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The internationalisation of R&D: past, present and future

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Abstract: In this perspective we discuss major trends that will shape the internationalisation of business R&D in the future. New scientific discoveries will provide new opportunities to innovate; the growing scientific capabilities in emerging economies will create new hot spots for relevant knowledge; new research activities will emerge from the need to combat climate change; digital technologies including artificial intelligence will further facilitate coordination and knowledge exchange within MNEs and help to create new products and services. Finally, techno-nationalism and new geo-political tensions urge for more attention to the interactions between MNEs and nation-states in science and technology. A perspective that considers science as a source of national superiority may be at odds with the global organization of R&D and innovation in multinational enterprises.

As a conclusion, we see most trends that contribute to the growth of R&D internationalisation as intact. IB research should bring nation-states back into the analysis as actors, not as mere locational factors, and build on its own rich tradition of embracing multifaceted approaches and transcending intellectual boundaries and explore the dynamics of MNE R&D internationalisation.

1. Introduction

This perspective discusses the future of the ‘internationalisation of R&D’ - the phenomenon whereby multinational enterprises (MNEs) perform R&D and innovation activities outside their home countries. Considered a marginal phenomenon in the 1970s and 1980s (Patel & Pavitt, 1991), the internationalization of R&D emerged as one of the engines for the growth of business R&D in many countries. After reaching new heights in 2010, MNE R&D internationalisation has been stagnating, while competition among countries in attracting and retaining MNEs’ overseas R&D has intensified. Is this a sign that the best days are over, and MNEs again prefer to invest in R&D in their home countries? This would considerably alter the way MNEs organize the creation and diffusion of knowledge. Is it a reaction to unfolding geopolitical developments or technological and environmental challenges? These questions reveal shortcomings in our understanding of R&D internationalisation.

In the following sections, we will address these gaps and have a closer look at four factors that will likely shape R&D internationalisation in the coming years. Our aim is to better understand if the current stagnation is a temporary phenomenon, or the start of a re-concentration of business R&D in the home countries and/or home regions of MNEs.

We expect that new scientific discoveries will provide new opportunities to innovate. The growing scientific capabilities in emerging economies will create new hot spots for relevant knowledge. The imperative of combating climate change and providing affordable clean energy will drive novel research activities. Digital technologies and AI will further facilitate coordination and knowledge exchange within MNEs and provide opportunities for new products, services and enterprises. At the same time, competitive thrust between China and the United States for global supremacy and current major political events such as the invasion of Russia in Ukraine will have a prolonged effect on the relations of countries, leading to politics undermining economics. Thus, disruptions for the internationalization of R&D may emerge from nationalistic conceptions of sovereignty and techno-nationalism which may increasingly move policy into conflict with the global strategies of MNEs.

The paper proceeds as follows: the next section presents the origins and current state of R&D internationalisation. In Section 3 and its sub-sections we discuss four drivers for the future of R&D internationalisation. The paper ends with conclusions for future research in Section 4.

2. What do we know about R&D internationalisation?

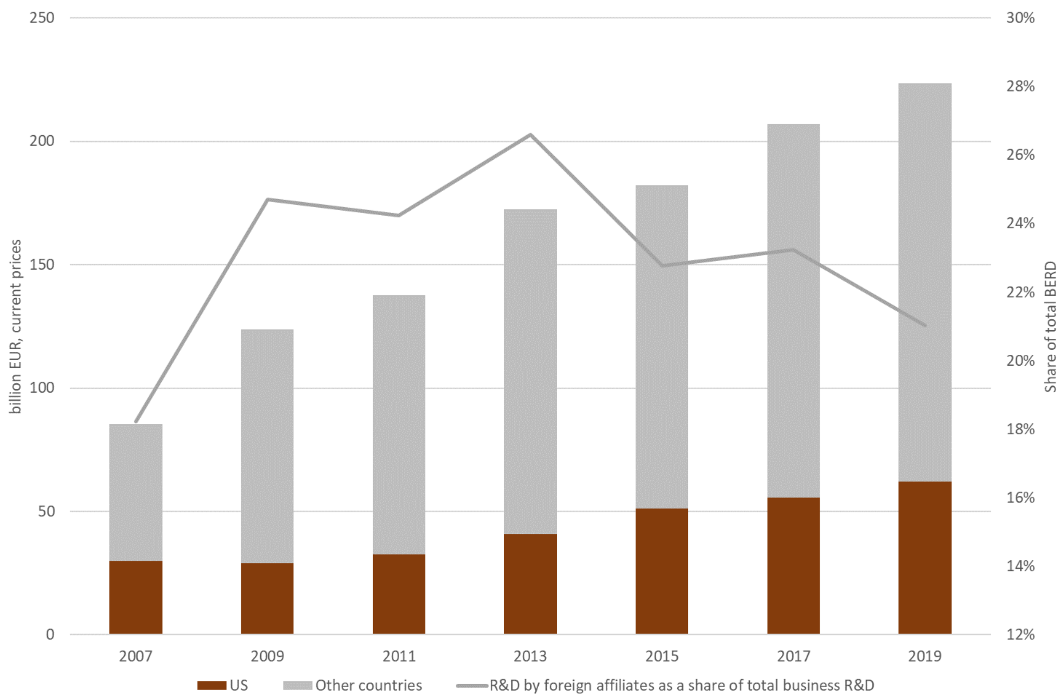
The origins of R&D internationalisation date back to the late 1950s and early 1960s where evidence of the phenomenon is found in the works of Dunning (1958), Safarian (1966), Brash (1966) and Stubenitsky (1970) with the latter to record the existence of overseas R&D activities of US MNEs in Europe by 1966. However, a systematic analysis of MNEs' R&D internationalisation starts with the reports of the US Tariff Commission in 1973, and the Conference Board by Creamer (1976), Ronstadt (1978) and Behrman and Fischer (1980). The 1980s saw a rise in investigations of reasons behind MNEs R&D internationalisation where market-seeking factors were enriched with knowledge-seeking motives as a response to a liberalized trade and investment environment and the rise of global competition. Since the second half of 1990s, advances in information and communication technologies (ICT) and the Internet in particular lowered some barriers for the diffusion of knowledge, facilitating the management of increasingly geographically dispersed R&D. Globalization expanded beyond the United States, Europe, and Japan. The intensified global competition forced companies to reduce R&D costs, while speeding up the development process. This led MNEs to rely more on external sources of knowledge from strategic R&D alliances, and mergers and acquisitions. In particular, MNEs followed the earlier fragmentation of value chains and the resulting internationalisation of manufacturing by establishing R&D facilities worldwide. Indeed, MNEs need to support foreign production with R&D and innovation in key markets, and search for innovation-relevant knowledge which cannot be found at home (Kuemmerle, 1997; von Zedtwitz & Gassmann, 2002; Dunning & Lundan, 2009; Papanastassiou, Pearce & Zanfei, 2020). This knowledge is often tacit and localized, so MNEs need to be present where the knowledge is, and link with actors in the host country to access it. At the same time, MNE subsidiaries are also embedded in knowledge networks within the MNE and can rely on knowledge from the headquarters and from other subsidiaries. This dual embeddedness (Meyer et al., 2011; Achcaoucaou et al., 2014) is one of the sources for an above-average innovation performance of many MNE subsidiaries.

R&D internationalisation emerged from single investments of US firms in Europe during the 1950s and 1960s into a noticeable trend in the 1980s and 1990s (Papanastassiou et al., 2020). The 2000s saw the opening of new host countries and a first wave of investments in the People's Republic of China (or China throughout the text), India, and other emerging economies. Research by von Zedtwitz (2004) and UNCTAD (2005) drew attention to the rise of emerging countries as hosts of the overseas R&D activities of MNEs from high-income countries. At the same time, multinational enterprises from emerging economies (EMNEs) appeared on the stage of R&D internationalisation after 2000 (Giuliani et al., 2014; Crescenzi et al., 2016). The acknowledgement of the existence of abundant talent in these countries, and the necessity to address the needs of these markets in a more tailored manner, made Western MNEs realise that ethnocentric strategies for innovation would mean missed opportunities both in terms of supply and demand.

In terms of theoretical developments, the traditional view of the MNE emphasizes its ability to transfer and exploit existing intangible assets abroad (e.g. Caves, 1996). In this view, R&D is mainly centralised in the parent company and international R&D activities focus on supporting manufacturing activities of local subsidiaries or adapting products and technologies developed in the home country to local market conditions (Vernon, 1979). However, MNEs have increasingly internationalised their R&D activities to improve their ability to access technological and scientific strengths abroad (Cantwell, 1989). Global competition and new markets, shorter product life cycles, the increased worldwide dispersion of technological capabilities, and the availability of scientists and engineers outside industrialized countries have provided an impetus for an increased global orientation of R&D. The geographic dispersion of MNEs' R&D activities to facilitate access to knowledge hubs with specialized expertise (Frost, 2001; Phene & Almeida, 2008; Belderbos et al., 2013) and increase the breadth of technological search (Lahiri, 2010), allowing for knowledge recombination (Castellani & Zanfei, 2006), and the formation of global knowledge networks of MNEs (Bathelt & Li, 2020). Despite these benefits, a major portion of corporate R&D is still conducted in the home countries of the MNEs (Belderbos et al., 2013), due to the potential foregone advantages of scale and scope economies, appropriability (IP protection) concerns, increased coordination costs, and difficulties related to knowledge integration and transfer (Belderbos et al., 2021; Belderbos & Castellani, 2023).

A series of economic and geopolitical crises starting with the Global Financial Crisis of 2008/2009 considerably slowed down R&D internationalisation. It seems that the process lost steam in the last decade, as can be seen in Figure 1 below. The Figure depicts R&D expenditures of foreign-owned affiliates in the United States (red) and in the rest of the world, mainly OECD countries. The data cover almost 90 per cent of global business R&D expenditures (BERD). In *absolute terms*, R&D expenditures of foreign-owned affiliates have been increasing steadily, from 85 bn EUR in 2007 to 223 bn EUR in 2019. However, in *relative terms* – as a share of total BERD depicted by the grey line – R&D internationalisation is declining. This can partly be explained by the fast growth of domestic business R&D expenditures in some Asian countries. Foreign-owned affiliates have only a small share of total business R&D in China and South Korea, and faster growth of domestic R&D in these countries results in a relative decline (see also Dachs & Zahradnik, 2022).

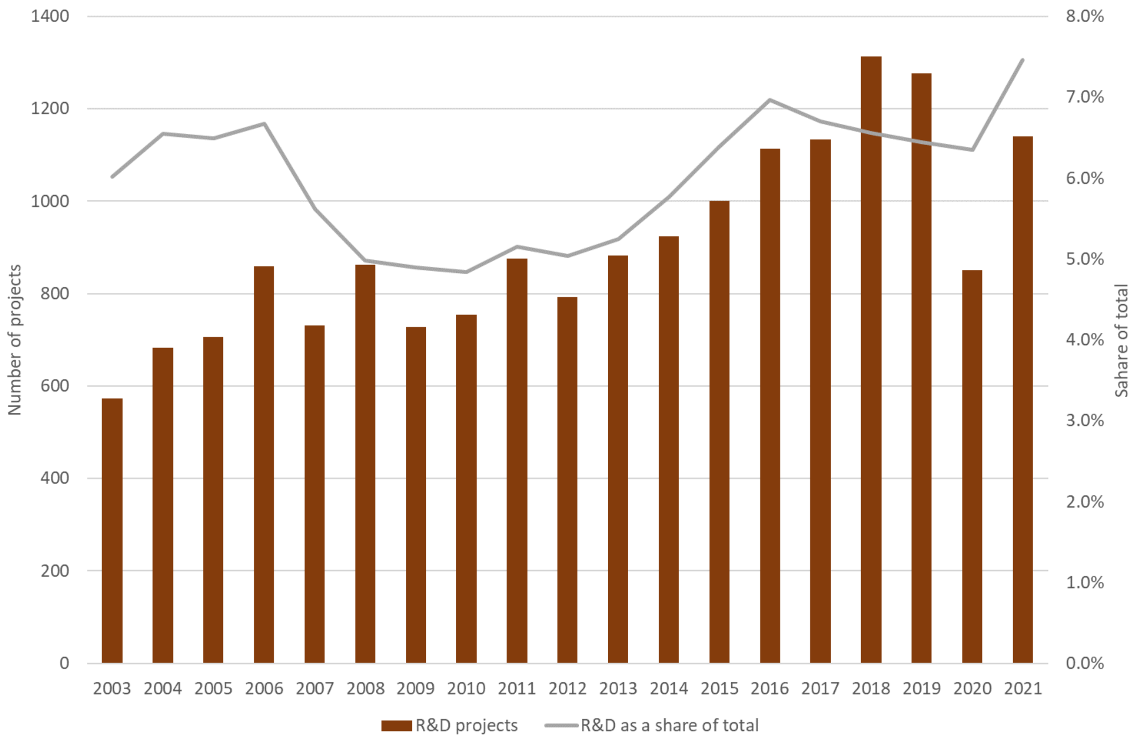
Figure 1: R&D expenditures of foreign-owned affiliates in billion EUR and as a share of total business R&D expenditure



Source: Own elaborations based on OECD, EUROSTAT, and national sources.

Greenfield investments in new cross-border R&D projects and the acquisition of R&D-intensive firms by foreign MNEs have been major drivers for the internationalisation of R&D in the 1990s and 2000s, but in the years after the Global Financial Crisis these activities stagnated. According to fDi Markets, a database that collects cross-border investment project announcements, the share of cross-border R&D projects fluctuated around 6.5% over the 2003-2021 period, with a low of 5% in the post-Financial Crisis period. Covid-19 was the latest hit to R&D-related investment projects, with the number of R&D investment projects dropping by one-third between 2019 and 2020, somewhat in line with an overall decrease in cross-border investment activity.

Figure 2: Cross-border R&D greenfield investment projects and R&D projects as a share of total projects, 2003-2021



Source: Own elaboration using fDi markets data

In terms of source countries, fDi Markets data reveal that the US MNEs are by far the largest investors, but their share has dropped by 13 percentage points from the 2003-2007 to the 2018-202 period. Countries that increased their share of outward foreign R&D projects include the UK, Ireland and China. The top 20 countries account for 93% of investment over the 2003-2021 period, consistent with a significant geographical concentration, but this share is declining, showing that more countries are engaging in international R&D activities than ever.

Destination countries for R&D projects are less geographically concentrated, with 77% (declining over time) of all projects taking place in the top 20 destination countries. The recent literature reflects this trend by pointing out the increasingly network-like characteristics of international R&D activities which have replaced the dyadic structures of the 1990s and 2000s (Papanastassiou et al., 2020, Dachs & Zahradnik, 2022).

Europe regained its role as the prime destination for cross-border R&D projects in recent years, thanks to a large number of intra-EU investments (which may point to regional integration rather than internationalisation), but also due to a doubling share of investments from Asia and higher investments from North America. The trend towards Asia has slowed down markedly: Comparing the 2003–2007 with the 2018–2021 period, Asia registered a drop in the relative share of inward cross-border investments in R&D. Nevertheless, Asia remains a very important location for R&D by foreign MNEs. The most relevant R&D locations for US multinationals according to the US Bureau of Economic Analysis (2023) are the United Kingdom (6 bn USD R&D expenditure), Germany (5.7 bn USD), Switzerland (5.4 bn USD), India (4.4 bn USD), and China (4.4 bn USD).

3. Looking ahead: four drivers and the future of R&D internationalisation

These observations raise the question if the expansion we have seen in the 1990s and especially in the 2000s will also proceed in the future, or if we are at the beginning of a persistent stagnation. As cross-border R&D investment decisions are based on many strategic, operational, and business-related factors, this section will discuss some important drivers that affect the pace of R&D internationalisation.

3.1 Populism and economic nationalism

Revisiting the extant literature on R&D internationalisation one can assert that demand and supply conditions in the home and host countries that determine the innovation strategies of large MNEs have been at the centre of the analysis (Papanastassiou et al., 2020). Since the seminal works of Ronstadt (1978) and Behrman and Fischer (1980) the economics-based narrative has more or less been consistent in terms of analysing the determinants and challenges in R&D internationalisation. This was, after all, the inevitable outcome as most overseas R&D was taking place between the high-income countries, characterised by trade and investment liberalisation and more or less stable political environments sharing similar democratic values.

Research on international R&D in emerging countries and, consequently and increasingly, from emerging countries was nevertheless (until recently) largely ignoring the fact that these activities have been taking place among countries with different political systems and often in a condition of significant geo-political tension. This has led to a dilemma of MNEs investing in host countries with unstable political systems where they are exposed to ownership risks of real assets and intellectual property, while mainstream IB theories are advocating that stable economic, political and institutional conditions are the very basic requirements to attract any form of FDI let alone international R&D (Dunning & Narula, 2003). To this end, economies with deficient political and economic systems may struggle to provide the complementary assets necessary to attract sophisticated R&D (Buckley, 2017).

These concerns where mostly explained away by growth expectations in these countries. It is only after the election of Xi Jinping (President of the People's Republic of China) in 2013, Donald Trump (President of the United States of America) in 2016, and Brexit also in 2016, that policymakers and academics began to recognize the implications of political instability on R&D and innovation, uncertainty and the risk associated with the rise of populism in the democratic Western world. Luo (2022) describes how the zero-sum world view of techno-nationalism can harm globalisation and MNEs that depend on global value chains. In the same vein, Petricevic and Teece (2019) analyse how constraints for MNEs may emerge from the rivalry between the United States and China resulting in an increasingly polarized world order. Cui et al. (2023) point to the prohibitive costs of such a bifurcated world which, in their opinion, will make such a scenario unlikely. However, the literature on R&D internationalisation so far has neither explicitly addressed the impact of politics on decisions about international R&D projects, nor has it addressed the role of MNEs as political entities in the spirit of the works of Kobrin (1979), Boddewyn (1988) and Child (2018).

Nevertheless, emerging countries such as India, China, and Türkiye with controlling and authoritarian political agendas are experiencing a rise in domestic R&D (Reddy et al., 2022; Sharmiladevi, 2022). The 2022 Global Innovation Index (Dutta et al., 2022) ranks China 11th whilst Türkiye and India entered the top 40 countries in R&D spending for the first time. Godinho and Simões (2023) show how techno-nationalism is forcing Chinese firms to intensify their innovative activities resulting in an impressive rise of patents, ranking China in the top five countries in computer processing, semiconductors, digital technologies and wireless telecommunication technologies.

The semiconductor industry is a focal point of the developments described above. Semiconductors are considered as a strategic sector, labelled as 'the new oil'. The global semiconductor market dropped by 7.4% in 2019, partly on the back of the trade war between China and the US, but since 2020 the sector is experiencing solid growth (3.1% in 2020) and 18.8% in 2021 (MarketLine, 2022). The largest consumer of semiconductors globally is China with over 50% of global consumption. China is also investing heavily in its domestic semiconductor sector in an effort for technological independence striving to catch up with the US and Taiwan (Li, 2018; MarketLine, 2022).

In July 2022, the US introduced the CHIPS and Science Act, which is aiming to strengthen domestic semiconductor design and research manufacturing in the US (White House, 2022). The US CHIPS and Science Act is a paradigm shift in policymaking because of the instruments it employs, but also because of its geopolitical purpose (Luo & Van Assche, 2023). Moreover, in October 2022 the United States government-imposed export restrictions on microchips, a range of goods related to chip manufacturing, and cut support by US firms or individuals for Chinese microchips companies, including R&D (Lis et al., 2022). Primarily aimed at setting back China's ambitions in chips production, as well as Chinese production that depends on chips' imports, it may also harm R&D internationalisation. The US CHIPS and Science Act, for example, restricts investments in China for those chipmakers that receive money from this funding scheme (Financial Times, 2023a).

Recent selective data for 2022 from fDi Markets show more R&D investment projects by US MNEs in Europe, but also friendlier Asian countries including Singapore, India and Taiwan. A significant flow of German R&D FDIs are destined for Greece, a potential newcomer in the sector, alongside Spain and Romania. This may indicate that techno-nationalism and the bottlenecks during the Covid-19 pandemic are beginning to shape cross-border investments towards "friendshoring".

Dividing the world into friends and foes is certainly creating an adverse climate for R&D internationalisation. But even if we assume de-coupling, it seems unlikely that all Western MNEs give up business in China which has become the main market for many of these companies. Rather, some MNEs will react to techno-nationalism with 'local for local' strategies by granting their Chinese subsidiaries more autonomy and creating more independent entities. One historical example for this strategy – but also for its downsides - is General Motors and its German subsidiary Opel during the Nazi regime (Turner, 2004). A recent article in The Wall Street Journal (2023b) introduces the term 'siloing' (which corresponds to the term 'multidomestic' used in the IB and strategy literature) to show how major western MNEs protect their investments in China. In a nutshell, they argue that the Chinese subsidiaries of Western MNEs such as the German Volkswagen and Japanese Lixil produce solely for the Chinese market and thus de-couple their Chinese activities from their global activities. This strategy, which signifies a return to the 1970s production and trade toolkit, reflects the anticipation of a prolonged geopolitical tension between China and USA. It may not lead to less but even more R&D internationalisation, since R&D for the Chinese market will mainly take place in China. However, as the literature on multi-domestic R&D organizations suggests, if R&D budgets are spread over several R&D locations, we will likely see parallel and redundant development activities and, eventually, lowered R&D efficiency (Gassmann & von Zedtwitz, 1999).

3.2 The global scientific landscape

Science is a factor which speaks in favour of a prolongation of current R&D internationalisation trends. The number of researchers, R&D expenditures, as well as the number of scientific publications are increasing globally, and there is little doubt that this growth will also continue in the future, even if some see a declining productivity of researchers (Bloom et al., 2020). An increasing stock of knowledge worldwide provides, in turn, new opportunities and incentives for MNEs to source knowledge abroad.

Between 1996 and 2020, the output of peer-reviewed science and engineering journal articles grew by 4.6 per cent annually (National Science Board, 2021). Scientific output, however, increased much faster in upper-middle-income and lower-middle-income economies than in high-income economies including the United States, European countries, or Japan. As a result, the bipolar scientific world led by North America was gradually replaced by a tri-polar world including Europe, North America, and Asia-Pacific (Gui et al., 2019). This was accompanied by a marked shift in the relative contribution of individual countries or country groups to the global stock of knowledge; the share of high-income economies dropped from 86% in 1996 to 54% in 2020, while upper-middle-income and lower-middle-income economies could increase their share on global publication output to 38% and 9%, respectively. Similar shifts can also be observed in the distribution of research personnel or R&D expenditures (Lewis et al., 2021).

Among emerging countries, China and India stand out (Lewis et al., 2021). China has surpassed the United States in terms of the number of publications in 2016; scientists located in India publish more than their peers in the United Kingdom or Japan. These improvements are impressive, even if we consider that research by US or European scientists is still more frequently cited than research by Chinese and Indian scientists, and some doubts about the effectiveness of the Chinese innovation system (König et al., 2022). Emerging countries are also gaining in various university rankings such as the QS, ARWU, Times Higher Education, or CWTS Leiden Ranking.

New opportunities for sourcing knowledge abroad also emerge from a different specialization of emerging economies. Publications in engineering and computer and information sciences, for example, are overrepresented in China and India, while health or social sciences are underrepresented (Lewis et al., 2021). This may attract MNEs in some sectors in particular, such as information and communication services. There is indeed some evidence that ‘new’ host countries such as India, China, or Israel predominantly attract R&D activities by US software and internet service firms, while US automotive, chemicals or mechanical engineering companies still favour ‘old’ host countries like Germany or France (Dachs & Zahradnik, 2022).

The question, however, remains how open these countries are to knowledge sourcing by multinational firms. The literature assumes that foreign-owned firms face obstacles when they try to enter networks in their host countries to access knowledge (Eden & Miller, 2004). These obstacles may emerge from unfamiliarity with norms, routines, habits etc, but may also arise because governments, firms, or research organizations treat foreign-owned firms differently than domestic entities. Another imminent challenge is competition for talent between foreign-owned firms and domestic organizations. A lack of scientists and engineers even challenges a large country like China (Sun & Cao, 2021). Moreover, such conflicts may intensify if foreign MNEs lure some of the best scientists to work on projects that contribute to their corporate knowledge base rather than on projects of national importance (von Zedtwitz, 2004). Just recently Microsoft announced its intention to move its Artificial Intelligence (AI) specialists from China to Vancouver, Canada, upsetting the Chinese government over the potential loss of valuable expertise (Financial Times, 2023b).

As discussed above, techno-nationalism – both at home and in host countries – may be another emerging obstacle to R&D internationalisation. If governments increasingly consider science as a tool for achieving goals of national interest, R&D activities of foreign-owned firms in their countries may raise scepticism. China, for example, exhibits increasingly "strong links between science, nationalism, patriotism, ideology, and the Communist Party" (Schwaag Serger et al., 2021). Xi Jinping, made it clear in a speech that "science has no borders, but scientists have motherlands" (Schwaag Serger et al., 2021). The recent drive by Chinese leadership to enhance technological self-reliance backed by the repatriation of Chinese scientists signals de-facto fragmentation in global scientific collaboration where the development of domestic technologies and innovations are prioritised at the expense of international R&D investments (Yu, 2023).

R&D internationalisation also requires some freedom to act on the side of host country organizations. However, there is evidence that academic freedom is lower in many upper and lower-middle-income economies than in Europe or North America, and pressure on academic freedom is rising in a number of these countries. Kinzelbach et al. (2022) report that scientists in Brazil, China, India, or Russia had substantially less academic freedom in 2021 compared to 2011. India and China are among the bottom 20% of a ranking of all countries worldwide. Moreover, from the viewpoint of techno-nationalism, it seems only logical that policy should have a stronger influence on the R&D agendas of MNEs.

3.3 Digital technologies

MNEs have always been at the forefront of adopting new technologies, and the inclusion of digital technologies was no exception (Marion & Fixson, 2021, Ahi et al. 2022). Among those, modern ICT has had the longest impact on R&D across all organizations, sectors, and industries. As one of the first contributions during the emergence of the Internet as a socially pervasive instrument, Howells (1995) discussed the impact of ICT on the global organization of R&D as well as the implications on foundational theories in technology management. Much work has focused on how international R&D management could best leverage these technologies, e.g., for remote communication and coordination (De Meyer, 1991), at the level of team dispersion (e.g. Boutellier et al., 1998) or at the level of task organization (e.g. Gassmann & von Zedtwitz, 2003).

The rapid MNE-led expansion of international R&D into China and India only supported the realization that global R&D and innovation networks involving such far-away countries (from an ethnocentric Western perspective) were only possible with well-functioning and powerful ICT – despite (or perhaps because of) the vulnerabilities such ICT networks vis-à-vis unwanted IP dissipation or local government restrictions. The adoption of digital technologies – Artificial Intelligence (AI), Virtual Reality and Augmented Reality (VR/AR) technology, simulation, social media, additive manufacturing (AM) for prototyping, etc. – reinforced the notion of a technology-driven acceleration of R&D and innovation. It is therefore no surprise that Papanastassiou et al. (2020, p.644) concluded that "the use of digital technologies appears to facilitate virtual collaborative environments, largely unaffected by distance, especially when codified knowledge transfer and processing are at stake."

But the impact of modern ICT and other digital technologies may not be as unilaterally supportive of international R&D as this quote suggests. It is uncontested that ICT has vastly expanded the spatial reach of R&D work, but some of the more recent developments – especially social media-embedded innovation tools, video conferencing, and VR/AR technologies – have also changed how we cooperate at a distance. Stay-home orders pronounced during the Covid-19 pandemic have accelerated the adoption of these technologies.

While ICT is the most widely adopted digital technology across industries and levels of organization, it is only one of many such emerging technologies including, e.g., VR/AR, AI, AM, cloud-based computing and software-as-a-service solutions, the Internet of Things, and in-silico simulation techniques. Each of those digital technologies have their specific advantages and applications, but all of them interact strongly with the performance and adoption of general ICT in new product development, especially in global R&D value chains (Strange & Zucchella, 2017).

The conventional logic, born out of the need to access remote knowledge and talent, understand local customers and markets, support local manufacturing and business development, and facilitate local creativity and innovation tasks, explains the geographic expansion of international R&D into far-away countries (Boutellier et al., 2008). More powerful and more easily available ICT and digital technologies allow local R&D partners to collaborate more easily with the global R&D organization, lowering transaction costs and entry hurdles for more intensive interaction between R&D headquarters and R&D subsidiaries, and between business R&D teams and suppliers, customers or other cooperation partner teams. The growing ICT familiarity of R&D specialists and R&D contributors (such as customers providing user feedback) also lessens spatial distance as one of the key detriments of cooperation quality (Marion et al., 2016). All in all, the ease of use and availability of ICT reduce the need for R&D operations to be centralized and sizeable to be efficient, i.e., reduces the constraints of space in the development of innovation (Nambisan et al., 2017) and it permits international R&D to be more spatially disseminated.

Moreover, the increasing power of ICT also reduces the need for in-person communication between R&D partners. Experts are being "called in" when needed and often just for limited tasks and amounts of time, which allows them to stay in their home-base locations. Digital natives also have different usage patterns of ICT, and this affects their reliance on conventional R&D input (von Zedtwitz, 2020). Virtual teams are being set up with no intention of ever meeting face-to-face during the duration of the project (Gilson et al., 2014). Data that used to require local in-person access is increasingly available remotely, such as patent filings, voice-of-the-customer observations, or high-performance computing. This allows firms to reduce headcount in expensive locations and rely more on experts in low-cost countries, joining the project as virtual team members. R&D organizations centralize into fewer locations, exploiting economies-of-scale as benefits from economies-of-scope are weakened due to ICT advances, and thus reduce their costly international footprint (one example is General Electric's closure of their research centres in Shanghai, Munich, and Rio de Janeiro). Related to this, AI and other digital technologies have the potential to profoundly change the innovation process (Cockburn et al., 2019). Here, key questions are whether and how firms use AI to either automate or augment human activities and the extent to which AI provides a new perspective on the exploration vs. exploitation debate (Johnson et al., 2022).

International R&D has often been driven by access to local talent, technology, and creativity. For instance, much of the inbound R&D investments in India, Israel or Ireland, to name a few, have been motivated by local excellence in ICT. Paradoxically, as R&D teams have become more distributed using more and more ICT, the less disruptive their impact has become (Chen et al., 2022). Virtual communication appears to curb the production of creative ideas (Brucks and Levav, 2022), but may be aiding in the quality of idea selection, which requires cognitive focus and analytical reasoning – all core to industrial R&D. These results empirically validate earlier research suggesting that international R&D is best centralized in the early stages of new product development, when tacit knowledge exchange prevails requiring frequent in-person communication, but may be decentralized in later stages, once R&D tasks can be decomposed and dealt with autonomously (Boutellier et al., 1998). Gassmann and von Zedtwitz (2003) also found hybrid forms of virtual innovation teams, with firms opting for more centralized R&D projects, the greater the stake of success or failure of the expected results.

Since digital technologies are going to be used even more in international R&D, regardless of their shortcomings in some phases of innovation, it should be acknowledged with some relief that the gap in productivity between centralized and spatially dispersed R&D teams has narrowed in recent years (Chen et al., 2022) and perhaps even closed entirely, in part to the introduction of increasingly powerful collaboration tools in the past two decades (Skype in 2003, Dropbox in 2007, Trello and Office 365 in 2011, Zoom in 2012, Google Drive in 2012, Slack in 2013, Overleaf in 2014, MS Teams in 2017, etc.). Face-to-face still matters, but local networks and digital networks appear to be complements rather than substitutes. This insight might also explain how companies that have a 'light international asset footprint' (UNCTAD,

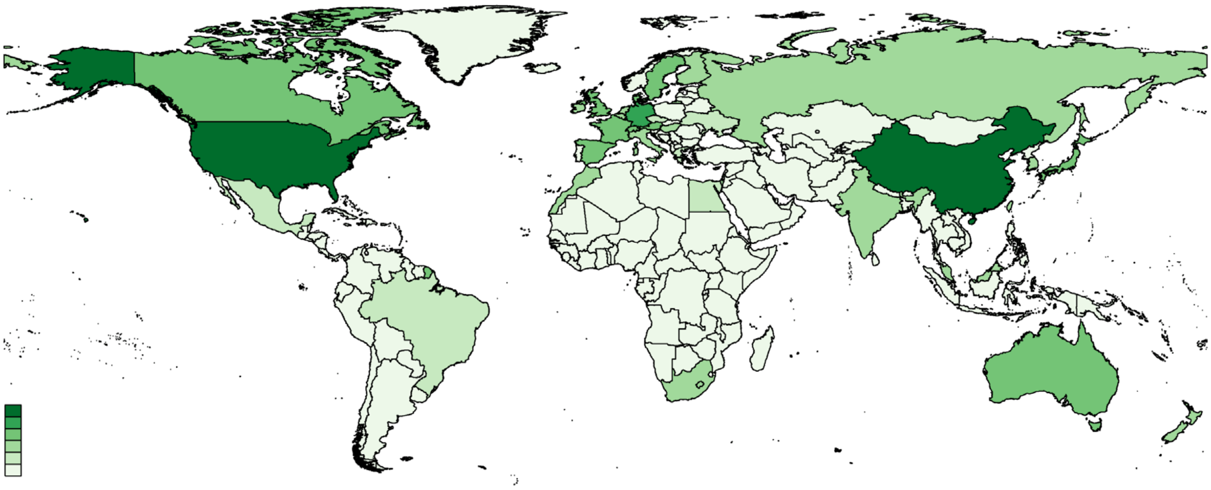
2022) manage to engage in cross-border and cross-disciplinary R&D, using social media and ICT networks not primarily designed for R&D use (Marion et al., 2016).

3.4 The sustainability challenge

Increasing environmental pressure and the policy push towards sustainable innovations are propelling the green technology market forward. The market is expected to grow at a compound annual growth rate of more than 7% for the period 2023-2030 (Contrive Datum Insights, 2023). MNEs have an advantage over non-globalized companies in developing sustainability-oriented innovation, as they have access to environmentally friendly knowledge pools in the global economy. In a recent paper Ahmadova et al. (2022) applied the FSA-CSA framework to assess MNEs international environmental performance whilst Amendolagine et al. (2023) relied on knowledge transfer, entry modes and location theory to explain the determinants of transfer by MNEs of green technologies to their subsidiaries. Orsatti et al. (2020) show that green technologies tend to be generated by heterogeneous R&D teams that have access to external knowledge sources and are capable of recombining loosely related knowledge inputs. Increased pressure to align with UN SDGs and globally tighter environmental regulations may also affect firms' R&D internationalisation strategies. Shi et al. (2023) confirm that MNEs indeed benefit from international spillovers from outward FDI in green technologies which may constitute a new motive for these investments.

Noailly and Ryfisch (2015) provide empirical evidence on the internationalisation of green R&D. Using data on inventors' addresses for 1,200 MNEs patenting in green technologies over the 2004-2009 period, the authors find that about 18% of green patents derive from MNEs' R&D investment conducted abroad. Fig. 3 maps the worldwide geographic distribution of offshored green patents. China, the US, and Germany are the top-destination countries when looking at the total number of green patents offshored. This figure also confirms the emergence of the US and China as "green innovation superpowers", as they are driving the global market for electric vehicles (Yang, 2023). Overall, the world's top R&D investors are also key contributors to the internationalisation of climate-related innovation. They own 70% of all global climate change mitigation or adaptation patents and over 10% of global climate-related trademarks (Amoroso et al., 2021).

Figure 3 Worldwide map – destination countries of green offshoring R&D



Source: Noailly & Ryfisch, 2015

Scholars studying the relationship between environmental regulation and green technologies find a positive link, especially among MNEs. For example, Jaffe and Palmer (1997) show that environmental compliance expenditures have a positive effect on R&D expenditures. As a matter of fact, environmental regulation may generate a 'derived demand' for pollution abatement technologies. These technologies could either be developed by regulated firms themselves or by foreign companies that operate in different sectors and regions from polluting firms. Indeed, MNEs are exposed to different institutional contexts characterized by heterogeneous environmental regulations. In their home and host countries and stakeholder pressures and are often induced to develop and adapt green technologies (Kawai et al., 2018). The environmental regulatory framework creates a market opportunity that may induce MNEs to locate green innovation activities geographically close to the regulated firms and the local environmental authority. For example, Li et al. (2018) document different cases of foreign subsidiaries that have promoted the diffusion of green technologies to local firms in China.

R&D internationalisation, regulatory restrictions, and sustainability practices seem to be positively related. The environmental economics literature emphasizes that in the absence of policy support, the private sector will always have too little incentive to invest in green R&D. Therefore, the level (and enforcement) of environmental policy in a country creates a local market for environmental goods for which green R&D is then needed.

Marin and Zanfei (2022) using COR&DIP database (edition 2015) on all patent applications of the 1000 top EU R&D performers and 1000 top non-EU R&D performers find that top R&D performers are more likely to offshore environment-related innovation activities in host countries characterized by stringent environmental policies. Similarly, (Kim et al., 2021) show that high exposure to foreign markets with more stringent environmental regulations stimulates MNEs' green patent applications.

Policy may also have a positive influence on climate-related innovation via subsidies. Many countries have put in place large funding schemes to support sustainable and digital transitions, which will play a catalytic role in attracting R&D investments by domestic firms and foreign MNES. For example, the EU Recovery and Resilience Facility (RRF) will provide up to €337.97 billion in grants and €385.85 billion in loans, with 37% of funds allocated to the green transition alone. In the US, the Inflation Reduction Act (IRA) will raise $738 billion, of which $391 billion in spending on energy and climate change. According to a recent study by the OECD, ‘green’ industrial policy instruments rose in most countries between 2019 and 2021 and have reached 0.24% of GDP in the countries surveyed (Criscuolo et al. 2023). There is no sign of a discrimination of foreign-owned firms in these initiatives. On the contrary, the European Commission (2023, p. 2) complains that “some of our partners’ initiatives can have undesired collateral effects on our own net-zero industries”, pointing to increased competition for green FDI.

In addition to environmental regulation, embedding sustainability practices into their corporate strategies to accommodate stakeholders' social and environmental expectations has become vital for many MNEs to build local legitimacy to overcome the liability of foreignness. The primary way for MNEs to gain in reputation is through local and global social initiatives in the different markets in which they operate and by interacting with the various stakeholders - non-governmental organizations (NGOs), industry associations, and governments. Therefore, firms' internationalisation is associated with their higher engagement in SDGs. MNEs that have both high R&D intensity and high internationalisation are more likely to develop more sustainability practices and more likely to maintain those practices over the long-term (Chakrabarty

& Wang, 2012; DasGupta et al., 2022). Amendolagine et al. (2023) and De Marchi et al. (2022) provide evidence that MNE subsidiaries are more likely to introduce green innovation and to implement a more holistic strategy toward sustainability, while Castellani et al. (2022) show that inward greenfield investments in green R&D provide a significant contribution to EU regions' specialisation in environmental innovation.

4. Conclusions and future research

Covid-19, supply chain disruptions, the war in Ukraine, and tensions between the United States and China have led some observers to believe that economic globalisation is at the crossroads or even a thing of the past. We believe that such challenges will not stop MNEs from pursuing investment opportunities and navigating in a turbulent global environment. Driven by the need to access knowledge, not available in the home country, MNEs will continue to locate a considerable share of their R&D and innovation activities abroad in future decades. Internationalisation will continue to be an important component of the global R&D strategies of MNEs.

Moreover, science will continue to provide new opportunities to innovate; the growing scientific capabilities in emerging economies will create new hot spots for relevant knowledge sourcing; digital technologies including AI will further facilitate coordination and knowledge exchange within MNEs; moreover, digitalization will also provide opportunities for new products, services and ventures across industries. Alongside these drivers, "green" technologies may emerge as an additional factor stimulating R&D internationalisation.

New challenges for R&D internationalisation may rise from policy. Current discussions in Europe and North America about friend-shoring and a decoupling of the West from China, and more cautious relationships with authoritarian states will continue. Rivalries between China and the US and techno-nationalism add to these tensions. R&D follows foreign direct investment, so decoupling may also mean less R&D internationalisation in several potential host countries. So far, to a large extent the literature on R&D internationalisation has missed to include geopolitics in analysing theoretically and empirically the phenomenon.

Future research on R&D internationalisation thus should embrace possible consequences of geopolitics at the country, enterprise, and entrepreneurial level. First, we should bring nation-states back into the analysis as decision-making actors that shape the competitive environment, and not as mere locational factors. The early IB literature (for example Dunning, 1994) reminds us that there were times when governments were critical and even hostile to FDI. Attitudes towards MNEs seem to shift again in the wage of the "Tech Cold War" between China and the United States (Tung et al., 2023). As China, India, the European Union and the United States are ramping up funds to support their economies in the digital and climate transition, national policy goals regain importance for the R&D strategies of MNEs.

Second, research on R&D internationalisation should recognize MNEs as political entities with their own agendas, which may intensify tensions between them and their home-country governments. Historian Niall Ferguson (2023) recently pointed out that the relations between policy and MNEs today have more in common with the 17th century than with the 20th: "No corporations in the 20th century were as powerful as the Dutch and English East India Companies in their heyday." The role of SpaceX and its Starlink satellite service in the Ukraine conflict illustrates the growing role MNEs and their leaders play in global affairs (Politico, 2023).

Third, IB research needs to investigate potential trade-offs between national policies and transnational business activities for MNEs. In a 'strategic' perspective on MNE-government interactions (Rugman & Verbeke, 2005), techno-nationalism will lead to less consistency and more conflict between the goals of governments and MNEs. Governments have initiated ambitious industry policy programmes such as the US CHIPS and Science Act. What do they expect in exchange for generous funding? From the viewpoint of techno-nationalism it may be unacceptable that domestic knowledge created with the support of local national public funding is exploited internationally. MNEs create international technology spillovers which also may benefit potential rivals of the MNE home country. Restrictions to expand in China for US chip makers that receive money from the US CHIPS and Science Act are one example (Financial Times, 2023a).

The interplay between techno-nationalism and science should revitalise the research agenda on national innovations systems (NISs) and in particular how the international R&D activities of MNEs interact with the local science base (Lundvall & Rikap, 2022; Petraite et al., 2022; Coveri & Zanfei, 2023). Thus, in the context of techno-nationalism it is important for future research to investigate how foreign-owned firms – with the goal to improve their competitiveness – can freely co-operate with domestic organizations, or are granted non-discrimination in terms of recruiting, R&D funding, investments and knowledge transfer. Furthermore, it is crucial to understand how MNEs' international R&D strategies address the disruptions created by techno-nationalism for finding solutions for global challenges such as climate change, access to clean water, or new pandemics as the political conditions for global scientific cooperation seem to worsen.

Progress in digitalization will also provide new research opportunities. First, we need to understand better how digital tools for collaboration over distance can substitute face-to-face contact, facilitate the absorption of tacit knowledge, and diminish the need for MNEs to be present in target markets for knowledge sourcing. This is a recurrent topic in R&D management - the 'death of distance' has been announced more than once! However, Covid-19 has considerably accelerated the diffusion of technologies not available just a few years ago. Second, a better understanding of how artificial intelligence alters innovation processes in MNEs may also lead to new insights into whether AI facilitates or hampers geographically dispersed R&D and innovation activities.

In this respect, sustainability concerns and environmental policies will also impact the R&D priorities of MNEs. It is thus important to understand how institutions will determine the future R&D agendas of MNEs. IB offers theoretical tools to assess the complex relationship between MNEs and institutional agents such as national governments, international organisations and civil society actors such as NGOs. Finally, future research should focus on particular sectors' international innovative activities as well as on the international R&D strategies of emerging market MNEs to understand how these MNEs, which come from weaker institutional environments, respond strategically and shape their R&D strategies accordingly when they invest in countries with strong environmental agendas (Gómez-Bolaños et al., 2022). To this end, the ethical dimensions of the geographical dispersion of international green innovative activities should also be the focus of future research.

At this point, we should stress that the interaction of different drivers, for example geo-politics and digitalisation should also provide new exciting opportunities for research. The geopolitical dimension of AI becomes crucial in understanding the current and future trends in international political economy and the role of MNEs' R&D strategies in this context. Similarly, future research should further explore how remote team building facilitated by digitalisation fosters diversity which could affect the micro-foundations of R&D internationalisation in the drive of green innovations (Marino & Quatraro, 2022). If we are serious about confronting the world's Grand Challenges, which by definition are unsolvable by individual firms or countries, we must continue to build and nurture a global network of research, development, and innovation.

The recent geopolitical, technological and environmental challenges revealed gaps in our understanding of MNE international R&D strategies. Future research agenda should shed light on how the convergence of politics-science-digitalisation and sustainability will define MNEs' international R&D strategies. Thus, IB scholarship should build on its own rich tradition of embracing multifaceted approaches and transcending intellectual boundaries, to explore the dynamics of MNE R&D internationalisation.

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