4.0	12.0	2.0	0.0	0.0	0.0	0.0
	Puerto Rico	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Republic of Moldova	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Romania	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Russian Federation	1.0	0.0	5.0	0.0	3.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0
	Saudi Arabia	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0	1.0	0.0	1.0	1.0	1.0	2.0	1.0	2.0	5.0	3.0
	Seychelles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Singapore	1.0	6.0	3.0	9.0	6.0	10.0	10.0	18.0	27.0	23.0	5.0	17.0	31.0	62.0	55.0	34.0	14.0	18.0
	South Africa	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	7.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
	Sri Lanka	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Thailand	0.0	0.0	1.0	2.0	4.0	1.0	1.0	7.0	4.0	12.0	7.0	6.0	5.0	12.0	29.0	20.0	28.0	21.0
	Trinidad and Tobago	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Tunisia	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
	Ukraine	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	United Arab Emirates	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	3.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
	Uruguay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Uzbekistan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Venezuela	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Zimbabwe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
United States	Total Patents	42,974.0	42,130.0	42,106.0	44,543.0	48,077.0	52,438.0	54,978.0	53,044.0	47,356.0	45,601.0	48,288.0	52,609.0	56,118.0	62,631.0	57,606.0	57,389.0	57,882.0	56,350.0
	Total co-operation with abroad	4,368.0	4,555.0	5,209.0	5,541.0	5,831.0	6,278.0	6,679.0	6,846.0	6,153.0	6,242.0	6,579.0	6,804.0	7,302.0	7,521.0	7,172.0	7,444.0	7,450.0	7,358.0
	Australia	65.0	53.0	45.0	69.0	94.0	111.0	106.0	86.0	74.0	72.0	77.0	91.0	72.0	79.0	69.0	88.0	73.0	98.0
	Austria	75.0	68.0	98.0	79.0	72.0	106.0	74.0	15.0	12.0	16.0	17.0	18.0	31.0	33.0	25.0	38.0	31.0	49.0
	Belgium	86.0	83.0	113.0	121.0	158.0	166.0	183.0	133.0	117.0	123.0	105.0	135.0	121.0	117.0	129.0	139.0	138.0	167.0
	Canada	346.0	337.0	321.0	286.0	309.0	363.0	385.0	439.0	418.0	377.0	421.0	453.0	431.0	394.0	313.0	274.0	344.0	300.0
	Chile	1.0	1.0	1.0	2.0	1.0	1.0	1.0	4.0	2.0	0.0	0.0	1.0	3.0	0.0	4.0	2.0	4.0	4.0
	Czech Republic	0.0	1.0	0.0	0.0	0.0	1.0	3.0	5.0	2.0	4.0	1.0	4.0	6.0	2.0	7.0	7.0	4.0	13.0
	Denmark	41.0	66.0	56.0	71.0	87.0	72.0	68.0	78.0	102.0	118.0	144.0	135.0	105.0	93.0	105.0	106.0	113.0	88.0
	Estonia	0.0	0.0	0.0	1.0	0.0	1.0	1.0	0.0	1.0	0.0	3.0	1.0	1.0	2.0	1.0	1.0	4.0	1.0
	Finland	127.0	160.0	184.0	203.0	217.0	197.0	143.0	119.0	107.0	96.0	139.0	189.0	236.0	176.0	140.0	144.0	141.0	201.0
	France	344.0	516.0	622.0	492.0	555.0	638.0	762.0	925.0	849.0	981.0	963.0	934.0	984.0	978.0	976.0	962.0	613.0	592.0
	Germany	801.0	786.0	741.0	764.0	697.0	789.0	789.0	841.0	736.0	756.0	843.0	924.0	1,020.0	1,077.0	919.0	1,067.0	1,089.0	1,001.0
	Greece	6.0	1.0	0.0	3.0	0.0	1.0	1.0	5.0	2.0	1.0	3.0	3.0	5.0	6.0	1.0	2.0	1.0	4.0
	Hungary	6.0	0.0	4.0	4.0	6.0	3.0	6.0	7.0	12.0	9.0	7.0	1.0	6.0	6.0	6.0	13.0	6.0	6.0
	Iceland	4.0	5.0	12.0	18.0	17.0	19.0	14.0	22.0	11.0	11.0	8.0	8.0	14.0	10.0	10.0	14.0	8.0	7.0
	Ireland	55.0	76.0	80.0	75.0	81.0	132.0	97.0	98.0	90.0	110.0	122.0	122.0	131.0	107.0	114.0	188.0	216.0	185.0
	Israel	105.0	77.0	67.0	71.0	67.0	75.0	95.0	90.0	72.0	81.0	80.0	78.0	106.0	108.0	94.0	89.0	86.0	132.0
	Italy	50.0	55.0	46.0	49.0	45.0	55.0	43.0	48.0	45.0	59.0	42.0	82.0	66.0	60.0	54.0	65.0	63.0	71.0
	Japan	381.0	374.0	458.0	610.0	648.0	709.0	613.0	529.0	474.0	483.0	491.0	505.0	519.0	612.0	526.0	540.0	637.0	605.0
	Korea	32.0	57.0	60.0	69.0	67.0	128.0	159.0	151.0	146.0	176.0	179.0	185.0	230.0	230.0	272.0	248.0	262.0	218.0

	Luxembourg	27.0	40.0	56.0	51.0	45.0	48.0	45.0	44.0	46.0	57.0	75.0	78.0	73.0	75.0	78.0	65.0	64.0	36.0
	Mexico	4.0	3.0	16.0	17.0	38.0	28.0	28.0	28.0	22.0	10.0	22.0	12.0	14.0	17.0	24.0	19.0	13.0	16.0
	Netherlands	423.0	407.0	735.0	729.0	706.0	704.0	849.0	1,012.0	986.0	835.0	747.0	629.0	700.0	820.0	816.0	887.0	657.0	542.0
	New Zealand	17.0	9.0	19.0	18.0	14.0	12.0	15.0	13.0	15.0	15.0	17.0	12.0	24.0	22.0	23.0	20.0	28.0	16.0
	Norway	10.0	16.0	13.0	9.0	15.0	9.0	20.0	18.0	22.0	26.0	23.0	15.0	26.0	49.0	48.0	52.0	65.0	38.0
	Poland	2.0	5.0	9.0	3.0	3.0	0.0	3.0	6.0	4.0	2.0	0.0	0.0	3.0	5.0	7.0	8.0	12.0	4.0
	Portugal	0.0	2.0	0.0	2.0	4.0	4.0	5.0	4.0	9.0	4.0	11.0	2.0	4.0	1.0	1.0	4.0	1.0	4.0
	Slovak Republic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	2.0	0.0	0.0	4.0	1.0	0.0	0.0	0.0
	Slovenia	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	2.0	3.0	1.0	0.0	0.0	2.0	2.0
	Spain	8.0	8.0	11.0	18.0	13.0	7.0	16.0	24.0	22.0	19.0	31.0	17.0	30.0	29.0	23.0	27.0	20.0	35.0
	Sweden	234.0	177.0	160.0	225.0	296.0	285.0	344.0	395.0	351.0	258.0	231.0	269.0	342.0	313.0	360.0	330.0	310.0	316.0
	Switzerland	501.0	635.0	676.0	674.0	688.0	783.0	826.0	900.0	881.0	892.0	904.0	792.0	842.0	908.0	817.0	766.0	855.0	706.0
	Turkey	0.0	1.0	0.0	3.0	2.0	2.0	5.0	1.0	1.0	5.0	2.0	3.0	6.0	10.0	4.0	2.0	6.0	4.0
	United Kingdom	477.0	349.0	359.0	348.0	373.0	352.0	338.0	368.0	300.0	292.0	343.0	443.0	346.0	423.0	442.0	495.0	567.0	530.0
	United States	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	European Union (28 countries)	2,628.0	2,664.0	3,116.0	3,111.0	3,222.0	3,422.0	3,589.0	3,758.0	3,456.0	3,462.0	3,561.0	3,706.0	3,894.0	3,949.0	3,873.0	4,158.0	3,853.0	3,668.0
	Algeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Andorra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Argentina	1.0	1.0	0.0	5.0	4.0	5.0	4.0	9.0	4.0	2.0	0.0	1.0	4.0	6.0	1.0	4.0	2.0	5.0
	Armenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	1.0	0.0	0.0
	Belarus	1.0	0.0	0.0	0.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0
	Bermuda	24.0	47.0	60.0	108.0	107.0	143.0	181.0	152.0	45.0	39.0	28.0	21.0	25.0	34.0	18.0	5.0	13.0	17.0
	Bosnia and Herze-govina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
	Brazil	3.0	5.0	8.0	7.0	3.0	3.0	6.0	14.0	11.0	5.0	13.0	14.0	16.0	15.0	13.0	13.0	17.0	23.0
	Bulgaria	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	2.0	3.0	0.0	2.0	0.0	0.0	0.0
	Cayman Islands	49.0	47.0	56.0	54.0	34.0	59.0	76.0	97.0	47.0	60.0	53.0	55.0	41.0	53.0	47.0	71.0	59.0	83.0
	China	21.0	15.0	26.0	28.0	55.0	81.0	169.0	190.0	177.0	250.0	345.0	408.0	524.0	453.0	541.0	508.0	547.0	706.0
	Chinese Taipei	13.0	30.0	44.0	39.0	48.0	45.0	53.0	54.0	64.0	44.0	61.0	57.0	72.0	88.0	106.0	104.0	127.0	126.0
	Colombia	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	1.0	2.0	0.0	2.0	6.0	8.0	2.0	1.0	5.0	5.0
	Costa Rica	0.0	0.0	0.0	1.0	0.0	3.0	0.0	0.0	0.0	0.0	1.0	0.0	2.0	1.0	0.0	0.0	5.0	0.0
	Croatia	2.0	3.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	0.0	0.0
	Cuba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Cyprus	3.0	2.0	1.0	1.0	1.0	0.0	4.0	8.0	3.0	3.0	5.0	7.0	5.0	2.0	2.0	3.0	8.0	6.0
	Democratic People’s Republic of Korea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Djibouti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ecuador	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
	Egypt	1.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	6.0	2.0	0.0	3.0	2.0	1.0	2.0
	El Salvador	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0
	Serbia and Montene-gro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

North Macedonia	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Georgia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Guatemala	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Hong Kong - China	24.0	24.0	29.0	40.0	53.0	62.0	38.0	33.0	28.0	48.0	44.0	53.0	51.0	75.0	73.0	64.0	71.0	81.0
India	12.0	18.0	20.0	41.0	49.0	36.0	16.0	24.0	25.0	34.0	55.0	42.0	61.0	47.0	59.0	60.0	59.0	63.0
Indonesia	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	2.0	2.0
Iran (Islamic Republic of)	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	1.0
Jamaica	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	1.0	1.0	0.0
Jordan	0.0	0.0	0.0	0.0	1.0	2.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Kazakhstan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0
Kenya	0.0	0.0	0.0	2.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
Kuwait	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
Latvia	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Lebanon	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0	3.0
Liechtenstein	2.0	2.0	2.0	0.0	1.0	2.0	5.0	2.0	2.0	5.0	2.0	4.0	1.0	6.0	1.0	8.0	11.0	23.0
Lithuania	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	1.0	1.0	3.0	1.0	3.0	2.0	2.0	2.0
Malaysia	3.0	1.0	5.0	5.0	2.0	2.0	1.0	6.0	9.0	14.0	8.0	13.0	35.0	15.0	6.0	11.0	0.0	6.0
Malta	0.0	0.0	0.0	0.0	1.0	0.0	0.0	3.0	2.0	6.0	7.0	3.0	4.0	6.0	6.0	9.0	0.0	11.0
Monaco	2.0	2.0	1.0	0.0	7.0	3.0	2.0	1.0	2.0	3.0	3.0	7.0	8.0	16.0	13.0	8.0	4.0	4.0
Mongolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Morocco	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	1.0
Nigeria	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
Pakistan	0.0	0.0	0.0	0.0	0.0	3.0	4.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	1.0	0.0	0.0	1.0
Panama	7.0	3.0	9.0	10.0	14.0	0.0	2.0	4.0	3.0	0.0	1.0	0.0	0.0	1.0	2.0	0.0	0.0	0.0
Peru	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	1.0
Philippines	1.0	0.0	0.0	0.0	2.0	7.0	2.0	0.0	1.0	0.0	1.0	1.0	2.0	5.0	0.0	1.0	0.0	0.0
Puerto Rico	1.0	3.0	3.0	7.0	10.0	12.0	9.0	25.0	15.0	26.0	42.0	36.0	50.0	54.0	47.0	108.0	214.0	281.0
Republic of Moldova	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	1.0	0.0	0.0	0.0	..
Romania	0.0	0.0	0.0	0.0	2.0	0.0	3.0	1.0	0.0	1.0	0.0	0.0	1.0	2.0	1.0	0.0	0.0	2.0
Russian Federation	6.0	13.0	9.0	17.0	24.0	9.0	16.0	27.0	14.0	7.0	13.0	14.0	24.0	31.0	9.0	18.0	18.0	11.0
Saudi Arabia	2.0	0.0	3.0	6.0	8.0	17.0	3.0	10.0	14.0	18.0	17.0	36.0	46.0	42.0	25.0	34.0	40.0	72.0
Seychelles	0.0	0.0	1.0	3.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
Singapore	27.0	35.0	37.0	49.0	62.0	36.0	76.0	64.0	74.0	80.0	99.0	96.0	126.0	127.0	117.0	148.0	108.0	109.0
South Africa	12.0	13.0	4.0	6.0	6.0	0.0	1.0	3.0	14.0	12.0	10.0	4.0	8.0	5.0	11.0	12.0	6.0	6.0
Sri Lanka	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thailand	2.0	4.0	2.0	3.0	3.0	1.0	1.0	4.0	1.0	2.0	3.0	2.0	0.0	2.0	5.0	5.0	4.0	5.0
Trinidad and Tobago	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Tunisia	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Ukraine	3.0	4.0	2.0	13.0	2.0	2.0	2.0	16.0	2.0	1.0	2.0	1.0	7.0	4.0	2.0	2.0	2.0	4.0
United Arab Emirates	0.0	0.0	0.0	1.0	0.0	1.0	2.0	3.0	1.0	2.0	5.0	4.0	7.0	6.0	9.0	7.0	7.0	4.0
Uruguay	0.0	0.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	3.0	3.0	0.0	0.0	1.0

	Uzbekistan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
	Venezuela	1.0	1.0	0.0	0.0	1.0	0.0	2.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
	Zimbabwe	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
China (People's Republic of)	Total Patents	1,547.0	882.0	1,287.0	1,693.0	2,300.0	3,855.0	5,206.0	6,430.0	6,853.0	10,723.0	14,098.0	18,097.0	19,984.0	23,532.0	26,983.0	34,197.0	44,073.0	49,251.0
	Total co-operation with abroad	239.0	259.0	408.0	554.0	612.0	870.0	1,046.0	1,241.0	1,371.0	1,673.0	1,986.0	2,556.0	2,954.0	3,374.0	3,771.0	3,870.0	4,043.0	4,044.0
	Australia	1.0	0.0	0.0	5.0	3.0	9.0	6.0	9.0	10.0	12.0	15.0	9.0	9.0	7.0	8.0	8.0	13.0	16.0
	Austria	0.0	0.0	1.0	1.0	1.0	4.0	2.0	2.0	2.0	3.0	2.0	1.0	7.0	9.0	2.0	6.0	15.0	20.0
	Belgium	0.0	3.0	0.0	4.0	1.0	5.0	4.0	5.0	4.0	16.0	12.0	12.0	18.0	15.0	7.0	16.0	12.0	20.0
	Canada	3.0	11.0	2.0	5.0	12.0	10.0	14.0	9.0	12.0	6.0	17.0	28.0	18.0	26.0	24.0	27.0	21.0	27.0
	Chile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0
	Czech Republic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	..
	Denmark	2.0	2.0	3.0	4.0	7.0	3.0	7.0	11.0	12.0	21.0	22.0	27.0	29.0	11.0	16.0	21.0	13.0	28.0
	Estonia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0
	Finland	3.0	10.0	16.0	13.0	41.0	28.0	40.0	56.0	108.0	113.0	155.0	155.0	227.0	201.0	114.0	88.0	119.0	180.0
	France	8.0	9.0	9.0	16.0	17.0	35.0	98.0	153.0	154.0	217.0	264.0	220.0	262.0	252.0	186.0	207.0	216.0	165.0
	Germany	22.0	20.0	21.0	40.0	40.0	71.0	92.0	128.0	157.0	177.0	227.0	318.0	278.0	248.0	262.0	241.0	282.0	367.0
	Greece	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hungary	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Iceland	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ireland	0.0	1.0	0.0	1.0	0.0	3.0	0.0	4.0	2.0	7.0	2.0	7.0	5.0	9.0	6.0	16.0	17.0	9.0
	Israel	0.0	0.0	0.0	1.0	3.0	3.0	5.0	4.0	6.0	2.0	0.0	3.0	3.0	2.0	1.0	5.0	2.0	6.0
	Italy	1.0	1.0	1.0	0.0	0.0	0.0	1.0	2.0	2.0	6.0	4.0	11.0	1.0	3.0	10.0	8.0	9.0	3.0
	Japan	14.0	14.0	22.0	30.0	27.0	41.0	39.0	42.0	38.0	83.0	145.0	224.0	198.0	216.0	272.0	337.0	413.0	481.0
	Korea	1.0	6.0	21.0	18.0	15.0	16.0	14.0	31.0	42.0	36.0	36.0	45.0	82.0	43.0	97.0	98.0	85.0	84.0
	Luxembourg	0.0	0.0	0.0	1.0	1.0	5.0	2.0	2.0	0.0	3.0	0.0	1.0	2.0	0.0	3.0	0.0	3.0	1.0
	Mexico	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	..
	Netherlands	2.0	4.0	35.0	70.0	90.0	132.0	71.0	70.0	82.0	99.0	63.0	83.0	109.0	87.0	77.0	97.0	91.0	72.0
	New Zealand	0.0	1.0	2.0	1.0	1.0	0.0	2.0	2.0	0.0	3.0	0.0	1.0	1.0	3.0	1.0	3.0	3.0	3.0
	Norway	0.0	0.0	0.0	0.0	0.0	1.0	3.0	1.0	0.0	2.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	3.0
	Poland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	1.0	1.0	0.0	0.0	0.0
	Portugal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
	Slovak Republic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Slovenia	0.0	0.0	0.0	0.0	1.0	1.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
	Spain	0.0	0.0	0.0	0.0	0.0	3.0	2.0	2.0	0.0	0.0	2.0	3.0	2.0	2.0	2.0	3.0	1.0	2.0
	Sweden	0.0	1.0	5.0	6.0	10.0	20.0	31.0	55.0	79.0	67.0	91.0	140.0	193.0	199.0	168.0	175.0	160.0	206.0
	Switzerland	2.0	10.0	19.0	19.0	32.0	36.0	36.0	51.0	57.0	73.0	71.0	84.0	120.0	122.0	145.0	141.0	182.0	117.0
	Turkey	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	United Kingdom	8.0	9.0	17.0	14.0	24.0	29.0	33.0	16.0	49.0	64.0	70.0	82.0	62.0	50.0	58.0	56.0	76.0	89.0
	United States	124.0	125.0	170.0	234.0	206.0	328.0	444.0	451.0	434.0	527.0	648.0	982.0	1,157.0	1,336.0	1,541.0	1,275.0	1,408.0	1,251.0

	European Union (28 countries)	45.0	57.0	107.0	164.0	225.0	327.0	371.0	482.0	627.0	763.0	881.0	1,014.0	1,144.0	1,060.0	886.0	898.0	954.0	1,124.0
	Algeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Andorra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Argentina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Armenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Belarus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Bermuda	0.0	0.0	1.0	1.0	0.0	10.0	6.0	7.0	2.0	1.0	1.0	1.0	2.0	0.0	2.0	0.0	0.0	0.0
	Bosnia and Herze-govina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Brazil	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	2.0	1.0	0.0	0.0	2.0	0.0	2.0	1.0	0.0	0.0
	Bulgaria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Cayman Islands	0.0	0.0	0.0	0.0	4.0	3.0	20.0	38.0	47.0	66.0	62.0	72.0	102.0	97.0	434.0	893.0	725.0	688.0
	China	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Chinese Taipei	9.0	5.0	19.0	21.0	24.0	18.0	16.0	42.0	43.0	50.0	39.0	26.0	26.0	51.0	56.0	45.0	42.0	43.0
	Colombia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Costa Rica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Croatia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Cuba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0
	Cyprus	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0
	Democratic People’s Republic of Korea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Djibouti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ecuador	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Egypt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Salvador	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Serbia and Montene-gro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	North Macedonia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Georgia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Guatemala	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hong Kong - China	34.0	33.0	58.0	54.0	52.0	48.0	53.0	54.0	34.0	50.0	46.0	59.0	38.0	67.0	83.0	93.0	187.0	172.0
	India	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	1.0	4.0	0.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0
	Indonesia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Iran (Islamic Repub-lic of)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Jamaica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Jordan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Kazakhstan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Kenya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Kuwait	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Latvia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Lebanon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0	1.0	0.0
	Liechtenstein	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0	3.0

	Lithuania	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Malaysia	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	4.0	0.0	5.0	3.0	5.0	2.0	12.0	2.0	1.0
	Malta	1.0	0.0	0.0	0.0	0.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Monaco	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mongolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
	Morocco	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nigeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pakistan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Panama	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Peru	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Philippines	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
	Puerto Rico	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	2.0	1.0
	Republic of Moldova	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Romania	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Russian Federation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	4.0	2.0	0.0	2.0	1.0	0.0
	Saudi Arabia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	1.0	0.0	0.0	1.0	3.0	3.0	7.0
	Seychelles	0.0	0.0	0.0	6.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
	Singapore	3.0	5.0	4.0	9.0	10.0	10.0	14.0	20.0	23.0	10.0	31.0	24.0	42.0	61.0	81.0	50.0	52.0	49.0
	South Africa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0
	Sri Lanka	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Thailand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	1.0	0.0	0.0	1.0	1.0	2.0	0.0
	Trinidad and Tobago	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Tunisia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ukraine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	United Arab Emirates	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	5.0	1.0	0.0	5.0
	Uruguay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Uzbekistan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Venezuela	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Zimbabwe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
World	Total Patents	102,746.0	104,710.0	108,587.0	118,594.0	132,449.0	144,892.0	154,406.0	159,880.0	150,262.0	156,622.0	172,190.0	188,385.0	196,348.0	######	207,806.0	218,227.0	######	235,071.0
	Total co-operation with abroad	16,026.0	16,902.0	18,483.0	20,006.0	21,679.0	23,773.0	25,231.0	26,481.0	24,638.0	24,591.0	26,247.0	28,101.0	29,525.0	30,695.0	30,623.0	31,048.0	31,288.0	30,014.0
	Australia	146.0	142.0	127.0	181.0	203.0	210.0	222.0	214.0	182.0	177.0	196.0	203.0	170.0	218.0	166.0	179.0	175.0	201.0
	Austria	222.0	252.0	284.0	332.0	293.0	296.0	294.0	217.0	272.0	264.0	315.0	333.0	376.0	372.0	362.0	406.0	401.0	367.0
	Belgium	253.0	252.0	326.0	368.0	404.0	463.0	530.0	487.0	465.0	496.0	521.0	548.0	593.0	500.0	481.0	483.0	578.0	529.0
	Canada	591.0	537.0	499.0	456.0	505.0	507.0	565.0	644.0	584.0	588.0	659.0	656.0	655.0	647.0	530.0	468.0	515.0	469.0
	Chile	1.0	5.0	2.0	4.0	3.0	1.0	1.0	9.0	7.0	6.0	8.0	8.0	15.0	6.0	9.0	7.0	12.0	14.0
	Czech Republic	9.0	16.0	7.0	13.0	27.0	20.0	16.0	23.0	19.0	28.0	14.0	37.0	51.0	55.0	49.0	46.0	43.0	41.0
	Denmark	162.0	197.0	214.0	222.0	259.0	224.0	235.0	293.0	354.0	341.0	449.0	439.0	343.0	360.0	372.0	358.0	377.0	348.0
	Estonia	2.0	3.0	1.0	1.0	4.0	4.0	7.0	13.0	10.0	6.0	11.0	5.0	6.0	7.0	9.0	7.0	18.0	17.0

Finland	355.0	469.0	506.0	489.0	563.0	531.0	565.0	727.0	692.0	625.0	720.0	738.0	840.0	685.0	585.0	521.0	572.0	727.0
France	825.0	1,050.0	1,135.0	1,127.0	1,251.0	1,419.0	1,779.0	1,961.0	1,986.0	2,140.0	2,197.0	2,137.0	2,290.0	2,419.0	2,257.0	2,176.0	1,754.0	1,677.0
Germany	2,275.0	2,417.0	2,362.0	2,445.0	2,542.0	2,964.0	3,249.0	3,377.0	3,189.0	3,347.0	3,613.0	3,667.0	3,606.0	3,442.0	3,325.0	3,445.0	3,648.0	3,616.0
Greece	9.0	4.0	2.0	6.0	3.0	10.0	4.0	18.0	8.0	14.0	9.0	6.0	9.0	13.0	4.0	8.0	11.0	8.0
Hungary	18.0	14.0	13.0	17.0	28.0	21.0	17.0	21.0	29.0	18.0	18.0	14.0	25.0	17.0	15.0	22.0	20.0	19.0
Iceland	8.0	17.0	26.0	23.0	20.0	25.0	22.0	43.0	38.0	23.0	23.0	15.0	16.0	20.0	11.0	20.0	9.0	10.0
Ireland	137.0	209.0	202.0	206.0	212.0	320.0	261.0	304.0	315.0	293.0	336.0	331.0	312.0	295.0	283.0	388.0	403.0	349.0
Israel	154.0	135.0	122.0	116.0	141.0	154.0	169.0	186.0	150.0	135.0	149.0	138.0	172.0	161.0	173.0	159.0	178.0	206.0
Italy	167.0	172.0	164.0	169.0	177.0	212.0	182.0	218.0	187.0	239.0	204.0	270.0	216.0	252.0	230.0	277.0	289.0	253.0
Japan	599.0	595.0	785.0	954.0	1,052.0	1,105.0	1,058.0	1,014.0	928.0	1,018.0	1,136.0	1,310.0	1,269.0	1,543.0	1,601.0	1,657.0	1,893.0	1,960.0
Korea	73.0	112.0	127.0	159.0	188.0	307.0	340.0	347.0	328.0	409.0	537.0	532.0	612.0	545.0	637.0	601.0	599.0	644.0
Luxembourg	132.0	129.0	168.0	168.0	197.0	227.0	267.0	286.0	236.0	342.0	354.0	412.0	483.0	492.0	434.0	425.0	398.0	315.0
Mexico	10.0	5.0	17.0	22.0	43.0	37.0	43.0	42.0	41.0	17.0	46.0	24.0	32.0	38.0	44.0	46.0	37.0	40.0
Netherlands	1,037.0	955.0	2,114.0	2,233.0	2,307.0	2,270.0	2,009.0	2,271.0	2,243.0	1,899.0	1,692.0	1,557.0	1,704.0	1,784.0	1,748.0	2,060.0	1,649.0	1,388.0
New Zealand	40.0	31.0	43.0	43.0	34.0	35.0	49.0	42.0	36.0	47.0	40.0	40.0	41.0	48.0	47.0	47.0	60.0	43.0
Norway	68.0	92.0	104.0	48.0	79.0	94.0	104.0	105.0	87.0	124.0	120.0	93.0	120.0	160.0	149.0	126.0	173.0	124.0
Poland	8.0	17.0	20.0	14.0	23.0	13.0	18.0	12.0	22.0	29.0	22.0	25.0	25.0	27.0	34.0	24.0	35.0	33.0
Portugal	8.0	20.0	10.0	11.0	17.0	18.0	21.0	20.0	28.0	27.0	27.0	20.0	23.0	19.0	18.0	30.0	31.0	28.0
Slovak Republic	4.0	3.0	2.0	3.0	2.0	4.0	8.0	6.0	7.0	4.0	10.0	8.0	8.0	12.0	12.0	6.0	10.0	12.0
Slovenia	5.0	6.0	5.0	2.0	7.0	13.0	15.0	14.0	11.0	18.0	10.0	13.0	13.0	15.0	23.0	13.0	14.0	11.0
Spain	40.0	41.0	69.0	75.0	73.0	60.0	98.0	118.0	132.0	128.0	139.0	138.0	165.0	147.0	137.0	140.0	137.0	154.0
Sweden	900.0	865.0	685.0	909.0	927.0	1,019.0	1,116.0	1,351.0	1,422.0	1,147.0	1,214.0	1,283.0	1,540.0	1,536.0	1,586.0	1,493.0	1,335.0	1,406.0
Switzerland	1,496.0	1,750.0	1,858.0	2,044.0	2,204.0	2,461.0	2,623.0	2,866.0	2,738.0	2,856.0	2,928.0	2,939.0	3,053.0	2,869.0	3,031.0	2,925.0	2,956.0	2,626.0
Turkey	9.0	5.0	8.0	8.0	5.0	7.0	10.0	5.0	6.0	12.0	11.0	12.0	24.0	23.0	31.0	15.0	17.0	20.0
United Kingdom	1,151.0	1,082.0	1,022.0	1,060.0	1,085.0	1,103.0	1,083.0	1,124.0	979.0	968.0	1,015.0	1,161.0	1,065.0	1,102.0	1,088.0	1,190.0	1,284.0	1,247.0
United States	5,388.0	5,498.0	5,544.0	6,041.0	6,729.0	7,456.0	7,954.0	7,845.0	7,030.0	6,839.0	7,367.0	8,631.0	9,101.0	9,822.0	9,496.0	9,296.0	9,297.0	8,650.0
European Union (28 countries)	7,382.0	7,800.0	8,942.0	9,514.0	10,012.0	10,829.0	11,338.0	12,114.0	11,881.0	11,722.0	12,213.0	12,459.0	12,992.0	12,793.0	12,369.0	12,708.0	12,375.0	11,993.0
Algeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0
Andorra	1.0	2.0	0.0	0.0	2.0	0.0	2.0	1.0	1.0	0.0	2.0	1.0	1.0	2.0	0.0	1.0	4.0	6.0
Argentina	1.0	4.0	0.0	9.0	6.0	11.0	6.0	17.0	6.0	7.0	7.0	6.0	12.0	12.0	4.0	13.0	11.0	15.0
Armenia	2.0	2.0	2.0	1.0	2.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	5.0	0.0	0.0
Belarus	6.0	0.0	1.0	2.0	3.0	2.0	3.0	1.0	0.0	2.0	2.0	0.0	0.0	2.0	3.0	2.0	3.0	4.0
Bermuda	34.0	59.0	76.0	138.0	144.0	162.0	200.0	169.0	57.0	51.0	55.0	34.0	41.0	57.0	24.0	8.0	30.0	30.0
Bosnia and Herze-govina	0.0	2.0	0.0	0.0	0.0	0.0	2.0	0.0	1.0	0.0	0.0	0.0	1.0	2.0	0.0	0.0	1.0	0.0
Brazil	11.0	20.0	23.0	26.0	20.0	18.0	25.0	33.0	30.0	25.0	35.0	32.0	48.0	49.0	44.0	40.0	44.0	52.0
Bulgaria	5.0	1.0	5.0	13.0	2.0	3.0	3.0	6.0	3.0	5.0	4.0	3.0	8.0	6.0	10.0	10.0	2.0	6.0
Cayman Islands	69.0	79.0	97.0	84.0	65.0	87.0	134.0	171.0	120.0	143.0	178.0	157.0	160.0	177.0	495.0	958.0	777.0	771.0
China	43.0	36.0	76.0	78.0	129.0	221.0	306.0	339.0	350.0	467.0	669.0	785.0	994.0	998.0	1,217.0	1,481.0	1,760.0	1,902.0
Chinese Taipei	28.0	67.0	96.0	102.0	114.0	92.0	107.0	123.0	126.0	117.0	118.0	108.0	109.0	144.0	177.0	171.0	205.0	199.0
Colombia	0.0	0.0	0.0	1.0	3.0	4.0	6.0	9.0	3.0	7.0	0.0	3.0	8.0	11.0	7.0	16.0	10.0	9.0

	Costa Rica	0.0	2.0	1.0	2.0	3.0	3.0	0.0	1.0	3.0	1.0	2.0	2.0	4.0	2.0	1.0	3.0	6.0	3.0
	Croatia	6.0	7.0	0.0	9.0	6.0	8.0	5.0	6.0	2.0	4.0	4.0	2.0	0.0	1.0	3.0	4.0	6.0	2.0
	Cuba	1.0	1.0	4.0	3.0	2.0	0.0	1.0	2.0	1.0	0.0	2.0	1.0	2.0	1.0	0.0	1.0	0.0	2.0
	Cyprus	38.0	19.0	30.0	24.0	41.0	37.0	61.0	38.0	32.0	50.0	34.0	43.0	36.0	32.0	55.0	33.0	34.0	33.0
	Democratic People's Republic of Korea	0.0	1.0	2.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0
	Djibouti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ecuador	0.0	2.0	1.0	1.0	2.0	2.0	5.0	1.0	2.0	0.0	0.0	3.0	0.0	2.0	0.0	3.0	0.0	0.0
	Egypt	2.0	1.0	1.0	3.0	1.0	2.0	2.0	0.0	1.0	4.0	4.0	11.0	6.0	1.0	4.0	3.0	2.0	6.0
	El Salvador	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0
	Serbia and Montene-gro	0.0	3.0	0.0	2.0	1.0	2.0	1.0	1.0	3.0	0.0	3.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
	North Macedonia	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	0.0
	Georgia	1.0	1.0	1.0	1.0	0.0	0.0	2.0	2.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0
	Guatemala	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
	Hong Kong - China	99.0	99.0	144.0	148.0	162.0	175.0	187.0	184.0	157.0	210.0	161.0	187.0	166.0	207.0	278.0	232.0	422.0	353.0
	India	21.0	32.0	55.0	68.0	77.0	65.0	40.0	52.0	56.0	85.0	89.0	91.0	95.0	88.0	110.0	120.0	124.0	143.0
	Indonesia	3.0	1.0	1.0	0.0	2.0	1.0	2.0	5.0	5.0	3.0	4.0	3.0	10.0	1.0	1.0	2.0	5.0	6.0
	Iran (Islamic Repub-lic of)	1.0	1.0	1.0	1.0	0.0	1.0	3.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	4.0	1.0	0.0	4.0
	Jamaica	0.0	0.0	2.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	0.0	2.0	0.0	1.0	1.0	0.0
	Jordan	0.0	1.0	1.0	1.0	1.0	3.0	0.0	0.0	1.0	1.0	2.0	2.0	0.0	5.0	0.0	1.0	0.0	2.0
	Kazakhstan	1.0	1.0	0.0	5.0	0.0	0.0	1.0	1.0	0.0	6.0	2.0	4.0	2.0	3.0	5.0	3.0	10.0	3.0
	Kenya	0.0	1.0	0.0	3.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	2.0	1.0	1.0
	Kuwait	1.0	1.0	1.0	2.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	0.0	2.0	2.0	0.0	..
	Latvia	5.0	2.0	3.0	3.0	4.0	3.0	8.0	2.0	3.0	2.0	6.0	1.0	3.0	4.0	0.0	2.0	8.0	4.0
	Lebanon	0.0	1.0	0.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	0.0	3.0	1.0	3.0	4.0	9.0	2.0	10.0
	Liechtenstein	43.0	45.0	39.0	34.0	52.0	58.0	50.0	357.0	45.0	66.0	81.0	84.0	175.0	198.0	212.0	243.0	234.0	259.0
	Lithuania	3.0	1.0	2.0	1.0	2.0	7.0	4.0	1.0	2.0	4.0	4.0	5.0	9.0	9.0	6.0	9.0	7.0	7.0
	Malaysia	12.0	11.0	16.0	16.0	15.0	23.0	21.0	34.0	24.0	50.0	25.0	45.0	60.0	40.0	27.0	44.0	21.0	25.0
	Malta	2.0	5.0	4.0	6.0	7.0	18.0	23.0	22.0	17.0	35.0	38.0	37.0	57.0	51.0	43.0	43.0	28.0	30.0
	Monaco	7.0	11.0	9.0	12.0	16.0	7.0	9.0	8.0	11.0	9.0	12.0	11.0	15.0	29.0	24.0	14.0	8.0	12.0
	Mongolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
	Morocco	0.0	1.0	0.0	0.0	0.0	1.0	3.0	5.0	0.0	1.0	2.0	3.0	4.0	3.0	3.0	3.0	3.0	8.0
	Nigeria	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
	Pakistan	0.0	0.0	0.0	0.0	0.0	4.0	5.0	0.0	0.0	1.0	1.0	0.0	3.0	0.0	1.0	0.0	2.0	2.0
	Panama	19.0	11.0	31.0	30.0	29.0	15.0	14.0	14.0	7.0	8.0	7.0	11.0	10.0	10.0	7.0	1.0	7.0	29.0
	Peru	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	4.0	1.0	0.0	2.0	2.0	2.0	2.0	1.0	1.0	2.0
	Philippines	3.0	0.0	0.0	2.0	4.0	12.0	5.0	4.0	3.0	3.0	5.0	6.0	16.0	10.0	2.0	5.0	2.0	3.0
	Puerto Rico	1.0	3.0	5.0	7.0	12.0	17.0	9.0	29.0	15.0	26.0	43.0	39.0	50.0	58.0	48.0	110.0	214.0	281.0
	Republic of Moldova	2.0	1.0	0.0	1.0	0.0	0.0	1.0	2.0	0.0	1.0	1.0	2.0	1.0	1.0	0.0	1.0	0.0	..
	Romania	0.0	3.0	0.0	1.0	3.0	2.0	4.0	1.0	2.0	3.0	3.0	2.0	6.0	4.0	5.0	4.0	4.0	4.0

	Russian Federation	50.0	54.0	66.0	46.0	70.0	40.0	46.0	68.0	40.0	49.0	77.0	67.0	64.0	66.0	61.0	59.0	68.0	73.0
	Saudi Arabia	5.0	2.0	6.0	11.0	19.0	40.0	12.0	27.0	34.0	39.0	35.0	75.0	109.0	123.0	92.0	61.0	70.0	129.0
	Seychelles	2.0	1.0	1.0	12.0	3.0	5.0	5.0	9.0	10.0	11.0	7.0	14.0	7.0	12.0	9.0	5.0	5.0	3.0
	Singapore	76.0	99.0	99.0	136.0	153.0	142.0	217.0	203.0	244.0	246.0	287.0	302.0	387.0	422.0	442.0	398.0	308.0	307.0
	South Africa	37.0	28.0	22.0	15.0	21.0	21.0	19.0	20.0	39.0	28.0	24.0	36.0	30.0	19.0	40.0	38.0	29.0	25.0
	Sri Lanka	0.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.0	1.0	0.0	1.0	1.0	0.0	3.0	2.0	1.0
	Thailand	2.0	5.0	4.0	5.0	9.0	3.0	4.0	17.0	8.0	14.0	16.0	15.0	10.0	25.0	47.0	38.0	54.0	42.0
	Trinidad and Tobago	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	2.0
	Tunisia	2.0	1.0	2.0	4.0	4.0	1.0	4.0	1.0	3.0	2.0	0.0	0.0	6.0	3.0	0.0	1.0	3.0	0.0
	Ukraine	13.0	15.0	14.0	24.0	11.0	15.0	11.0	47.0	9.0	12.0	13.0	10.0	13.0	16.0	11.0	9.0	8.0	14.0
	United Arab Emirates	3.0	1.0	4.0	7.0	10.0	6.0	13.0	6.0	17.0	19.0	24.0	15.0	28.0	42.0	34.0	33.0	36.0	38.0
	Uruguay	4.0	4.0	9.0	6.0	6.0	1.0	3.0	1.0	5.0	2.0	2.0	3.0	4.0	5.0	6.0	4.0	6.0	4.0
	Uzbekistan	0.0	0.0	0.0	0.0	2.0	1.0	0.0	0.0	0.0	1.0	0.0	3.0	3.0	1.0	0.0	0.0	0.0	1.0
	Venezuela	1.0	1.0	0.0	0.0	1.0	2.0	2.0	0.0	1.0	0.0	2.0	0.0	1.0	1.0	0.0	0.0	1.0	1.0
	Zimbabwe	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Data extracted on 30 May 2020 12:50 UTC (GMT) from OECD.Stat