From few to many: main trends in the internationalization of business R&D*

Bernhard Dachs[a] and Georg Zahradnik[b]

Abstract

The paper studies the internationalization of business research and development (R&D) from 2003 up to 2017. It highlights three major results: first, R&D expenditure by foreign-owned firms has been growing, but more slowly than R&D expenditure of domestically owned firms. This is mainly due to the fast growth of business R&D in China, where foreign-owned firms have only a small share of overall business R&D. Second, R&D internationalization has become more network-like and diverse in terms of industries and countries, and less dominated by single relationships between large nations. The rise of emerging economies as host and home countries is just one of several major shifts. Service industries have gained importance as well, but often remain invisible because only a few countries collect data on R&D internationalization in services. The internationalization of R&D has yielded considerable benefits for home and host countries in the form of higher aggregate R&D expenditure and spillovers. Political de-globalization, weakening international institutions and a focus on "national interest" in science and technology may threaten these benefits in the future. A continuation of the policy of non-discrimination of foreign-owned firms and more, not less, international cooperation is necessary.

Keywords: internationalization, research and development, innovation, transnational companies

JEL classification codes: F23, O33, O38

* Received: 20 November 2021 – Revised: 18 March 2022 – Accepted: 21 March 2022

The authors would like to thank the editorial team of *Transnational Corporations* and two anonymous reviewers, as well as Mario Cervantes and Ari Van Assche for their valuable comments and suggestions. Financial support from the Organisation for Economic Co-operation and Development Directorate for Science, Technology and Innovation is gratefully acknowledged.

[a] Corresponding author. Center for Innovation Systems and Policy, AIT Austrian Institute of Technology, Vienna, Austria (bernhard.dachs@ait.ac.at)

[b] Center for Innovation Systems and Policy, AIT Austrian Institute of Technology, Vienna, Austria

1. Introduction

In recent decades, transnational corporations (TNCs) have invested considerable resources in research and development (R&D) outside their home countries, a process that has been labelled the internationalization of R&D (Dunning and Lundan, 2009; Papanastassiou et al., 2020; UNCTAD, 2005). The internationalization of R&D relates not only to investment policy but also to other policy areas such as science, technology and innovation policy. Foreign-owned firms account for large shares of or even most R&D expenditures in the business sector in small and medium-sized countries. Moreover, foreign-owned R&D-intensive firms provide jobs for high-skilled R&D personnel and are a major source of knowledge spillovers for domestically owned firms and research organizations (Crescenzi et al., 2020; Hall, 2010).

The aim of this paper is to provide an overview of the internationalization of business R&D up to 2017. This contribution builds on a rich literature. One stream of this literature analysed the motives, strategies and drivers behind R&D internationalization (Belderbos et al., 2016; Cantwell and Mudambi, 2005; Papanastassiou et al., 2020) and identified two main strategies. First, firms use R&D and innovation activities abroad to adapt existing products and technologies to the needs of foreign markets (a "competence-exploiting" strategy; Cantwell and Mudambi, 2005). Second, TNCs are increasingly forced to create or source new knowledge at locations abroad because this knowledge is often not available in the home country (a "competence-creating" strategy; Cantwell and Mudambi, 2005). Moreover, various contributions have revealed that host-country characteristics (such as market size and openness, availability of skilled personnel, excellence of research, spillovers and intellectual property rights regimes) explain the current patterns of R&D internationalization to a considerable degree (Athukorala and Kohpaiboon, 2010; Siedschlag et al., 2013; Thursby and Thursby, 2006).

A second stream of the literature has examined the impacts of R&D internationalization on home and host countries (Castellani and Pieri, 2013; D'Agostino et al., 2013; Dunning and Lundan, 2009; Guimón, 2009; Hall, 2010). The R&D activities of foreign-owned firms generate considerable benefits for their host countries. An important part of these benefits relates to technology spillovers from foreign-owned firms to domestic ones (Hayakawa et al., 2012; Keller and Yeaple, 2009; Keller, 2010; Mayer and Sinani, 2009; Singh, 2007). TNC affiliates can also contribute to structural change towards a higher share of technology-intensive firms and to the emergence of clusters in the host country (Crescenzi et al., 2020; Driffield et al., 2009). Some of these effects, for example in the form of reverse knowledge spillovers, also benefit the home countries of TNCs (Ambos and Schlegelmilch, 2006; D'Agostino et al., 2013).

Finally, another stream of the literature has addressed organizational aspects of overseas R&D activities (Gupta and Govindarajanan, 2000; Mudambi et al., 2014). R&D internationalization generates considerable costs for coordination and transfer of knowledge inside a company group. Moreover, the strong linkages between TNCs and their home innovation systems may hamper R&D internationalization (Narula, 2002; Patel and Pavitt, 1999). To offset these disadvantages, firms with overseas innovation activities need to derive considerable advantages in terms of access to localized knowledge.

The paper is structured as follows. Section 2 provides a brief overview of the data. Section 3 investigates global trends in R&D internationalization. Sections 4 and 5 investigate patterns of R&D internationalization at country level in more detail. Section 6 looks at the industry level, while section 7 provides an additional focus on the role of service industries in R&D internationalization. Section 8 discusses possible consequences of the COVID-19 pandemic for R&D internationalization. Section 9 presents policy aspects. Section 10 closes with some conclusions.

2. Data

The data collection for this paper focused on the countries with the highest R&D expenditures worldwide according to the Main Science and Technology Indicators Database of the Organisation for Economic Co-operation and Development (OECD). The final data set included 27 countries (see notes of figure 1). The data were collected from the OECD, the Statistical Office of the European Union (Eurostat) and national statistical offices, including the Bureau of Economic Analysis of the United States Department of Commerce, the National Bureau of Statistics of China, the Ministry of International Trade and Industry of Japan and the Office for National Statistics in the United Kingdom. Our data cover the period from 2003 to 2017, the last year for which data are available for most countries. In some cases, however, this period is shorter because of the lack of available data.

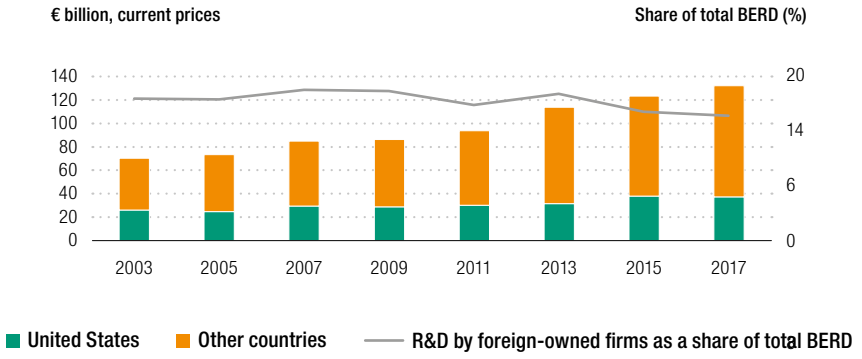
Considerably fewer data are available for non-OECD and non-European countries. The National Bureau of Statistics of China provides only aggregated data and no industry or country breakdown. No data are published by the statistical offices of Brazil, India, the Republic of Korea, the Russian Federation or Singapore. Given the scale of business R&D in these countries, this is a notable obstacle to a global analysis of R&D internationalization. Another challenge in non-OECD countries are statistical definitions that deviate from the OECD standards. The National Bureau of Statistics of China, for example, provides various data on R&D activities of foreign-owned firms in China. Following the Eurostat (2012) recommendations for the collection of data, we always chose data for majority ownership, in the case of China sole foreign funds – that is, enterprises owned by a non-Chinese entity.

The point of departure for the analysis is total business expenditure on R&D (BERD) in a particular country, which can be broken down into BERD by foreign-owned firms (inward BERD) and BERD by domestically owned firms (domestic BERD). Outward BERD, in contrast, is R&D expenditure by foreign affiliates of domestic TNCs. We employ this indicator in section 7.

3. Global trends

We first look at trends in R&D internationalization at the global level. Figure 1 shows inward BERD as well as inward BERD intensity, the ratio of inward BERD to total BERD. The data indicate a considerable increase in inward BERD from about €73 billion in 2003 to €124 billion in 2017. Inward BERD intensity, however, remained constant at 13 per cent, after reaching a peak of 16 per cent in 2007. Although firms spent much more on R&D abroad in 2017 than in 2003 in absolute terms, inward BERD intensity did not changed much. In 2017 it was even lower than in 2007. Alkemade et al. (2015) and Laurens et al. (2015a) come to similar conclusions with patent data. The main reason for this stagnation is – surprisingly – the rapid growth of BERD in China. Chinese firms contributed about a third of the increase in BERD during the period. That country's inward BERD intensity, however, is low. Moreover, inward BERD in the United States grew only slowly compared with total BERD.

Figure 1. R&D expenditure by foreign-owned firms by value and share of total BERD, 2003–2017



Source: Authors' calculations based on data from OECD, Eurostat and national statistical offices.

Note: Complete data: Austria, Canada, Ireland, Italy, Japan, Switzerland, the United Kingdom and the United States. From 2011 onward, only manufacturing and construction data: Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, the Netherlands, Norway, Poland, Romania, Slovakia, Slovenia, Spain and Sweden. For China and Israel: only data on large, solely foreign-owned manufacturing firms.

Global relations between countries in terms of inward BERD constitute an increasingly dense network. Figure 2 depicts the relations between the main players in this network by summarizing interactions between the European Union (EU) including the United Kingdom (EU-28) and China, Japan and the United States, as measured by inward BERD. The size of the pie charts shows the size of inward BERD for each country, while the slices of each pie chart represent inward BERD by EU, Japanese, Swiss and United States companies and by companies from the rest of the world. The countries included in the figure cover the lion's share of R&D expenditure of foreign-owned firms worldwide in manufacturing industries.

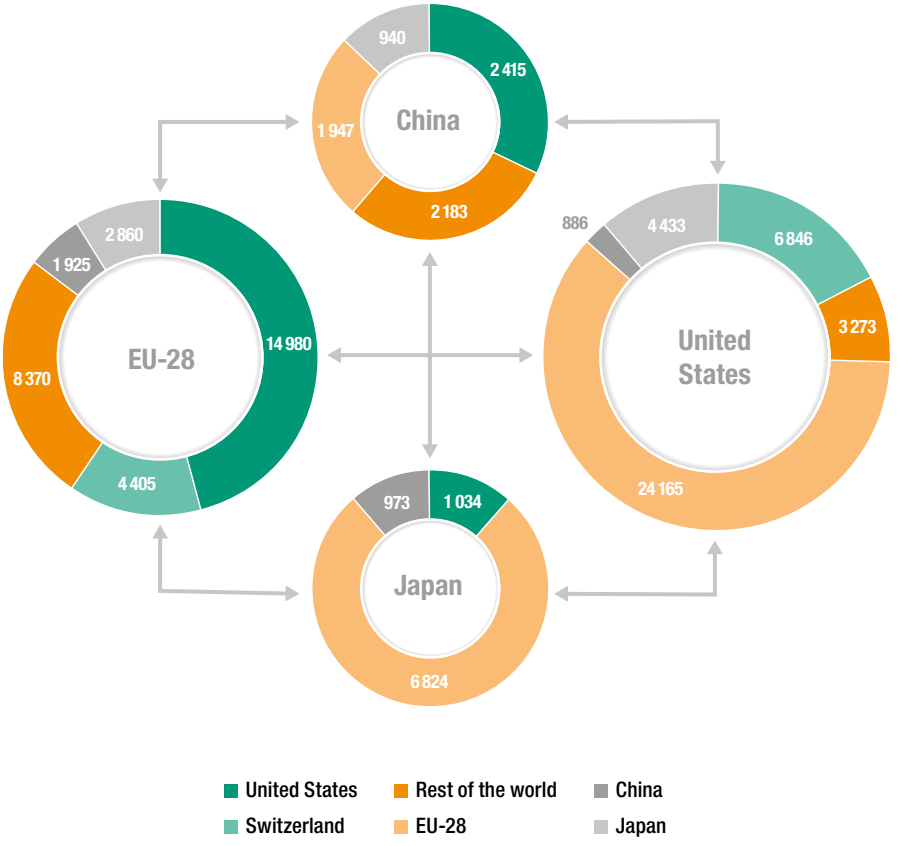
On the global scale, R&D internationalization is dominated by the relationship between the United States and the EU-28. In 2017, United States TNCs spent about €15 billion on R&D in the EU, while EU TNCs spent €24 billion in the United States. Another important European player is Switzerland. R&D expenditure by Swiss firms in the EU-28 and the United States amounts to more than €10 billion. Altogether, the United States hosts R&D activities by foreign-owned firms equivalent to about €40 billion, while the corresponding amount for the EU is €33 billion. R&D expenditure by EU firms in other EU member states (intra-EU internationalization) is excluded here.

These results contain two main uncertainties: First, most countries do not provide BERD data for foreign-owned firms in service industries; however, the services sector was one of the most dynamic in terms of business R&D during the last decade (section 7). Second, as mentioned earlier, no data are available for some countries, in particular for emerging economies. We do know, however, that inward BERD in these countries, including China, is still smaller than that of the United States and the EU. In 2017, China's inward BERD was slightly smaller than that of Japan and considerably lower than the corresponding values for Germany or the United Kingdom. According to United States outward BERD data, United States TNCs spent about $3.5 billion on R&D in China and India each, but $8.2 billion in Germany and $6.4 billion in the United Kingdom. With the perspective of growing tensions between China and the United States over technology (section 9), the further development of these investments is crucial for the future of R&D internationalization.

The role of emerging countries constitutes the biggest difference between the internationalization of R&D and the internationalization of production in global value chains (GVCs) (Timmer et al., 2014). According to data from the World Input-Output Database (WIOD), the share of value added in global manufacturing value chains that can be attributed to high-income countries is 48 per cent.[1] In contrast, we estimate that high-income countries attract at least 80 per cent of total inward BERD worldwide.

[1] Data provided by the WIOD consortium (Robert Stehrer, Vienna Institute of International Economic Studies).

Figure 2. Inward BERD in manufacturing between China, the EU-28, Japan and the United States, 2017 (€ million, current prices)



Source: Authors' calculations based on data fromthe United States Bureau of Economic Analysis (BEA), Eurostat, China National Bureau of Statistics and Japanese Ministry of International Trade and Industry.

Note: Inward BERD by United States firms in the EU-28 is proxied by BEA data on R&D of United States TNCs in the EU. Inward BERD by EU firms in Japan includes that by Swiss firms. No country breakdown for Chinese inward BERD was available; country shares are based on foreign patent applications.

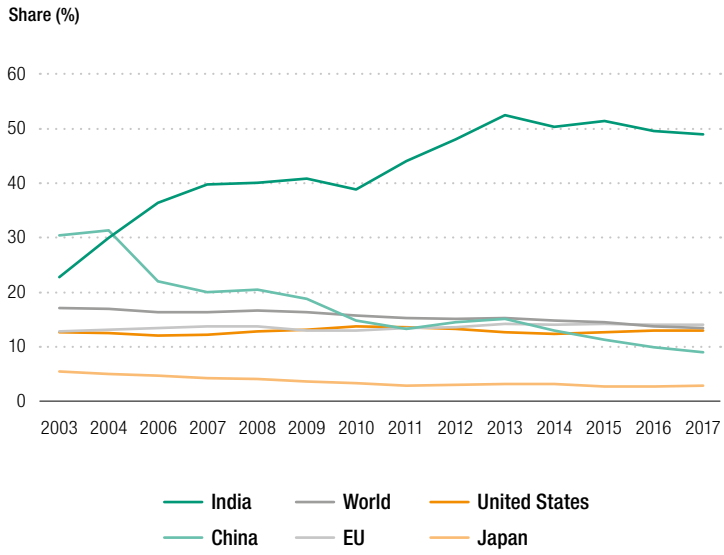
Patent data can help to estimate the amount of missing inward BERD in emerging economies. Patent data includes information on the location of the patent applicant(s) as well as on the location of the inventor(s). By comparing these two locations, researchers can identify all inventions in country A for which a patent application has been submitted by organizations from country B, C, D and so on (Laurens et al., 2015b). The share of patent inventions owned by foreign

applicants in total patent inventions in country A can be used as an indicator for R&D internationalization. We use patent applications under the Patent Cooperation Treaty with priority year 2017, retrieved from the OECD patent database.

From the data, it appears that the countries missing in figure 1 account for 12 per cent of domestic patent inventions applied for by foreign residents worldwide. The share of countries in Africa, Central and South America, and Asia (excluding China and India) that are host countries is small. Altogether, these countries account for about 4 per cent of global patent applications by foreign residents.

Patent data also confirm the trends described in this section. Figure 3 depicts the share of patent applications by foreign residents in total domestic patent inventions for various countries and the EU including the United Kingdom (EU-28) from 2003 to 2017. The share of foreign applicants is quite stable in the EU, Japan and the United States, whereas it decreases considerably in China. India is the only exception, with a rising share of domestic patent inventions owned by foreign applicants. The negative trend in China also contributes to an overall decreasing degree of R&D internationalization.

Figure 3. Patent inventions applied for by foreign residents as share of domestic patent inventions, in various countries and the EU, 2003–2017



Source: OECD Patent Database.

4. Patterns of R&D internationalization at country level

We now move from the global perspective to the country one. There is a considerable degree of heterogeneity in the internationalization of R&D at the national level. In some countries, foreign-owned firms account for more than half of total BERD, while in other countries their contribution to total BERD is below 20 per cent. To illustrate the relative size of R&D by foreign-owned firms in different countries, figure 4 compares inward BERD intensity for various countries between 2003 and 2017.

In general, inward R&D intensity is highest in certain small countries. Foreign-owned firms account for more than 50 per cent of total BERD in Austria, Belgium, Croatia, Czechia, Hungary, Ireland, Israel and Slovakia. All of these countries enjoyed considerably faster inward BERD growth since the start of the new millennium than did large countries. Other small countries, such as Denmark, Finland and Switzerland, had much lower inward BERD intensities.

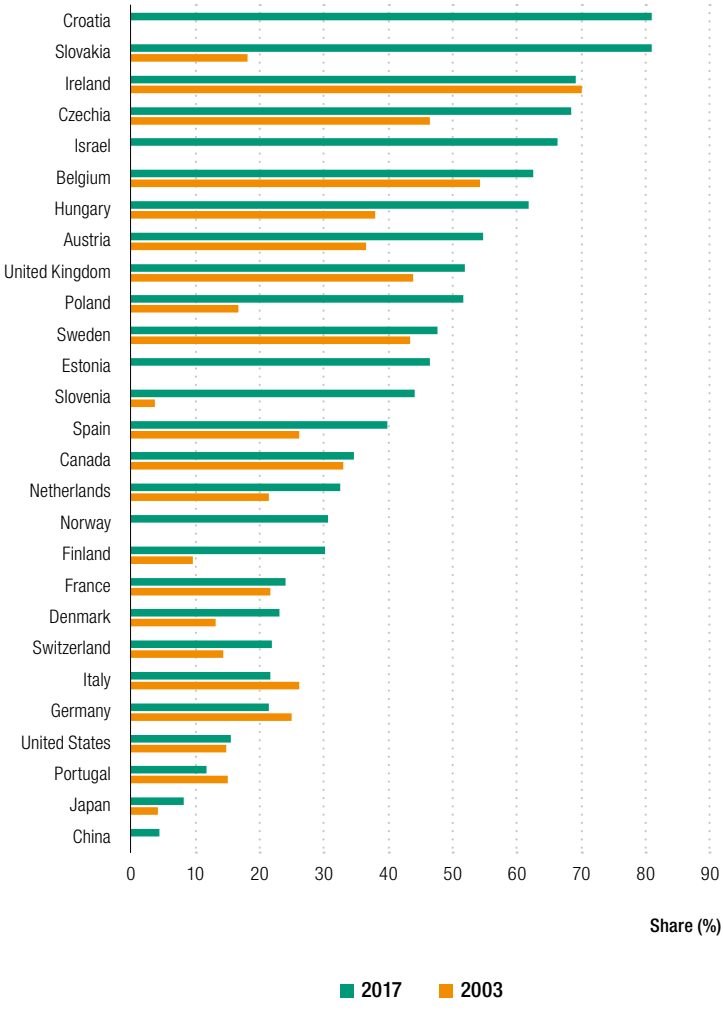
Large countries, such as France, Germany and the United States, show inward R&D intensities between 17 and 30 per cent, considerably lower than corresponding values for most small countries. China and Japan are the least internationalized countries in the sample, even though China is a major destination for new R&D ventures by TNCs. The United Kingdom stands out as a large country with a high inward BERD intensity. This can be explained by the role of the United Kingdom as a location for the European headquarters of non-European firms. The future will show how the withdrawal of the United Kingdom from the EU will affect inward BERD in the country.

The data indicate that levels of R&D internationalization have been increasing between 2003 and 2017 in the vast majority of countries where data are available. Only four countries (Ireland, Italy, Germany and Portugal) experienced a decrease in inward BERD intensity between 2003 and 2017, while 15 countries showed an increase. However, R&D internationalization emerges only slowly in some countries, as inward BERD intensities stagnate in Canada, France and several other countries. Huge changes between 2003 and 2017 can be observed only in small countries, most notably in some Central and Eastern European countries.

This result somewhat contradicts the message from figure 1 that R&D internationalization is stagnant or even decreasing. Large countries, in particular China or the United States, set the overall trend. These two countries have quite low and stagnant inward BERD intensities, strongly determining the overall picture. To gain an impression of the scale of R&D internationalization, it is therefore also important to consider absolute inward BERD. Total inward BERD is highest in the largest countries, even if these countries have low inward BERD intensities.

The United States accounts for the lion's share of total inward BERD (€38 billion) worldwide, followed by Germany and the United Kingdom. Israel has more inward BERD than Belgium, China, France, Japan or Sweden, which all have quite similar levels of total inward BERD at about €5 billion each.

Figure 4. Inward BERD intensity, 2003 and 2017 (Share of total BERD)



Source: Authors' calculations based on data from Eurostat, China National Bureau of Statistics, Japanese Ministry of International Trade and Industry and the United States Bureau of Economic Analysis.

Note: Data for Switzerland are for 2008 instead of 2003.

5. The role of different investor countries

The previous section showed that countries vary considerably in the contributions they receive from foreign-owned firms to total BERD. In this section we focus on the relative importance of different investor countries, identified as the home country of the TNC. In the past the most important investor countries were Germany, the United Kingdom and the United States. After 2011, "new" investor countries, mostly emerging economies in Asia, appeared in FDI statistics (Crescenzi et al., 2016; Giuliani et al., 2014; Narula, 2012). Israel and some other smaller countries became more active in recent years. Recent research (Athukorala and Kohpaiboon, 2010; Siedschlag et al., 2013) has shown that sociocultural or spatial proximity is an important factor for explaining the importance of single investor countries. The common language, for example, explains the large amounts of inward BERD by United States TNCs in Ireland and in the United Kingdom.

We measure the role of different investor countries by the share of inward BERD from a particular country in total inward BERD (table 1). The table distinguishes between Germany, other member countries of the EU, the United States and all other non-EU countries. The importance of geographical proximity is illustrated by the data for Austria and Czechia, where the largest shares of inward BERD come from neighbouring Germany. Belgium, another neighbour, has only weak ties with Germany. Central and Eastern European countries have seen high growth rates in inward BERD in recent years; this growth mostly originated from European TNCs, including German companies. R&D internationalization in these countries therefore entails a strengthening of ties among EU member states. Slovenia and Croatia are exceptions, with high shares of inward BERD from non-EU countries.

The last two columns of table 1 report the share of the largest country or top investor country in total inward BERD for 2007 and 2017. As a general trend, the share of the top investor country declined in the majority of countries. In 2007, four countries had a share of more than 50 per cent for the top investor country; in 2017, only Croatia was left. Thus, dependence on a single investor country decreased. The internationalization of R&D evolved from dyadic relations and regional integration with neighbouring countries towards a more global integration. If we consider that knowledge transfer from abroad is a main benefit for host countries, more heterogeneity in terms of investor countries may also mean more heterogeneous knowledge, which is a good thing. However, country patterns should not be overinterpreted as they often result from the activities of a few TNCs; single investment decisions by TNCs have a big impact on the national level when total BERD in the country is small.

TNCs from "new" investor countries are often included in a "rest of the world" group. A rough estimate for the share of this "rest of the world" group is total inward BERD minus inward BERD by TNCs from Canada, the EU, Japan, Switzerland

Table 1. Share in total inward BERD and top investor country share by host country, 2007 and 2017 (Per cent)

	Share in 2007				Share in 2017				Top investor share	
Country	Germany	Other EU	United States	Other non-EU	Germany	other EU	United States	Other non-EU	2007	2017
Austria	56	13	9	22	42	16	10	32	56	42
Belgium	4	47	42	7	4	39	43	25	42	43
Bulgaria	..	20	..	80	9	43	4	45	..	..
Croatia	..	..	..	..	1	25	1	73	..	55
Czechia	40	37	2	21	47	23	11	19	40	47
Denmark	23	55	13	9	23	25	17	35	30	23
Estonia	2	23	69	6	3	66	12	20	69	39
Finland	6	32	30	32	7	31	30	32	30	30
France	18	33	34	16	16	34	21	29	34	21
Germany	..	47	36	18	n/a	45	24	31	36	24
Hungary	36	55	6	3	42	24	12	22	36	42
Italy	..	..	..	..	15	40	17	28	..	17
Netherlands	7	38	32	23	7	24	36	33	32	36
Norway	4	82	6	7	6	40	28	26	49	28
Poland	7	63	27	3	12	..	19	..	27	19
Slovakia	22	62	14	2	30	52	7	11	34	34
Slovenia	..	..	..	..	28	26	..	46	71	28
Spain	15	46	18	20	25	53	12	10	18	26
Sweden	2	52	39	7	19	31	9	41	39	26
United Kingdom	6	30	51	14	6	24	37	33	51	37
United States	14	46	..	39	14	40	..	46	26	16

Source: Authors' calculations based on data from OECD, Eurostat, the United States Bureau of Economic Analysis and the United Kingdom Office for National Statistics.
Notes: The United States is included in other non-EU in Belgium and Slovenia. Only manufacturing except for Austria, the United Kingdom and the United States.

and the United States (table 2). R&D expenditure by this group of countries in the EU (without the United Kingdom) increased from €2 billion or 14 per cent of total inward BERD in 2013 to 19 per cent in 2017. Data for the years before 2013 are mostly not available. The corresponding value for the United States has risen from 11 per cent (2013) to 14 per cent (2017), so the share of inward BERD by "new" investor countries is a bit higher in the EU than in the United States. These results, however, should be considered only as a lower threshold as some host countries do not report data for individual investor countries.

Table 2 shows some interesting results at the level of individual countries. Inward BERD by Chinese-owned firms in Europe increased considerably, even if this growth was partly due to missing data for 2013 and before. From these results, we can assume that Chinese firms spent roughly the same on R&D in Europe in 2017 as Japanese firms did. This growth is most likely the result of some takeovers by Chinese firms in recent years. Chinese inward BERD in the United States is about $1 billion, so in 2017 the EU hosted more R&D by Chinese firms than by United States firms. This may be an early sign of the geopolitical tensions between the United States and China. Indian, Israeli and Korean firms, in contrast, prefer the United States to the EU by a wide margin. The drop in R&D by Indian firms in the EU from 2013 to 2015 can be explained by disinvestments in Germany.

Table 2. R&D expenditure by TNCs from "new" investor economies in the EU and the United States, 2013, 2015 and 2017

	EU (€ million)			United States ($ million)		
	2013	2015	2017	2013	2015	2017
Inward BERD without Canada, China, Europe, Japan and the United States	2 036	1 779	2 974	5 238	6 259	7 594
Includes:						
China	207	558	900	449	548	1 422
Hong Kong (China)	25	14	225	43	..	634
Republic of Korea	49	34	297	710	1 067	1 557
India	329	56	89	93	107	213
Singapore	10	68	66	382	388	403
Taiwan Province of China	9	10	20	96	121	87
Israel	77	73	116	927	863	1 097
Offshore financial centres	342	226	587	..	..	..

Source: Authors' calculations based on data from Eurostat and the United States Bureau of Economic Analysis.

Notes: Values for the EU have been summed from data for individual countries published by Eurostat; Ireland and the United Kingdom not included.

Inward BERD by TNCs from other Asian countries in the EU fell short of Chinese investments. The Republic of Korea followed with about €300 million. Indian firms spent at least €88 million on R&D in the EU; however, data on inward BERD of Indian firms in the United Kingdom – by far their most important host country – are not available. The presence of Korean firms was much smaller in the EU than in the United States, which may be explained by larger potential knowledge sources in the United States for information and communication technology (ICT).

Israel gained importance as an investor country as well, but R&D activities by Israeli TNCs in the EU are still very limited when compared with those in the United States. Another rising group of economies are offshore financial centres. This group includes the Bahamas, Bermuda, the Cayman Islands, Jersey, Liechtenstein and others. In 2017, they accounted for about 10 per cent of total inward BERD by extra-EU firms (excluding those from Canada, Japan, Switzerland and the United States) in the EU. This group most likely consists of TNCs with roots in the EU or in the United States that moved their head offices for tax purposes. Data for the United States are not available for this country group.

6. The industry perspective

The internationalization of R&D is also highly industry specific. Table 3 provides an overview of R&D internationalization at the industry level. Owing to data constraints, it includes only the seven largest manufacturing industries measured by inward BERD. These are all high-technology or medium-high technology industries: chemicals; pharmaceuticals; machinery and equipment; computer, electronic and optical products; electrical machinery and apparatus; motor vehicles; and other transport equipment (including aircraft and spacecraft).

The table shows clear geographical preferences for different industries, which may reflect locational advantages: the United States shows a specialization in pharmaceuticals and electronics, while the EU-28 countries have high shares in all other industries. The pharmaceutical industry was the largest in R&D internationalization in 2017 with a worldwide inward BERD of €29 billion. R&D activities of foreign-owned firms in pharmaceuticals were highly concentrated in the United States. Spillovers may be particularly relevant in science-based industries such as pharmaceuticals. There is evidence that excellent knowledge has become more concentrated (Crescenzi et al., 2016; Paunov et al., 2019), which makes these strategies even more relevant.

BERD in the motor vehicles industry was dominated by four large countries – the United States, the United Kingdom, Japan and Germany – which together host almost 90 per cent. Producers of computers, electronic and optical products accounted for €12 billion in inward BERD worldwide, ranking the industry third,

behind only pharmaceuticals and motor vehicles. Again, the United States was the single most important host country. Within the EU-28, more than two thirds of worldwide inward BERD in the industry is concentrated in the three large countries: Germany, France (14 per cent each) and the United Kingdom (13 per cent). The distribution of inward BERD in electrical machinery and apparatus was quite similar to that in the computer industry.

Inward BERD in the remaining industries, by contrast, is much less concentrated. The EU-28 attracted about two thirds of total inward BERD in chemicals and chemical products, while most of the remaining third was located in the United States. Within the EU, a number of countries accounted for more than 5 per cent of worldwide inward BERD in the chemical industry, most notably the three largest countries – Germany (18 per cent), France (11 per cent) and the United Kingdom (9 per cent) – but also some medium-sized countries such as the Netherlands (5 per cent).

Table 3. Share of total inward BERD by host country and industry, 2017
(Billions of euros and per cent)

Country	Chemicals	Pharmaceuticals	Computers, electronics	Electrical machinery	Machinery	Motor vehicles	Other transport
Total (€ billion)	5.0	29.1	12,2	4,7	8.5	16.8	3.8
Austria	3	1	4	11	6	4	1
Belgium	3	7	1	1	3	1	0
Czechia	0	0	0	3	1	2	1
Denmark	1	0	1	1	4	0	0
Finland	1	0	2	4	2	0	1
France	11	2	14	5	7	5	5
Germany	18	2	14	23	28	16	42
Hungary	0	0	0	1	0	1	0
Italy	3	1	1	6	5	1	6
Netherlands	5	1	2	1	3	0	1
Poland	0	0	1	1	0	1	1
Spain	2	1	0	2	1	3	11
Sweden	3	0	1	7	2	10	4
United Kingdom[a]	9	9	13	5	9	21	2
Japan	9	9	13	5	9	21	2
United States	31	65	35	25	28	31	12
EU-28	62	25	56	73	73	66	75

Source: Authors' calculations based on data from OECD, Eurostat, the United States Bureau of Economic Analysis, the United Kingdom Office for National Statistics and Japanese Ministry of International Trade and Industry.

[a] Data for the United Kingdom are for 2018 instead of 2017.

Other transport equipment is the only industry segment in which the United States was not the single most important location; it ranked fourth, with a share of only 12 per cent of total inward BERD worldwide. In contrast, Germany accounted for more than 40 per cent. Spain (at 11 per cent) also significantly contributed to the cumulative EU share of about 75 per cent. However, it should be noted that intra-EU linkages, in particular in the aerospace industry, were responsible for the lion's share of the inward BERD in some EU countries. The distribution across countries therefore followed the locational decisions of Airbus and other European aerospace companies, which in turn are also shaped by political considerations to a considerable degree.

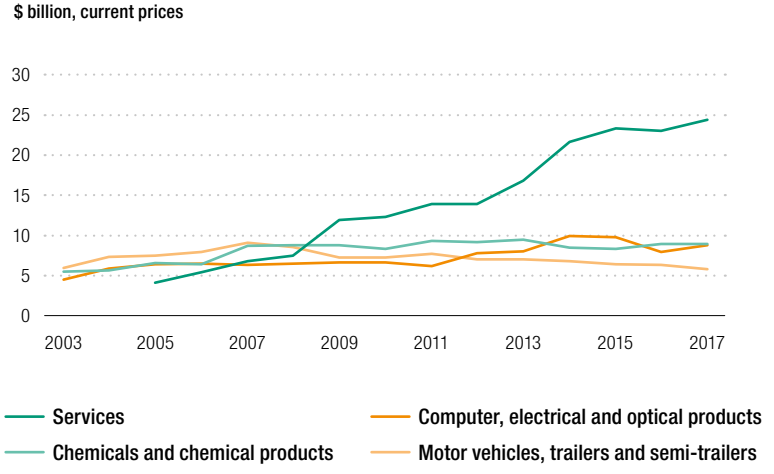
7. The role of service industries in R&D internationalization

Service industries have intensified their R&D efforts considerably in recent years (OECD, 2015). They also play a vital part in the internationalization of R&D. Yet, very little is known about this trend. National statistical offices in the EU are only required to collect inward BERD data for mining, manufacturing, utilities and construction, but not for service industries (Eurostat, 2012, p. 75); only a few countries, including Austria, Sweden, the United Kingdom and the United States, can provide such data. From the available data, it appears that services account for a quarter to a third of inward BERD. Generalizing from this approximation, it can be expected that there is much more R&D by foreign-owned firms in services than official statistics currently report.

The United States is one of the few countries that provides detailed data for services. Figure 5 depicts outward BERD by United States TNCs – that is, expenditure outside the United States – by the industry of the subsidiary. From the figure it appears that the services sector was the main driver behind the expansion of R&D abroad by United States TNCs. All other sectors have remained stagnant since the financial crisis of 2008. In 2017, services accounted for 44 per cent (or $24 billion) of United States outward BERD. This corresponds to the share of service industries in total business R&D, in several OECD countries, which is about 40 per cent (De Backer et al., 2015).

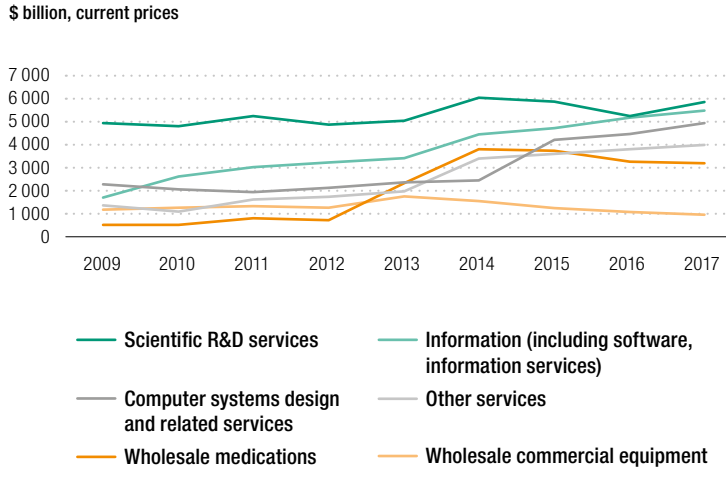
Figure 6 provides a closer look at United States outward BERD in service industries since the financial crisis of 2008. Scientific R&D services were the largest segment. They include corporate R&D centres of TNCs, which are often organized as independent legal entities and thus classified as scientific R&D services, not manufacturing firms. Another services sector segment that is closely related to manufacturing is wholesale. This segment includes firms that are affiliated with manufacturing TNCs but recognized as wholesale firms because they have no manufacturing activities but sell the products of their parent company. Wholesale commercial equipment and wholesale medication are the two most important examples.

Figure 5. R&D expenditure abroad by United States TNCs in various sectors and industries, 2003–2017



Source: Authors' calculations based on data from the United States Bureau of Economic Analysis.

Figure 6. R&D abroad by United States TNCs in various segments of the services sector, 2009–2017



Source: Authors' calculations based on data from the United States Bureau of Economic Analysis.

The rising R&D expenditure of service industries also reflects a changing division of labour between specialized suppliers of (knowledge-intensive) services and manufacturing firms (De Backer et al., 2015). This specialization promotes trade in R&D services between firms, often within GVCs (Moris, 2018). One example is contract R&D services. For example, the pharmaceutical industry has outsourced clinical trials and other stages of the R&D process to specialized firms during the last decade. Moreover, the emergence of R&D-intensive biotechnology firms has created a new division of labour between small and large firms in the pharmaceutical industry. There is also an increasing division of labour within service value chains; that is, specialized suppliers who provide services to other service firms. An example are various creative and media services. The current trend towards teleworking will certainly expand this "slicing up" of service value chains.

A third important driver of R&D internationalization in services are information, communication and software services. Their growth is clearly driven by new opportunities provided by ICT. Hernández et al. (2019) show that ICT services increased their share of global BERD from 11 per cent in 2009 to 15 per cent in 2019. Currently two service companies – Alphabet and Microsoft – are among the top five largest R&D performers worldwide. New technologies such as artificial intelligence may further contribute to the growth of information services.

United States outward BERD data also make it possible to relate various service industries with the host countries where these investments take place. To compare the specialization of different host countries in service R&D of United States firms, we calculate a revealed comparative advantage (RCA) index (see annex) that relates the share of services in a particular host country to the corresponding share of services in total BERD by United States companies abroad.

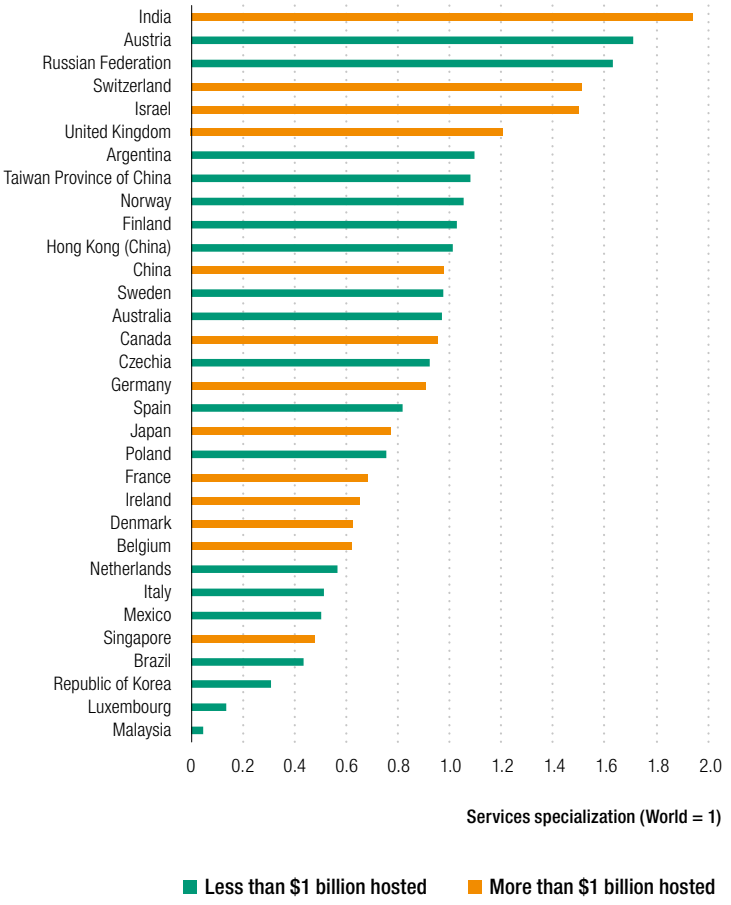
The results are depicted in figure 7. A value higher than one means that a country is specialized in services relative to the world average in United States outward BERD. Results for smaller countries should be treated with caution: even single investments can change the overall specialization of small countries. Countries that host less than $1 billion of outward BERD of United States TNCs are therefore highlighted in grey.

The RCA index shows that among the large host countries, India and Israel as well as Switzerland and the United Kingdom have the highest specialization in R&D in services. Investment data (Joseph et al., 2019) confirm this finding: for example, ICT and commercial R&D services account for more than 80 per cent of total R&D-related FDI in India. Argentina, Austria and the Russian Federation also have a high specialization index but host only a small volume of R&D activities compared to the aforementioned countries. A low service specialization index value, in contrast, indicates that United States TNCs in those countries specialize in manufacturing R&D or in mining. Specialization values below 0.6 can be found in Western European countries, including Belgium, Denmark, Italy and the Netherlands,

but also in the Republic of Korea. The second largest host country of R&D activities by United States TNCs – Germany – has an index value of 0.9 and is therefore quite in the middle of the distribution. China has a similar position.

From the figure it appears that services-related outward BERD predominantly takes place in countries that have only recently become major host countries for United States R&D investments, in particular Israel and Asian countries without Japan. The specialization index for the EU without the United Kingdom is 0.79, whereas the value for Asia (without Japan) is 1.11.

Figure 7. Services BERD specialization index, various host countries, as outward BERD by United States TNCs 2017



Source: Authors' calculations based on data from the United States Bureau of Economic Analysis.

These results also indicate that changes in the relative importance of host countries may proceed through expansion into new locations and industries rather than through disinvestment. The volume of R&D in "old" manufacturing industries by United States TNCs held constant in recent years; at the same time, growth was much stronger in services and in Asian locations. The EU still hosts 43 per cent of all R&D by United States TNCs in manufacturing, but only 27 per cent of that in information services and 33 per cent in professional, scientific and technical services. The shift towards services therefore results in a decrease of Europe's share in total outward BERD of United States companies. This leads to the question, what factors make emerging economies attractive for service R&D of United States firms? This may be a fruitful question for further research.

Finally, can we generalize these findings for United States service TNCs? The shares of European and Asian firms in global R&D expenditure in ICT services are much lower than those of their United States competitors. European, Japanese and to some extent also Chinese and Korean TNCs are much more specialized in manufacturing – in particular in automotive and chemicals – than United States firms. Thus, the trends observed in this section may overstate the actual development. Obviously, more data on R&D internationalization in services are needed than are available today.

8. COVID-19 and the internationalization of R&D

Measures to contain the COVID-19 pandemic brought the world economy to a standstill during the first half of 2020 and severely affected FDI (UNCTAD, 2021). The only currently available source on the effects of the COVID-19 crisis on R&D internationalization is fDi Markets,[2] a database that provides information on announced greenfield investment projects from media sources. Its data show a decline in the number of greenfield R&D investment projects by 34 per cent from 2019 and 2020, in line with an approximate 30 per cent decline in all FDI projects.

The economic crisis of 2020 most likely has also affected the ability of companies to invest in R&D (Paunov and Planes-Satorra, 2020), although evidence on the size of these losses is not yet available. From the literature, however, we can say that firms reduce their R&D activities during a recession because of liquidity constraints, restrictive bank lending or demand uncertainty, among other factors (Barlevy, 2007). Experiences from the global financial crisis of 2008/09 indicate that the crisis hit R&D expenditure of foreign-owned firms harder than that of domestically owned firms (Dachs et al., 2014): in only five countries did inward BERD grow faster than

[2] See www.fdimarkets.com.

domestic BERD between 2007 and 2009. In the majority of countries (12 out of 17), R&D expenditure by foreign-owned firms decreased or grew more slowly than R&D expenditure by domestically owned firms. This may be explained by the fact that TNCs are usually more exposed to international trade than domestically owned firms, and R&D internationalization is closely connected to GVCs in production (Belderbos et al., 2016). Thus, we may also assume a decrease of inward BERD relative to total BERD during the COVID-19 crisis.

A more subtle, long-term effect of the crisis may come from obstacles to R&D cooperation. Knowledge sourcing by TNC affiliates crucially depends on cooperation with external partners in the host country, which often takes place in face-to-face interactions. These interactions have been severely restricted by travel constraints and the temporary shutdown of university labs in several countries during the COVID-19 pandemic. The pandemic also demonstrated that digital tools can substitute for face-to-face interaction, as many firms moved to digital cooperation tools in order to proceed with their operations during 2020 (OECD, 2021). Such tools are certainly sufficient to maintain exchange in long-established partnerships and within a TNC but may not be sufficient enough to establish cooperation with new partners. Forming new partnerships requires building trust and a common understanding in the beginning, which seems only possible in face-to-face communication. Underdeveloped external networks and a consequent lack of heterogenous external partners are the main obstacles to radical innovation (Sandberg and Aarikka-Stenroos, 2014).

Another rather unexpected effect of the pandemic is a surge in investments in digital technologies (Paunov and Planes-Satorra, 2020). We speculate that these investments may have a negative, de-globalizing effect on R&D internationalization when they allow firms to better cooperate and transfer knowledge over distance. The availability of localized knowledge in the host country that is not available in the home country is one of the main reasons why firms go abroad with their R&D activities. Higher degrees of digitalization may therefore reduce the need for R&D internationalization when firms are able to access this knowledge from their home countries. These considerations, however, are highly speculative; the current trend in the geography of innovation is not more equality, but a more unequal distribution of innovative activity (Paunov et al., 2019). Digitalization helps firms to "orchestrate" GVCs and link knowledge and production globally (Alcácer et al., 2016), so we may see more, not less R&D internationalization because of the COVID-19 pandemic.

9. Policy trends

R&D internationalization takes place within the multinational framework of trade and investment policies. This policy framework has shown some signs of weakness recently: Witt (2019) identifies the diminishing role of international trade institutions and the United States as global "hegemon" as reasons for political de-globalization. Rodrik (2018) considers the rise of populism as another reason for political de-globalization. Moreover, science and technology increasingly have become the focus of international policy, as seen in the "tech cold war" between China and the United States,[3] discussions about "technology sovereignty" in the EU (European Commission, 2021) and some indications that China shields its growing R&D system from the rest of the world (Schwaag Serger et al., 2021).

In the OECD and in EU member states, however, today's policies towards TNC affiliates still follow the principle of non-discrimination, as can be seen by the very small number of science, technology and innovation policy measures directed towards TNCs.[4] Increasing technological competition between countries may reverse this practice, despite the benefits of R&D internationalization discussed in the introduction. It may reduce the willingness of TNCs to locate R&D outside their home countries, or it may favour some host countries while making investments in other locations less attractive. Governments striving for technological sovereignty may also prefer domestic firms when it comes to R&D funding, or they may restrict exchange between foreign firms and the domestic knowledge base. This may lead to less R&D internationalization and fewer benefits from it. Given the global nature of many of today's challenges, however, it seems that we need more, not less cooperation.

Another policy trend that is less obvious but nevertheless has high relevance for the internationalization of R&D are tax credits, which have become an increasingly popular support for business R&D in recent years (Appelt et al., 2019). The number of OECD countries that grant tax credits for business R&D increased from 19 to 30 (out of 36) between 2012 and 2018; the amount of tax reliefs added up to $45 billion in 2016 (Appelt et al., 2019).

The literature usually assumes that financial incentives are not important attractors for the R&D activities of multinational enterprises (Athukorala and Kohpaiboon, 2010; Thursby and Thursby, 2006). Tax credits for R&D challenge this finding because they are particularly appealing for TNCs. First, R&D tax credits offer opportunities to minimize corporate income taxes. This gives TNCs additional benefits that smaller

[3] *The Economist*, "Huawei and the tech cold war. China v America", 18 July 2020.
[4] EC-OECD, STIP Compass: International Database on Science, Technology and Innovation Policy (STIP), https://stip.oecd.org (accessed 7 May 2021).

firms do not have, for example by shifting R&D expenditure between countries. Income-based tax incentives for R&D that allow profit shifting through licence income are particularly attractive for TNCs with multiple R&D locations. Second, R&D tax credits incur considerably lower application costs than direct R&D funding, so it may be possible for a TNC subsidiary to raise much more money than with a single application. Third, several countries do not have an upper limit for funding from R&D tax credits. This favours firms with large R&D performance because they can avoid administering a large number of single project applications.

Empirical evidence for individual countries that have introduced tax credits reveals that this instrument has indeed displaced other forms of R&D funding and is by far the most popular type of public support for the R&D activities of TNC affiliates (European Commission, 2017). Tax credits may have a much larger role in financing R&D in TNCs today than they had during the 2010s. They may have changed the way TNCs perceive the locational advantages of countries and plan investments in R&D.

10. Summary and closing remarks

This paper provided an overview of the main trends in the internationalization of business R&D up to 2017. R&D expenditure by foreign-owned firms has increased in absolute terms, but not as a share of total business R&D expenditure (BERD). This is mainly due to the fast growth of business R&D in China, where foreign-owned firms have only a low share in total BERD.

R&D internationalization has become more diverse during the last decade and moved from dyadic relationships between neighbouring countries towards a more network-like pattern of interrelationships. Today, more countries are involved in R&D internationalization than ever before. Emerging economies, most notably India and China, have been able to increase their share of global inward BERD in recent years but are still hosting considerably less R&D by foreign-owned firms than are either countries in Europe or the United States. The growth of R&D internationalization in emerging economies is not associated with disinvestments by United States firms in Europe but is instead a result of the build-up of new R&D activities in information, communication, R&D and engineering services. These segments are the drivers of R&D internationalization in the services sector. India and Israel are the host countries where this trend is most visible.

As in every empirical study, there are also some factors that limit the results of this analysis, the largest being the fact that the available data mainly covers OECD countries and manufacturing industries, which both represent a decreasing share of the global economy. Data for emerging economies and for service industries are mostly not available. Thus, we also assume that some parts of R&D internationalization remain invisible because of a lack of data. Improving the

evidence base should therefore be a priority for future work in order to gain a more comprehensive picture. Collecting more data for service industries as well as on R&D internationalization in South American, Asian and African countries is the most important priority for future work.

Emerging economies and R&D internationalization in services may also be the two most fruitful areas for future research. Both challenge our theoretical perceptions of R&D internationalization, which have been developed for manufacturing industries in Europe and the United States. How do forms of corporate governance such as State ownership or family ownership, which are found in TNCs from emerging economies, affect internationalization strategies? What is the role of governmental policies in the strategies of TNCs from emerging economies? What makes emerging economies attractive for R&D of service firms? What is the role of scientific knowledge and interactions with clients for service R&D internationalization? How do the characteristics of service innovation and the propensities of underlying knowledge bases relate to international knowledge-sourcing strategies of service firms?

The internationalization of R&D yields considerable benefits also from a policy perspective. Host countries benefit from R&D investments by foreign-owned firms and knowledge spillovers, while home countries of TNCs may receive reverse knowledge spillovers from overseas R&D activities. To our knowledge, there is no empirical evidence that would suggest that overseas R&D investments crowd out domestic R&D activities.

Can policymakers expect that R&D internationalization and its benefits will continue to grow in the future? It seems likely, as the trends that have fuelled R&D internationalization in the past are still in place: new technological opportunities, in particular in ICT; the growth of service industries and firms from emerging economies; the demand by multinational enterprises for knowledge that is not available in the home country; and the geographical concentration of this knowledge in a few hotspots around the world. The current COVID-19 crisis, in particular travel restrictions and the shutdown of university labs, has strained R&D internationalization in 2020 and 2021; however, these obstacles should be only temporary.

Developments that work towards de-globalization are mostly related to policies that consider science and technology as a question of national interest and an area of foreign policy. An example are the tensions between the United States and China over technology. Such developments make a friendly and non-discriminating climate for R&D internationalization less likely. If countries want to reap the benefits of globalization in the future, a continuation of the policies of non-discrimination of foreign-owned firms and of more, not less international cooperation is necessary. This seems also relevant given the global nature of many of today's challenges. Policymakers should not take globalization and its benefits for granted.

References

Alcácer, Juan, John Cantwell and Lucia Piscitello (2016). "Internationalization in the information age: a new era for places, firms, and international business networks?", *Journal of International Business Studies*, 47(5), pp. 499–512.

Alkemade, Floortje, Gaston Heimeriks, Antoine Schoen, Lionel Villard and Patricia Laurens (2015). "Tracking the internationalization of multinational corporate inventive activity: national and sectoral characteristics", *Research Policy*, 44(9), pp. 1763–1772.

Ambos, Björn, and Bodo B. Schlegelmilch (2006). "Learning from foreign subsidiaries: an empirical investigation of headquarters' benefits from reverse knowledge transfers", *International Business Review*, 15(3), pp. 294–312.

Appelt, Silvia, Fernando Galindo-Rueda and Ana Cinta González Cabral (2019). "Measuring R&D tax support", OECD Science, Technology and Industry Working Papers No. 2019/06 (Paris: OECD).

Athukorala, Prema-Chandra, and Archanun Kohpaiboon (2010). "Globalization of R&D by US-based multinational enterprises", *Research Policy*, 39(10), pp. 1335–1347.

Barlevy, Gadi (2007). "On the Cyclicality of Research and Development", *American Economic Review*, 97(4), pp. 1131–1164.

Belderbos, René, Leo Sleuwaegen, Dieter Somers and Koen De Backer (2016). "Where to locate innovative activities in global value chains. Does co-location matter?", OECD Science, Technology and Industry Policy Papers No. 2016/30 (Paris: OECD).

Cantwell, John, and Ram Mudambi (2005). "MNE competence-creating subsidiary mandates", *Strategic Management Journal*, 26(12), pp. 1109–1128.

Castellani, Davide, and Fabio Pieri (2013). "R&D offshoring and the productivity growth of European regions", *Research Policy*, 42(9), pp. 1581–1594.

Crescenzi, Riccardo, Arnaud Dyèvre and Frank Neffke (2020). "Innovation catalysts. How multinationals reshape the global geography of innovation", Geography and Environment Discussion Paper Series No. 7 (London: London School of Economics and Political Science).

Crescenzi, Riccardo, Carlo Pietrobelli and Roberta Rabellotti (2016). "Regional strategic assets and the location strategies of emerging countries' multinationals in Europe", *European Planning Studies*, 24(4), pp. 645–667.

D'Agostino, Lorena M., Keld Laursen and Grazia D. Santangelo (2013). "The impact of R&D offshoring on the home knowledge production of OECD investing regions", *Journal of Economic Geography*, 13(1), pp. 145–175.

Dachs, Bernhard, Robert Stehrer and Georg Zahradnik, eds. (2014). *The Internationalization of Business R&D* (Cheltenham: Edward Elgar).

De Backer, Koen, Isabelle Desnoyers-James and Laurent Moussiegt (2015). "Manufacturing or services – that is (not) the question. The role of manufacturing and services in OECD economies", OECD Science, Technology and Industry Policy Papers No. 2015/19 (Paris: OECD).

Driffield, Nigel, James H. Love and Karl Taylor (2009). "Productivity and labour demand effects of inward and outward foreign direct investment on UK industry", *The Manchester School*, 77(2), pp. 171–203.

Dunning, John H., and Sarianna M. Lundan (2009). "The internationalization of corporate R&D: a review of the evidence and some policy implications for home countries", *Review of Policy Research* 26(1–2), pp. 13–33.

European Commission (2017). *Internationalisation of Business Investments in R&D and Analysis of Their Economic Impact* (BERD Flows): Final Report (Brussels: European Union).

_____ (2021). "On the global approach to research and innovation. Europe's strategy for international cooperation in a changing world", Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2021) 252 final, Brussels.

Eurostat (European Commission, Statistical Office) (2012). *Foreign Affiliates Statistics (FATS) Recommendations Manual* (Luxembourg: Publications Office of the European Union).

Foray, Dominique (2004). *The Economics of Knowledge* (Cambridge, Massachusetts: MIT Press).

Giuliani, Elisa, Sara Gorgoni, Christina Günther and Roberta Rabellotti (2014). "Emerging versus advanced country MNEs investing in Europe: a typology of subsidiary global-local connections", *International Business Review*, 23(4), pp. 680–691.

Guimón, Jose (2009). "Government strategies to attract R&D-intensive FDI", *Journal of Technology Transfer*, 34(4), pp. 364–379.

Gupta, Anil K., and Vijay Govindarajanan (2000). "Knowledge flows within multinational corporations", *Strategic Management Journal*, 21(4), pp. 473–496.

Hall, Bronwyn A. (2010). "The internationalization of R&D", Working Paper, August. University of California at Berkeley. https://eml.berkeley.edu/~bhhall/papers/BHH10_RND_international_August.pdf.

Hayakawa, Kazunobu, Tomohiro Machikita and Fukunari Kimura (2012). "Globalization and productivity: a survey of firm-level analysis", *Journal of Economic Surveys*, 26(2), pp. 332–350.

Hernández, Héctor, Nicola Grassano, Alexander Tübke, Sara Amoroso, Zoltan Csefalvay and Petros Gkotikis (2019). *The 2019 EU Industrial R&D Investment Scoreboard* (Luxembourg: Publications Office of the European Union).

Joseph, Reji K., Biswajit Dhar and Akoijam A. Singh (2019). "FDI in R&D in India: an analysis of recent trends", Working Paper No. 209 (New Delhi: Institute for Studies in Industrial Development).

Keller, Wolfgang (2010). "International trade, foreign direct investment, and technology spillovers", in Bronwyn A. Hall and Nathan Rosenberg, eds., *Handbook of the Economics of Innovation* (Amsterdam: Elsevier), pp. 794–829.

Keller, Wolfgang, and Stephen R. Yeaple (2009). "Multinational enterprises, international trade, and productivity growth: firm-level evidence from the United States", Review of Economics and Statistics, 91(4), pp. 821–831.

Laurens, Patricia, Christian Le Bas, Antoine Schoen and Philippe Larédo (2015a). "Internationalisation of European MNCs R&D: 'deglobalisation' and evolution of the locational strategies", *Management International*,19(4), pp. 18–33.

Laurens, Patricia, Christian Le Bas, Antoine Schoen, Lionel Villard and Philippe Larédo (2015b). "The rate and motives of the internationalization of large firm R&D (1994–2005): towards a turning point?", *Research Policy*, 44(3), pp. 765–776.

Mayer, Klaus E., and Evis Sinani (2009). "When and where does foreign direct investment generate positive spillovers? A meta-analysis", *Journal of International Business Studies*, 40(7), pp. 1075–1094.

Moris, Francisco (2018). "Intangibles trade and MNEs: supply-chain trade in R&D services and innovative subsidiaries", *Journal of Industry, Competition and Trade*,18(3), pp. 349–371.

Mudambi, Ram, Lucia Piscitello and Larissa Rabbiosi (2014). "Reverse knowledge transfer in MNEs: subsidiary innovativeness and entry modes", *Long Range Planning*, 47(1), pp. 49–63.

Narula, Rajneesh (2002). "Innovation systems and 'inertia' in R&D location: Norwegian firms and the role of systemic lock-in", *Research Policy*, 31(5), pp. 795–816.

_____ (2012). "Do we need different frameworks to explain infant MNEs from developing countries?", *Global Strategy Journal*, 2(3), pp. 188–204.

OECD (Organisation for Economic Co-operation and Development) (2015). *OECD Science, Technology and Industry Scoreboard 2015: Innovation for Growth and Society* (Paris: OECD).

_____ (2021). *Teleworking in the COVID-19 Pandemic: Trends and Prospects* (Paris: OECD).

Papanastassiou, Marina, Robert Pearce and Antonello Zanfei (2020). "Changing perspectives on the internationalization of R&D and innovation by multinational enterprises: a review of the literature", *Journal of International Business Studies*, 51, pp. 623–664.

Patel, Parimal, and Keith Pavitt (1999). "Global corporations and national systems of innovation: Who dominates whom?", in Daniele Archibugi, Jeremy Howells and Jonathan Michie, eds., *Innovation Policy in a Global Economy* (Cambridge: Cambridge University Press), pp. 94–119.

Paunov, Caroline, Dominique Guellec, Nevine El-Mallakh, Sandra Planes-Satorra and Lukas Nüse (2019). "On the concentration of innovation in top cities in the digital age", OECD Science, Technology and Industry Policy Papers No. 2019/85 (Paris: OECD).

Paunov, Caroline, and Sandra Planes-Satorra (2020). *Science, Technology and Innovation in Times of Covid-19 and Policy Responses: Preliminary Overview in June 2020*, Background report for the OECD virtual workshop, "Science, technology and innovation in times of Covid-19: what policy responses for the recovery?" held on 17 and 24 June (Paris: OECD).

Rodrik, Dani (2018). "Populism and the economics of globalization", *Journal of International Business Policy*, 1(1), pp. 12–33.

Sandberg, Brigitta, and Leena Aarikka-Stenroos (2014). "What makes it so difficult? A systematic review on barriers to radical innovation", *Industrial Marketing Management*, 43, pp. 1293–1305.

Schwaag Serger, Sylvia, Cong Cao, Caroline Wagner, Xabier Goenaga and Koen Jonkers (2021). "What do China's scientific ambitions mean for science and the world?", *Issues in Science and Technology*, 5 April. https://lup.lub.lu.se/record/5a892371-fb55-4750-883c-d0b78948b333.

Siedschlag, Iulia, Donal Smith, Camelia Turcu and Xiaoheng Zhang (2013). "What determines the location choice of R&D activities by multinational firms?", Research Policy, 42(8), pp. 1420–1430.

Singh, Jasjit (2007). "Asymmetry of knowledge spillovers between MNCs and host country firms", *Journal of International Business Studies*, 38(5), pp. 764–786.

Thursby, Jerry, and Marie Thursby (2006). *Here or There? A Survey of Factors in Multinational R&D Location* (Washington, D.C.: National Academies Press)

Timmer, Marcel P., Abdul Azeez Erumban, Bart Los, Robert Stehrer and Gaaitzen J. de Vries (2014). "Slicing Up Global Value Chains", *Journal of Economic Perspectives*, 28(2), pp. 99–118.

UNCTAD (United Nations Conference on Trade and Development) (2005). *World Investment Report 2005: Transnational Corporations and the Internationalization of R&D* (New York and Geneva: United Nations).

_____ (2021). *World Investment Report 2021: Investing in Sustainable Recovery* (New York and Geneva: United Nations).

Witt, Michael A. (2019). "De-globalization: theories, predictions, and opportunities for international business research", *Journal of International Business Studies*, 50(7), pp. 1053–1077.

Annex

Revealed Comparative Advantage (RCA) Index

The RCA index relates the share of a good or an economic activity in a particular subgroup to the corresponding share of this good or activity in the whole sample. Values of the index larger than one indicate that the good or activity in question has a higher share in the subgroup than in the whole sample, thus indicating a specialization. The index is defined as follows:

$$RCAij = \frac{X_{ij}/\sum_j X_{ij}}{\sum_i X_{ij}/\sum_i \sum_j X_{ij}}$$