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R&D offshoring in climate technologies to emerging economies: opportunities and challenges for Europe

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The CARISMA Project started in February 2015 and received funding from the European Horizon 2020 programme of the EU under the Grant Agreement No. 642242. CARISMA intends, through effective stakeholder consultation and communication, to ensure a continuous coordination and assessment of climate change mitigation options and to benefit research and innovation efficiency, as well as international cooperation on research and innovation and technology transfer.

This Working Document serves as Deliverable 7.4 under the CARISMA project.

Executive Summary

Research and development (R&D) is increasingly taking place on a global scale across a geographically dispersed set of interlinked units and activities. A prominent feature of the globalisation of R&D is the increasing offshoring of R&D to emerging economies, such as India, China and Brazil undertaken by multinational companies (MNCs) based in Europe. Drawing on a review of the literature, consultations with key stakeholders and firm-level case studies in the context of specific climate technologies, this report provides an updated overview of R&D offshoring, focusing on the key drivers and challenges for the MNCs involved.

The report identifies the following main drivers for the observed increase in R&D offshoring to emerging economies: (i) cost considerations; (ii) the effective adaptation of products to local markets; (iii) the search for talent and new ideas; and (iv) the aspiration to tap into local systems of innovation. The main challenges of R&D offshoring the report identifies are: (i) cultural and organisational differences; (ii) how to manage globally dispersed R&D activities; and (iii) how to protect intellectual property rights.

The report concludes that R&D offshoring can lead to benefits and opportunities for accelerating the development and diffusion of climate technologies, but may also lead to challenges for European countries. Recommendations for European policymakers to encourage R&D offshoring could involve including enabling mechanisms in bilateral trade agreements. If countries decide they want to limit R&D offshoring, they can consider, for instance, increasing funding for domestic private sector R&D, implementing programmes to increase the amount of graduates in the natural sciences and engineering.

Finally, it is suggested to treat R&D offshoring in climate change mitigation technologies as a form of technology transfer from the Global North to the Global South, and adopt initiatives at the international level, including in the UNFCCC technology-related bodies aimed at stimulating international R&D cooperation in various climate technologies.

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1 Introduction

The Paris Agreement requires the limitation of global average temperature increase to well below 2°C above pre-industrial levels. Consequently, it is urgent to reduce greenhouse gas (GHG) emissions sharply. It is widely recognised that the development and diffusion of climate technologies should be a central element in achieving this goal (Haselip et al., 2015). Europe aims to take a leading position in reducing GHG emissions, and is adopting ambitious policies for the development and diffusion of climate technologies. However, research and development (R&D) into new processes, products and technologies is increasingly being undertaken on a global scale across a geographically dispersed set of interconnected activities and units.

Several emerging economies, such as China, India and Brazil, have developed innovative capabilities, enabling firms and industries and other actors in these countries to engage in cutting-edge R&D in various technologies (Bruche, 2009; Branstetter et al., 2013). This globalisation of innovation means that global R&D is expanding from within and across the classic Triad of Europe, Japan and the United States to increasingly involving new players in innovation in emerging economies (Altenburg, 2008; Fu and Zhang, 2011).

Across various sectors, including those related to climate-friendly technologies, the increase in innovation capabilities has led to the emergence of so-called global innovation networks (GINs) involving R&D cooperation between multinational companies (MNCs) based in Europe or the US and firms and other actors in emerging economies (Liu et al., 2012). A key part of such newly emerged GINs involves industrialised-country MNCs relocating R&D and knowledge-intensive activities to offshored R&D units in emerging economies. This offshoring of R&D involves a shift from the traditional offshoring of labour-intensive production activities to increasingly higher value-added, knowledge-intensive and creative parts of technology development (Manning et al., 2008; Lewin et al., 2009).

The offshoring of R&D to emerging economies has raised concerns in Europe and the US about the potential risk of the loss of 'knowledge-intensive' jobs, the 'hollowing out' of the home-country's knowledge base and the erosion of industrial leadership in key technologies (Zuniga and Jabbour, 2009). For the individual MNCs involved, concerns have been raised that the benefits of offshoring R&D may not in all cases be worthwhile due to the hidden costs involved (Larsen et al., 2013). However, an overview of the challenges and opportunities of the offshoring of R&D that can guide policy formulation and planning for European industries is currently lacking.

On this basis, in this report we focus on updating insights on the offshoring of R&D to emerging economies by MNCs based in Europe. The primary objective of the report is to identify the key advantages and disadvantages of this global restructuring of innovation activities for European firms and industries involved in R&D in climate technologies. This will enable us address the question of whether and how R&D offshoring to emerging economies contribute to accelerate the development and diffusion of climate technologies.

In terms of policy recommendations, special emphasis is put on the role of policies and interventions at both the national level of EU member states and the European level in

relation to the offshoring of R&D to emerging economies. The findings of the report are therefore mainly aimed at informing (i) national policy-makers, such as government agencies involved in science and education; (ii) representatives of private-sector actors, including industry and trade associations; and (iii) European decision-makers, such as representatives of bodies under the European Commission that are involved in international R&D cooperation. The findings of the report may also be of use to bodies at the international level involved in global R&D cooperation in climate technologies, such as the Climate Technology Centre and Network (CTCN) and other initiatives under the United Nations Framework Convention on Climate Change (UNFCCC).

The report is structured as follows. Section 2 describes the methodology used in the report. Section 3 provides numerical indicators of R&D offshoring to emerging economies. Section 4 presents the main findings on the key drivers of and barriers to R&D offshoring based on a review of the literature. Section 5 presents two case studies of R&D offshoring in the context of climate technologies. The concluding Section 6 provides a brief summary and lists the report's main policy recommendations.

2 Methodology

This report has been drawn up based on three mains sources of data collected during the CARISMA project: (i) a review of the academic literature on R&D offshoring; (ii) consultations with key stakeholders at a workshop on R&D offshoring in the context of climate technologies; and (iii) in-depth interviews with representatives of firms involved in R&D offshoring in relation to specific climate technologies.

The review mainly includes sources from the peer-reviewed literature, but the grey literature has also been drawn on, including reports prepared by the United Nations Conference on Trade and Development (UNCTAD), the Organisation for Economic Co-operation and Development (OECD) and the European Commission. Journal papers have been identified through snowballing (Wohlin, 2014), as well as more systematic searches on the internet and the ISI Web of Knowledge database by using search strings combining key concepts of interest, such as "emerging economies", "R&D offshoring", "China", "India", "Brazil" and "Internationalization of R&D".

The workshop on R&D offshoring in the context of climate technologies was held in Copenhagen in March 2016 and convened representatives from academia, the private sector, government and international donor agencies. During the workshop, presentations were given by invited speakers, discussed with the audience, recorded digitally and made available on the CARISMA webpage.[1] The report also draws on feedback and input received at a side event held on 18 May 2017 at the meeting of the Subsidiary Bodies that formed part of the UNFCCC meeting in Bonn, where preliminary findings of the report were presented and discussed.[2]

Finally, the report draws on a total of forty in-depth face-to-face interviews conducted with representatives of two case study firms analysed in the report involved in R&D offshoring to emerging economies. Interviewees included employees working within the headquarters of the firm in the home country (Denmark and the Netherlands) and employees working in the local R&D units in the foreign countries (India and Brazil). The employees interviewed spanned across functional divisions and managerial levels of the organisations, including technical employees (such as chief technical officers and laboratory workers), shop floor workers, R&D managers, management and human resource personnel. The interviews addressed in detail their experience with R&D offshoring to emerging economies.

[1] See: http://carisma-project.eu/
[2] See: http://enb.iisd.org/climate/sb46/enbots/18may.html#event-1 or https://www.youtube.com/watch?v=p6iyzEOokgg

3 Indicators of the rise of R&D offshoring to emerging economies

The offshoring of R&D activities to foreign locations by MNCs based in industrialised countries started decades ago and is therefore nothing new in the global economy as such. Traditionally, the main destinations of R&D offshoring have been the Triad economies, i.e. the US, Europe and Japan. However, since the beginning of the new millennium, a new trend has emerged in which a number of emerging economies, especially China and India, began attracting large R&D investments from MNCs. This new trend was made particularly apparent to a broad audience with the publication of UNCTAD's annual World Investment Report for 2005 (UNCTAD, 2005). The report paid particular attention to MNCs and the internationalisation of R&D, as it presented various types of data demonstrating the rise of emerging economies as destinations for R&D and innovative activities. From Figure 1 below it becomes apparent, first of all, that R&D activities were increasingly being relocated abroad towards the end of the twentieth century. Second, from the late 1990s and to the beginning of the new millennium, China and India raised their combined proportion of total R&D sites from 6% of the total in 1995 to 14% in 2004. This led INSEAD and Booz Allen Hamilton (2006; 3) to conclude that "China and India are on the brink of overtaking Western Europe as the most important locations for foreign R&D for U.S. companies".

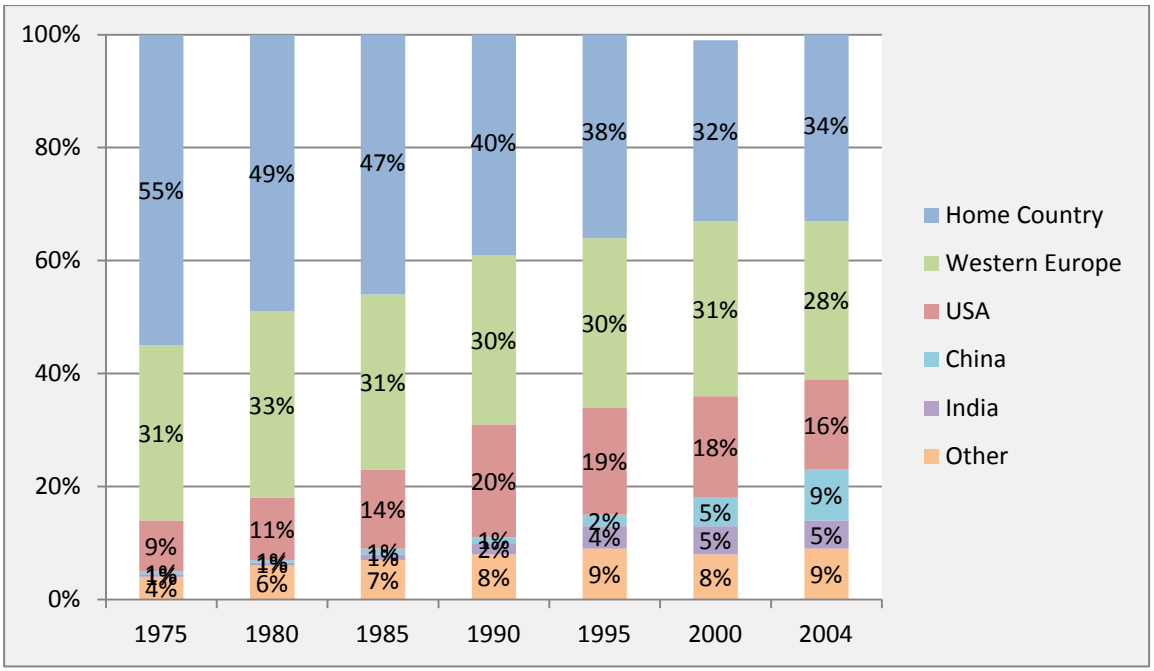

Figure 1. Share of R&D sites of total number of R&D sites in a survey of 186 companies. Source: INSEAD and Booz Allen Hamilton (2006).

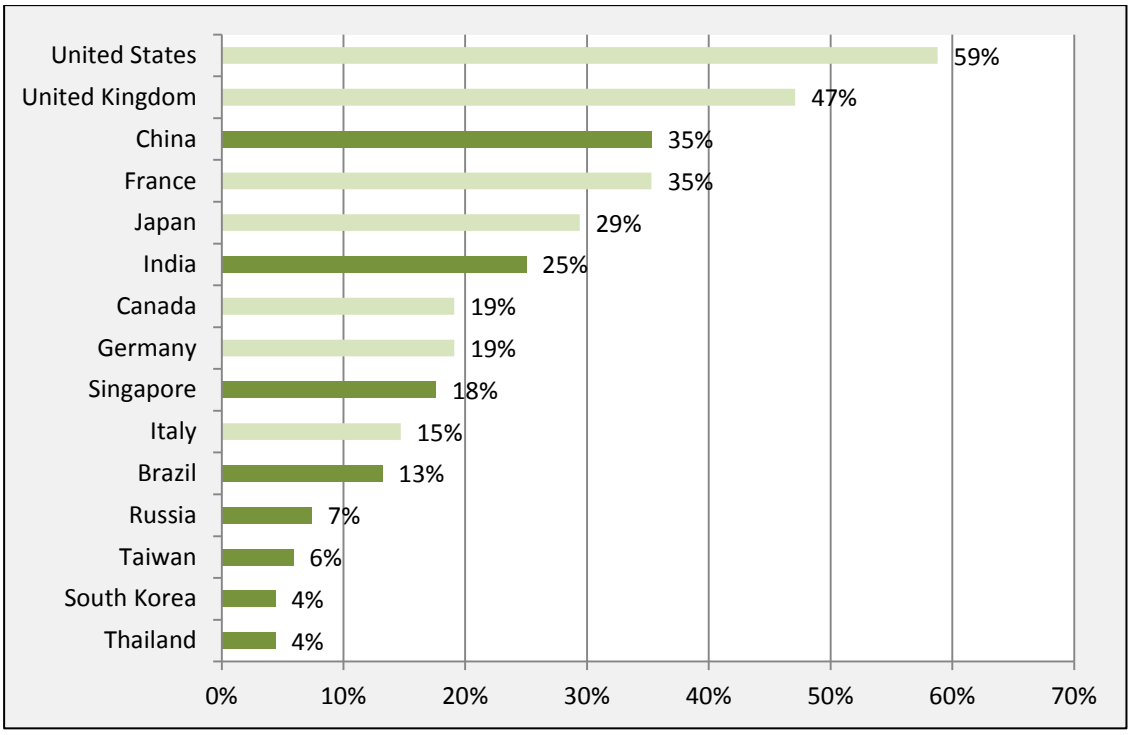

Figure 2. Foreign locations in 2004 of largest R&D spenders among the MNCs surveyed. Source: UNCTAD (2005).

Accentuating the growing importance of China and India in particular as destinations for R&D offshoring, Figure 2 presents a selected list of the foreign R&D locations of the largest R&D spenders among MNCs in 2004: 35% and 25% had R&D locations in China and India respectively, while 13% had R&D activities in Brazil. For US companies in particular, expenditure on R&D in non-OECD Asian markets (primarily China, India and Singapore) increased tenfold in the period from 1994-2008, reaching USD 3,4 billion (Idea Consult et al., 2014).

For India, Figure 3 shows how R&D investments by US MNC affiliates increased from a level of almost zero during the 1990s to almost USD 600 million in 2008 (Basant and Mani, 2012). Similarly, overseas R&D expenditures of US-based MNCs amounted in 2008 to $37 billion of which the combined share of China, South Korea, Taiwan, and Singapore increased from 11% in 1998 to 20% in 2008 (National Science Board, 2012). Another testament to the growing attractiveness of emerging economies in this period is the fact that, of the total number of green-field R&D projects between 2002 and 2004, 59% were established in developing economies (UNCTAD, 2005). At that time, 62% of the respondents surveyed as part of the UNCTAD study indicated China as being among the most attractive prospective R&D destinations for the coming five-year period (2005-2009), as opposed to 41% choosing the US and 29% choosing India (UNCTAD, 2005). As reported by Laursen and Santangelo (2017), this trend has continued, and China has been ranked first in the world for green-field foreign direct investment in R&D projects every year since 2010. Moreover, the number of foreign-owned R&D units in China increased from around 1,200 in 2008 to around 1,500 in 2013 and is expected to increase further to 1,750 in 2018 (Jolly et al., 2015; Zheng, 2010). A similar pattern can be found in India, where the number of foreign-owned R&D units increased from 49 in 1999 to 200 in 2007 and to 1,031 in 2013 (Sujit, 2013).

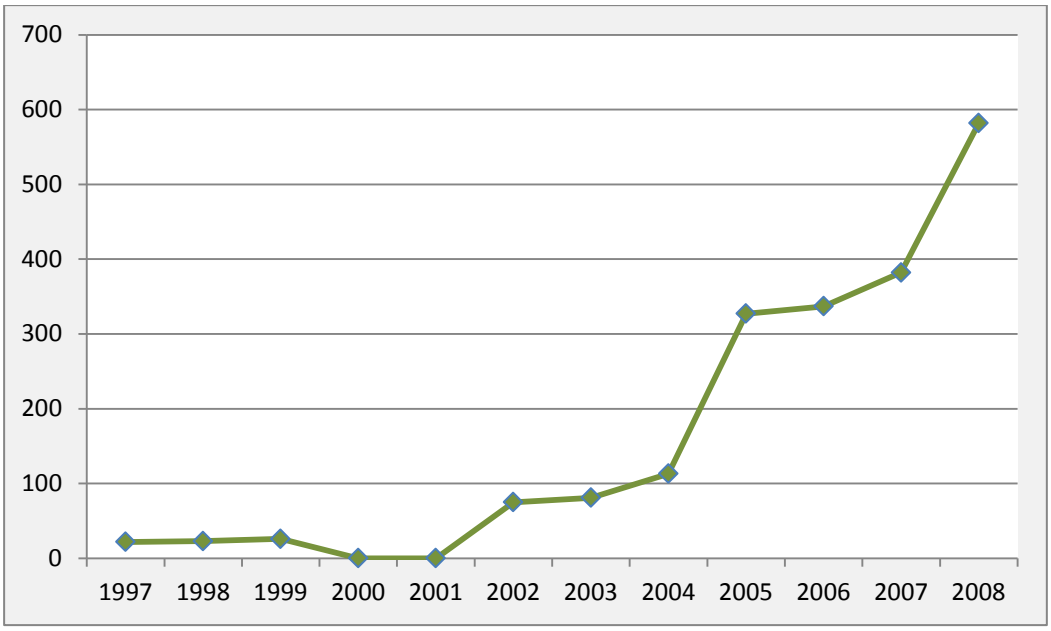

Figure 3. R&D investments in India by US MNC affiliates (mio. USD). Source: Basant and Mani (2012).

Another indicator of the increasing offshoring of R&D has been provided by Branstetter et al. (2013), who show that the annual number of jointly invented patents involving a US-based MNC and at least one inventor from China or India has increased from below ten in 2000 to around 1,200 in 2010 in China and from around fifty in 2000 to 700 in 2010 in India. This pattern has been confirmed in a more recent study focusing on the EU, which also finds that China, India and Brazil are rapidly rising in popularity as partners for cross-border joint inventions (Giuliani et al., 2016). Similarly, in a study of international collaboration in science and innovation among G20 economies from 2003-2012, China, India and Russia in particular were found to be among the economies that were most heavily involved in international joint inventions (OECD, 2016).

R&D offshoring mainly takes place in high-tech and R&D-intensive sectors, such as information technology, telecommunications, software design, pharmaceuticals, automotive and chemicals (Gassmann and Han, 2004; Bruche, 2009; Krishna and Bhattacharya, 2009). With specific reference to climate technologies, Schmidt and Huenteler (2016) present a two-dimensional typology of technologies based on the capabilities needed to design and manufacture various technologies (see Figure 4). According to this typology, examples of the most R&D and design-intensive climate technologies, which requires relatively low levels of production capabilities, includes wind turbines, geothermal, concentrated solar power, large-scale hydropower and biotechnology (upper left quadrant in Figure 4) (see also Binz et al., 2017). Climate technologies that require high levels of design and manufacturing capabilities (upper right quadrant in Figure 4) include electric vehicles, large-scale batteries and trains. Given their R&D and knowledge-intensive nature, we expect R&D offshoring to mainly take place in relation to the technologies placed in the two upper quadrants. This explains our focus on wind turbines and biotechnology in the two case studies conducted for this report. Interestingly, however, few studies have specifically focused on R&D offshoring in relation to climate technologies (notable exceptions include Noailly and

Ryfisch, 2015; Haakonsson, 2013). Offshoring to emerging economies in relation to climate technologies placed in the two lower quadrants of Figure 4 is likely to involve manufacturing activities rather than R&D and knowledge-intensive activities and will therefore not be dealt with in further detail in this report.

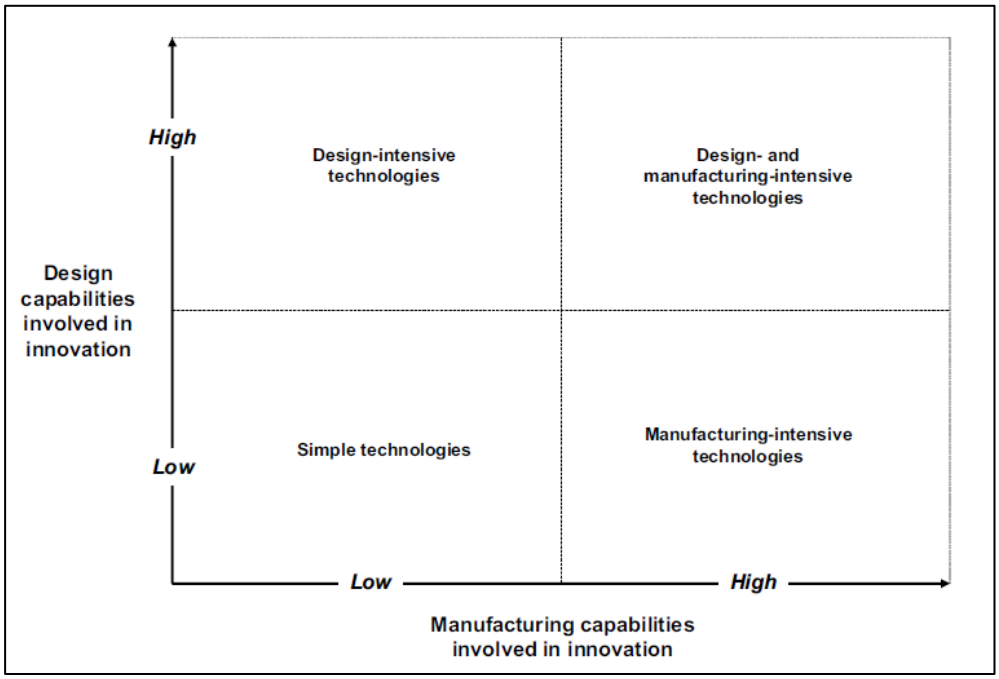

Figure 4. Typology of climate technologies. Source: Schmidt and Huenteler (2016)

Notwithstanding the specific sector in question, R&D offshoring is mainly undertaken by large MNCs with the necessary organisational capacity and financial resources, though small and medium-sized enterprises have also engaged in R&D offshoring (Massini and Miozzo, 2012; Chaminade et al., 2014). MNCs that have established R&D centres in emerging economies include Motorola, Microsoft, IBM, GlaxoSmithKline and Unilever (Shin-Horng, 2004). As we will show later, in the pharmaceutical and biotechnology industries offshored R&D activities may include preclinical R&D, clinical trials and laboratory testing and experimentation, while in relation to microchips such activities mainly involve software development and computer programming (Grimes and Miozzo, 2015; Hamdouch and He, 2009).

Most often, offshored R&D activities include what are referred to in the literature as 'problem-solving' tasks as opposed to 'problem-framing' tasks (Lynn and Salzmann, 2007; Schmitz and Strambach, 2008; Massini and Miozzo, 2012). While the former are concerned with R&D aimed at addressing specifically defined challenges, the latter involve R&D targeted at pushing the boundaries of a firm's current product offerings, thus producing new innovations. Problem-framing tasks may therefore be considered as lying at one end of a continuum, consisting of R&D that is not at the core of a company's strategic activities, to the other end of the spectrum, which involves R&D that is at the core and that is essential in sustaining the company's competitive advantage (Contractor et al., 2010). While MNCs typically retain most of their core and strategic R&D activities at home, the R&D activities they offshore to units in emerging economies mainly involve the less strategic and core aspects of R&D (Massini and Miozzo, 2012; Søberg, 2012;

Branstetter et al., 2013). This slicing up of the R&D value chain potentially means that resources are freed up for MNCs to focus on conducting core R&D activities at home (Castellani and Pieri, 2013; D'Agostino and Santangelo, 2012; D'Agostino et al., 2013).

4 Drivers of and challenges to R&D offshoring to emerging economies

This section will present some of the main findings from a review of the academic literature on R&D offshoring to emerging economies concerning its key drivers and barriers. So far, the international business and management literature has devoted most attention to analysing the managerial implications of this increasing trend. The main focus in this literature has been on the main drivers leading MNCs based in industrialised countries to offshore particular functions, the specific locations and modes of governance chosen, and the final outcomes in terms of financial and/or innovative performance (Castellani and Pieri, 2013; Larsen et al., 2013). These subjects have been analysed with an emphasis on the managerial aspects and operational challenges for the MNCs involved. It should be noted that the literature on R&D offshoring to emerging economies can be considered a subset of a much larger body of literature on R&D internationalisation, which is not covered in this report. The specific drivers and barriers of R&D offshoring to emerging economies, which will addressed in the following, are shown in Table 1 below.

Table 1. Key drivers and barriers of R&D offshoring highlighted in the academic literature. Source: Gassmann and Han (2004); Lewin et al. (2009); Søberg (2012).

Drivers and benefits of R&D offshoring	**Barriers to and challenges of R&D offshoring**
• Costs of conducting R&D • Effective adaptation of existing products to local markets • The global race for talent and new ideas • Tapping into specialised clusters and innovation systems	• Cultural and organisational differences • Management and coordination of globally dispersed R&D activities • Intellectual property rights and spill-overs of knowledge and technology

4.1 Drivers and benefits of R&D offshoring

Costs of Conducting R&D

One of the key drivers of the increase in the offshoring of R&D and knowledge-intensive activities to emerging economies is the availability of a well-educated and skilled local labour force with relative lower wage levels compared to their counterparts in Europe and the US (Idea consult et al., 2014; INSEAD and Booz Allen Hamilton, 2006). This availability of low-cost labour relates not only to the blue-collar labour force undertaking labour-intensive production activities, but also to white-collar technical and management personnel, such as engineers, plant managers, R&D directors and chief technology officers. Since R&D is a highly capital-intensive activity, there is a continued need for MNCs to identify ways of improving the economic efficiency of innovation activities by reducing costs. This need has become even greater with increases in the expense and complexity of R&D through which technology-leading MNCs try to distinguish themselves from their competitors in order to maintain their competitive positions (Zuniga and Jabbour, 2009). Hence, placing R&D activities in lower-wage destinations, such as China and India, is an attractive option for MNCs to reduce labour costs significantly in order to

lower the overall costs of their R&D activities (Dossani and Kenney, 2003; Kedia and Lahiri, 2007).

However, the literature has also pointed out that the significance of such cost considerations has declined over the past ten to fifteen years, as wages have increased significantly in China and India, especially for scientists and engineers in the large cities and economic regions. Hence, while access to a low-cost workforce was one of the main drivers for R&D offshoring in 2006, as shown in Figure 7, it has gradually been accompanied by additional drivers.

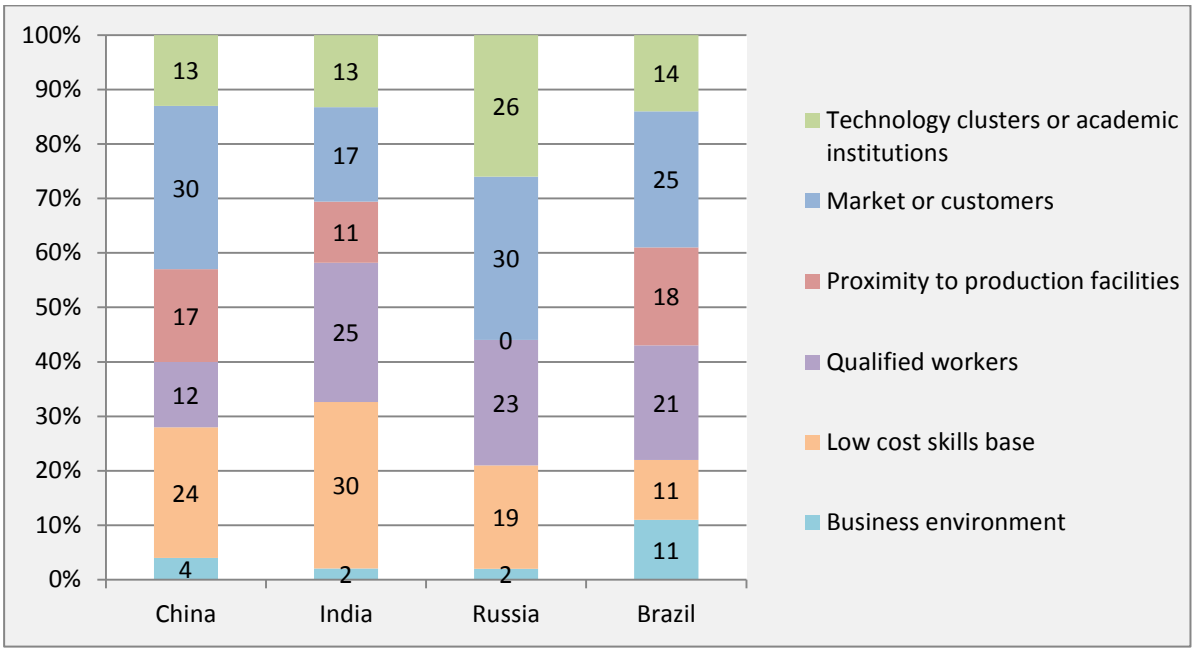

Figure 5. Drivers for the establishment of R&D units in emerging economies. Source: INSEAD and Booz Allen Hamilton (2006)

Effective adaptation of existing products to local markets

A second driver of R&D offshoring is the need for MNCs to be able to respond swiftly and effectively to changing conditions in the local and regional markets they serve abroad (Noailly and Ryfisch, 2015). Given the significant size of markets in emerging economies and associated market opportunities, MNCs typically aspire to obtain knowledge about a variety of issues related to the local and context-specific conditions that may influence sales in these markets (Lewin et al., 2009). Such issues include having relevant information on customer preferences, competing products, regulatory frameworks, incentive schemes and local systems of governance (Idea Consult et al., 2014). Obtaining knowledge about these issues in many cases requires having a local presence, which also includes devoting resources to nurturing and sustaining personal connections and relationships with key actors and agencies locally. Often there is also a need to change and modify existing products and technical design specifications in order to cater to specific local requirements. Entering new markets is therefore typically not a straightforward question of transferring equipment and promoting the sale of existing products to new markets and customers.

The literature suggests that the establishment of R&D units provides a platform for MNCs based in industrialised countries to conduct targeted market intelligence in order to enhance the speed of introducing products to markets and to conduct the necessary product changes (Lewin et al., 2009). Indeed, a good understanding of the market is increasingly required for foreign MNCs to compete with other foreign MNCs and domestic competitors in the markets of emerging economies. This means that foreign MNCs sometimes use the establishment of local R&D units as a market entry strategy. In other cases, the establishment of local R&D units in emerging economies by MNCs based in industrialised countries is a continuation of their previous placement of production and manufacturing activities in these locations (Bruche, 2009; Lema et al., 2015; Motohashi, 2015). The role of local R&D units mainly as adaptors of current products and services to local market conditions is referred to in the literature as 'home-base exploitation' to emphasise that MNCs are exploiting their products and competitive advantages in new markets (Gassmann and Han, 2004; von Zedtwitz, 2015).

However, the literature also points out that over time many local R&D units develop more advanced innovative capabilities that allow them to engage in innovation activities conducted by MNCs globally. The mandate of the local R&D units therefore shifts away from being mainly focused on R&D devoted to the adaptation and modification of existing products to local markets. This shift has been termed 'home-base augmentation' to signify that MNCs are increasingly utilising local R&D units to generate new knowledge rather than exploiting the existing knowledge and competences (Ujjual and Patel, 2013; von Zedtwitz, 2015).

The global race for talent and new ideas

A third driver of R&D offshoring to emerging economies has been the emerging shortage of skilled talent in developed countries and the simultaneous increase in the availability of skilled talent in China and India in particular (Lynn and Salzmann, 2007). The concerns over sustaining sufficient access to skilled knowledge workers, especially scientific and engineering talent, has led to what has been called a 'global race for talent' (Lewin et al., 2009). In attempting to stay at the forefront of innovation, MNCs have established R&D units in emerging economies to make use of the growing pools of engineering and science students graduating from the educational institutions that have been established in recent years. These local talents are particularly attractive, as they combine a high level of education with diverse cultural and social backgrounds, allowing them to contribute new types of knowledge and ideas to the existing knowledge base of foreign MNCs (ref?). As creativity and the generation of new ideas are fundamental aspects of R&D activities, MNCs based in industrialised countries are therefore establishing R&D units in emerging economies to attract and recruit local talent, thus expanding and diversifying their knowledge base (Singh, 2008; Bruche, 2009).

R&D offshoring to emerging economies thus forms part of the continued efforts undertaken by MNCs to improve their innovative performance. Manning et al. (2008;35) note: "For a growing number of companies, reducing labour costs is no longer the only strategic driver behind offshoring decisions. Accessing pools of highly skilled talent around the world has emerged as a new key strategic driver".

It should be noted, however, that there is often a need for MNCs to invest; the benefits of diversity do not come for free. They provide training programmes and supervision, at least initially, in order to upgrade the skills and competences of employees of the local R&D units. Such measures are mainly targeted at competence development and specialisation in the specific industries and technologies in question (Criscuolo and Narula, 2007).

Tapping into specialised clusters and innovation systems

In a number of emerging economies there has been a general increase in the emergence of specialised clusters and local innovation systems. Such localised knowledge hubs are typically concentrated geographically in specific regions and major cities in emerging economies, such as Shanghai in China and Bangalore in India. They consist of suppliers of goods and services, informal networks, tacit knowledge, production systems and research institutions specialised in a particular industry (Chaminade and Plechero, 2015).

The accumulation of specialised knowledge and expertise in such areas, which may include local industrial high-tech parks, may be important for MNCs based in industrialised countries to tap into, especially if this knowledge is not readily available in their home country (Haakonsson and Ujjual, 2015). Hence, MNCs sometimes establish local R&D units in these specialised clusters with the purpose of engaging with these local actors and organisations, for example, through collaborative R&D projects, in order to obtain access to new knowledge.

This trend towards knowledge-seeking investments as a motivation for R&D offshoring has been underlined by the general increase in investments in R&D and the strengthening of educational systems. However, this trend is also enabled by a profound change in the firm-level strategic management of R&D over the past two decades, where the traditional process of innovation in which firms fund an in-house R&D department has gradually been superseded by the increasing dislocation of the innovation process across a network of external partners and offshore sites. In the literature, this decentralisation of R&D has been referred to as the 'organisational decomposition of the innovation process' (Schmitz and Strambach, 2008; 2009), and emphasizes the movement towards more open models of innovation (Chesbrough, 2003).

Hence, rather than developing new knowledge and expertise in-house in specific areas, R&D increasingly involves sourcing such knowledge from external partners, for example, through mergers and acquisitions of specialised suppliers or joint R&D, or through the establishment of local R&D units in areas with specialised knowledge (Contractor et al., 2010; Massini and Miozzo, 2012). Consequently, MNCs are moving toward a multi-hub structure where R&D activities are located and organised across various regions globally (Criscuolo and Narula, 2007).

4.2 Barriers to and challenges of R&D offshoring

While the potential benefits of R&D offshoring are often clear in theory, in practice there are several barriers and challenges that MNCs based in industrialised countries need to overcome in order to reap the benefits effectively. These are described below.

Cultural and organisational differences

As with other sorts of operations abroad, MNCs face challenges in operating in an environment with cultures, languages, organisational routines, social practices and traditions that differ significantly from those of the MNC's home country. Such cultural and organisational differences can lead to different types of problems, such as misunderstandings, estrangement, conflicts and other types of difficulties with collaboration that may reduce the economic advantages of establishing R&D units abroad.

The literature has therefore repeatedly pointed out that effectively avoiding and overcoming these challenges involves a cost in terms of prioritising and implementing various mitigation measures and management initiatives. Specific measures devoted to this purpose may include management efforts aimed at creating a common company culture, shared forms of communication and fostering the building of trust and working relationships across departments. However, managing challenges related to cultural differences not only affects the firm's internal activities, including the relationship between the MNC's head office and the local R&D unit, it is equally important with regard to managing relations with various actors and organisations in the external (local) environment.

In China, for instance, the special culture of doing business through informal networks and relations, the so-called 'Guanxi' culture, often constitutes a challenge for foreign MNCs in terms of partnering and engaging with local universities, research institutions and regulatory agencies (Gassmann and Han, 2004; Choudhury et al., 2012; Ujjual and Patel, 2013). As noted by Contractor et al. (2010;1224): "the contracting environment, culture, work habits, and institutional environment in each foreign nation need to be learned. The costs of data transmission may have reduced substantially, but cultural and institutional distance between nations remains an obstacle and a significant cost".

It is worth noting, however, that the degree to which culture becomes a challenge varies according to the type of R&D being carried out. Some MNCs experience difficulties in fostering a conducive intra-organisational culture of innovation across borders and in merging various national cultural traits into a coherent whole (Haakonsson, 2013). This may be the case even for relatively simple R&D tasks, which means that often more support from the MNC's head office is needed in order to enable the local R&D unit to thrive in the new environment (von Zedtwitz, 2015).

Management and coordination of globally dispersed R&D activities

A second challenge repeatedly mentioned in the literature concerns the difficulties related to the coordination and management of various interconnected R&D units that are dispersed globally and that comprise multiple and diverse sources of knowledge (Reger, 2004; Criscuolo and Narula, 2007; Lewin et al., 2009; Contractor et al., 2010; Massini and Miozzo, 2012). The nature of the innovation process means that the effective combination and integration of diversified knowledge from various places into a coherent whole is an extremely difficult task. As noted by Criscuolo and Narula (2005;3): "it is one thing to implement a dispersed R&D structure; it is quite another to achieve successful and efficient coordination, since personnel and management do not always adapt to

these new structures, as they require inordinate amounts of coordination as well as new knowledge-exchange and networking abilities".

Whereas codified knowledge, such as patents, standards and design specifications, can be transferred relatively easily when geographical proximity is lacking, the tacit and implicit nature of advanced and specialised knowledge is much more difficult to transfer between distant R&D units (Persaud et al., 2015). This constitutes a key challenge for MNCs involved in R&D offshoring, as R&D is underpinned by a significant degree of tacit knowledge created from the daily interactions and practical activities through which employees cooperate face to face and exchange ideas in order to solve various tasks and develop new solutions.

While modern telecommunications systems have contributed to overcoming such challenges, R&D managers are still faced with substantial difficulties in creating the enabling conditions that are conducive to the exchange of tacit knowledge and direct interaction across R&D units (Reger, 2004). The costs of coordinating and integrating dispersed R&D units effectively are considerable, and if not managed properly they can end up having a negative effect on the quality and innovative performance of the MNC itself (Singh, 2008; Contractor et al., 2010).

Consequently, MNCs typically devote significant resources to ensuring as frequent and regular face-to-face interaction as possible in the form of, for example, exchanges of employees across units, coordination visits by R&D managers and the formation of joint project work across R&D units (Criscuolo and Narula, 2007; Rabbiosi and Santangelo, 2013; Persaud et al., 2015; Søberg, 2012; Singh, 2007; Frost and Zhou, 2005). While such measures can indeed help to improve the effectiveness of communication and knowledge exchange across units, they involve significant costs related to travel, project management and coordination (Contractor et al., 2010).

Intellectual property rights and spill-overs of knowledge and technology

While the establishment of local R&D units in emerging economies enables MNCs based in industrialised countries to take advantage of the available pool of knowledge and the local talent base, it also make them vulnerable to the loss of proprietary technology and knowledge to local actors and organisations. Spill-overs from the foreign MNC to local competitors and cooperation partners can, for example, take place through intra-industry labour turnover, the direct copying of technical drawings or products, engagement with local sub-suppliers, corporate espionage and cooperative R&D projects with local universities and research institutions (Zhao, 2006).

Since competition in knowledge-intensive industries is based mainly on technological progress from continued R&D, there is a strong economic incentive for both local companies and other foreign MNCs to obtain access to knowledge from the MNC's local R&D units. This incentive to acquire technology and know-how is especially pronounced for local companies in emerging economies that are aspiring to catch up with those MNCs that are operating at the technology frontier.

The literature has therefore pointed out that MNCs based in industrialised countries involved in R&D offshoring try to prevent spill-overs to the local economy based on

longer term strategies for sustaining their competitive advantages vis-à-vis their local competitors (Schmitz and Strambach, 2008; Castellani et al., 2015; Laursen and Santangelo, 2015; Lema et al., 2015). The implementation of such measures is based on the rationale that ultimately the spill-over of knowledge created through R&D activities will prevent MNCs from being able to reap the commercial benefits of their investments in R&D (Lynn and Salzmann, 2007). Spill-overs from local R&D units therefore potentially involve an economic loss for the MNC.

Since intellectual property rights (IPR) regimes in many emerging economies do not adequately ensure the protection of proprietary knowledge, such as trademarks and products, MNCs typically put in place measures aimed at preventing and reducing copying and knowledge dissemination to third parties (Søberg, 2012; Buss and Peukert, 2015). Such measures may include the enforcement of strict visiting rules and regulations in company offices and plant sites, non-competition clauses in employment agreements, and the sub-contracting of smaller packages rather the full product to local suppliers (Hansen et al., 2016).

5 Case studies of R&D offshoring in the context of climate technologies

In this section, two case studies of R&D offshoring in the context of climate technologies will be presented based on firm-level research conducted as part of the CARISMA project, which includes interviews with key firm representatives. These case studies will provide information on how R&D offshoring takes place in practice and will also serve to illustrate some of the key findings from the literature review presented above, especially concerning the key drivers of and barriers to R&D offshoring. The case studies involve two world-leading Danish companies from the wind turbine and biotechnology industries that have offshored their R&D to India and Brazil respectively. The companies have been anonymised under the names Alpha and Beta due to sensitivity concerns.

5.1 R&D offshoring to India by a leading Danish supplier of wind turbine blades

Company background

Alpha was created in 1940, at which time it mainly produced wooden furniture. From the early 1950s the company started producing various products based on fibreglass materials, such as boats and caravans. In the late 1970s, the experience it had acquired in manufacturing fibre-glass materials and related production techniques laid the foundations for the decision to start producing wind turbine blades. Subsequently, the company gradually focused increasingly on the production of these blades for the emerging wind turbine market.

Alpha is currently headquartered in Denmark and has a global presence with established manufacturing capacity and other ongoing activities in eight countries spread across four continents: Denmark, India, China, Spain, Poland, Canada, USA and Brazil. It employs over 6,000 people globally across specialised divisions related to R&D, blade manufacturing, local sale offices, services and logistics.

The company is the world's largest independent supplier of rotor blades to the wind industry: over one-fifth of the wind turbines in use globally operate on blades developed by Alpha. Since its inception in 1978, it has produced more than 185,000 blades powering an installation capacity of approximately 77 GW and has earned a total revenue of 750 million Euros, with a total of 46 million Euros before interest and tax (total profit of 6 million Euros). Recently, Alpha was sold for a total enterprise value of 1.5 billion Euros.

The development of modern, advanced, large-scale wind turbines is a highly capital- and technology-intensive process, which involves continued R&D undertaken by the leading global wind turbine manufacturers, such as Vestas, Siemens, Gamesa, Nordex, and General Electric. Blades constitute a critical component in influencing the operational efficiency and hence economic feasibility of wind energy. Given the sensitive nature and complexity of blades, the typical procedure of leading wind turbine suppliers therefore involves the development and production of blades either in house or by outsourcing to a small group of first-tier suppliers, such as Alpha. This means that Alpha continuously invests significant resources in R&D to improve the efficiency of its wind blade technology

in order to remain a first-tier supplier and meet the high quality requirements expected from wind turbine suppliers.

Offshoring of production to India

Initially, blade production and R&D activities were located in Denmark, that is, close to the company's main markets in Europe. However, over time, as Alpha gradually internationalised, a number of blade production facilities were established in overseas markets.

The first of these overseas investments involved the establishment of a local blade-manufacturing plant in 1993 in Dabaspet District in Bangalore in the state of Karnataka, south India. One of the motivations for Alpha's management to establish a local production facility in India at that time was the increase in local market demand, especially from around 1993. This increase in local demand was mainly related to the adoption of conducive national and state-level policies, such as reductions in import duties, tax rule incentives, the provision of soft loans and government incentives to attract foreign direct investment.

In addition, Alpha's set up of a local manufacturing facility reflects the typical procedure of first-tier suppliers in following their main clients in overseas markets by establishing local component production assuming the expected benefits outweigh the costs, especially given the bulky nature of wind turbine blades, which are costly and difficult to transport. In this case, it was felt, the localisation of blade manufacturing could lower the costs in order to increase competitiveness in both the Indian market and regional markets.

Finally, the adoption of local content requirements also seems to have played a role in incentivising Alpha to establish the local production of blades in India.

Offshoring of R&D and knowledge-intensive activities to India

In 2007, Alpha established a local R&D unit in close proximity to the existing production facility in Bangalore. Initially, the main strategic reasons for establishing this R&D unit involved the need to increase local engineering capacity in order to adapt and modify the existing products and designs, which had been developed in Denmark, to the local conditions. Increasing the local engineering capacity would allow a higher degree of control and more rapid responses to adapting products to local conditions and demands. The R&D unit thus also functioned as a 'listening post' to collect market intelligence for sales and marketing purposes. Furthermore, the projected shortage of qualified engineers and technicians in Denmark spurred interest in reaping the benefits of the availability of a large pool of skilled workers in India, especially in the fields of electrical and mechanical engineering. The relatively lower cost of the Indian engineers provided an opportunity to reduce the overall costs of R&D activities.

In the beginning, the main activities of the local R&D unit involved routine-based functions and labour-intensive engineering activities, such as making detailed calculations, preparing technical drawings, making design modifications and related engineering support. Over time, however, especially from 2010 onwards, the mandate

for the R&D unit shifted increasingly to more strategic and knowledge-intensive engineering tasks.

This progression in the technical ability of the R&D unit to move from 'problem-solving' to 'problem-framing' activities (see also section 3) meant that the R&D unit became capable of undertaking more complex and independent engineering tasks, such as basic and conceptual engineering (as opposed to detailed engineering).

This progression is exemplified by the emergence of the R&D unit as a centre of excellence in the design of new web moulds and related engineering support provided to all the in-house Alpha manufacturers of web moulds globally. Further, the local R&D unit was responsible for managing and coordinating a global R&D programme on aeroacoustics and dynamics in relation to the development of the longest blade ever produced by Alpha. The Indian R&D unit has also taken the lead in relation to R&D of blade reliability based on monitoring plants while in operation and incorporating this information into global R&D activities.

The local R&D unit has filed over 25 patents since 2007, a further indication of its advanced stage of innovation capability. In parallel with the increasing involvement of the R&D unit in Alpha's global innovation activities, the unit expanded from seven employees when it was established in 2007 to 150 employees in 2016. Nonetheless most of the core and strategic R&D activities are still conducted in Denmark.

Overcoming challenges and reaping benefits

Upgrading the innovation capabilities of the local Indian R&D unit depended significantly on the training, supervision and strategic recruitment undertaken by Alpha's head office. It appears that the strategic motivation for dedicating specific resources to this purpose was the management's long-term objective of incorporating the R&D unit into Alpha's global R&D and innovation activities. This would eventually allow the company to take advantage of the availability of a local skilled workforce in order to reduce costs and enhance the effectiveness of the company's global R&D activities.

A substantial proportion of the resources devoted to capacity-building involved training and supervision programmes aimed at integrating the Indian R&D unit into the global organisation through courses in enhancing cross-cultural understanding and effective communication systems. These training efforts were encouraged by the foreseen challenges related to differences in organisational working practices and culture across the Danish and Indian organisations. Efforts were also undertaken to retain local employees in order to prevent spillover of knowledge to local competitors.

The circumstance that Alpha operates as a project-based organisation in which functional divisions and project teams work together globally helped in enabling the development of a common company culture and shared modes of operation. Alpha's management also actively promoted the development of an interconnected and coherent global organisation by encouraging collaboration between global team members on specific projects through frequent travel and face-to-face meetings.

5.2 R&D offshoring to Brazil by a leading Danish biotechnology company

Company information

Beta is a globally leading biotechnology company headquartered in Copenhagen in Denmark. The company was founded in 2000 as a spin-off from a Danish multinational pharmaceutical company. Beta develops and produces industrial enzymes and microorganisms, which are used to replace chemicals and reduce energy, water and raw materials in a wide range of industries including household care, food and beverage, agriculture and bioenergy.

Innovation in Beta requires not only strong coordination of R&D and technological development upstream in the value chain but also an effective downstream network to integrate its products and solutions into the industrial processes of its customers and suppliers. Beta has production facilities in Argentina, Brazil, Canada, China, Denmark, the United Kingdom, India and the United States. It furthermore maintains a global network of R&D sites located in Brazil, China, Denmark, the United Kingdom, India, Japan and the United States. Each R&D site represents a certain set of skills and competences, which are tied together by a global knowledge management system. Beta invests heavily in R&D and has an extensive patent portfolio. It employs more than 5,000 people of which approximately 20% work in R&D.

The industrial enzyme market is highly competitive and has variable profit margins depending on industry applications. To operate at the technological frontier, Beta needs to optimise its industrial enzyme technologies to fit raw material characteristics and local market conditions. Optimisation essentially involves screening and selection of cost efficient enzyme variants and determining their optimal dosing range for maximum yield. This is a knowledge and technology intensive process, which involves learning and feedback from user producer interaction at the costumer sites. A substantial part of the R&D effort in Beta therefore takes place in proximity to its key markets.

Offshoring of R&D activities to Brazil

The story of Beta in Brazil began in 1975 with the establishment of a sales office. In 1989, it established production and supply chain facilities. During the next two decades, Beta developed strong production capabilities in Brazil, which improved the operational efficiency and the cost and performance of its products. Subsequently, in 2009, Beta established a local R&D unit in Brazil with the main purpose to gain a foothold in the growing bioethanol market. At that time, Brazil was one of the largest producers of bioethanol in the world and the market was considered by Beta to have a significant export potential.

To stay competitive Beta needed to optimise its industrial enzyme technology to fit local raw materials and local market conditions. In Brazil, the primary feedstock in bioethanol production is sugarcane. The R&D efforts conducted at the local R&D unit mainly involved the screening and selection of enzyme variants to provide biological solutions to Latin-American markets. Based on intensive and prolonged R&D activities, Beta was in 2012 contracted to supply a customised version of its industrial enzyme technology to the first commercial-scale second generation bioethanol plant in Brazil.

Overcoming challenges and reaping benefits

The continuous optimisation of successive generations of its enzyme technology based on R&D conducted at the local R&D unit allowed Beta to develop increasingly complex costumer-specific solutions in Brazil. Building the capabilities and the knowledge base within the local R&D unit to manage and implement technical change with increasing complexity is for example reflected in the delivery of customised solutions for second generation ethanol from sugarcane bagasse.

This capability-building process relied on a number of deliberate and continuing efforts undertaken by Beta. Firstly, Beta continuously implemented various training programs of the scientists and engineers at the local R&D unit with a view to develop their ability to conduct increasingly complex and advanced R&D in enzyme technology.

Secondly, strategic recruitment of specialists with significant experience in bioethanol production was undertaken by Beta, which meant that over time, the local R&D unit increased from 12 employees in 2011 to more than double in 2016.

Thirdly, Beta engaged in R&D cooperation with Brazilian universities and research institutions, which allowed the local R&D unit to tap into the accumulated knowledge in the local innovation system.

Fourthly, Beta implemented various measures to increasingly integrate the local R&D unit within the global R&D network of the company. This allowed the scientists and engineers at the local R&D unit appropriate the vast amount of knowledge available within Beta.

Finally, the R&D unit relied significantly on continuous interaction and strategic partnerships with costumers and users, which enabled the local R&D to learn from the practical aspects and operational experience from plant sites.

6 Conclusion

This report set out to present up-to-date information on the offshoring of R&D to emerging economies undertaken by MNCs based in Europe with a view to identifying the key advantages and disadvantages for MNCs undertaking R&D in climate technologies. Specifically, the report aimed at addressing the question of whether and how R&D offshoring to emerging economies contribute to accelerate the development and diffusion of climate technologies. This question was addressed through a review of the academic literature, stakeholder consultations and case study research.

The report finds that R&D offshoring indeed leads to benefits and opportunities for accelerating the development and diffusion of climate technologies that are R&D and knowledge-intensive in nature.

First, placing R&D activities in emerging economies involves an opportunity for the MNCs involved to reducing the costs of R&D by shifting R&D activities to locations that have a workforce available with relatively lower salary levels compared to their European counterparts. Offshoring of R&D to emerging economies therefore enables the MNCs involved to implement R&D in a more cost effective manner, which contributes to accelerate the development of new technology.

Second, the need for foreign MNCs to be able to adapt existing products to local markets effectively in order increase speed to market constitutes a strong impetus for R&D offshoring. Accordingly, the establishment of local R&D units allow the MNCs involved to accelerate the diffusion rate of various climate technologies by increasing the sale of their products. Due to the significant scale of the markets, the accelerated diffusion of climate technologies in emerging economies, such as China and India, may contribute significantly to drive down prices on a global scale, thereby stimulating further uptake.

Third, given the shortage of qualified engineers in Europe and the availability of a well-educated and skilled workforce in many emerging economies, MNCs offshore R&D in order to secure continued access to talent, knowledge and new ideas. Placing R&D activities in emerging economies thus allows MNCs to overcome an important bottleneck to maintaining and expanding R&D activities with the purpose to accelerate technology development.

Finally, the literature has highlighted that European MNCs offshore R&D to emerging economies with the aim of tapping into the knowledge available in local innovation systems and specialised clusters. By locating R&D units in such clusters, the MNCs can avoid devoting significant resources and investments in acquiring all of the needed expertise in-house in a centralised R&D unit. This enables R&D activities to be undertaken more cost-effectively.

However, the literature has also identified a number of barriers and challenges to R&D offshoring for the involved MNCs.

The first is related to the challenges that MNCs experience with regard to cultural and organisational differences between the offshored R&D units and other parts of the MNC, including the MNC's own headquarters. Companies have typically responded by adopting

measures aimed at ensuring a greater degree of cultural integration, trust and social relationships across the offshored R&D units and other organisations within the MNC.

Second, the management and coordination of a globally dispersed set of interlinked R&D activities constitutes a substantial challenge in terms of organisation and effective communication. Modern communication tools are part of the solution to this, but the problem cannot be fully taken away as R&D activities often requires the exchange of tacit knowledge, which depends critically on face-to-face interaction.

Finally, the literature has pointed out that MNCs devote significant efforts to protecting their IPR and to preventing the spilling over of knowledge and technology to the local economy from the offshored R&D units. Efforts devoted to this purpose include initiatives to improve the retention rate of employees and careful management of linkages with local sub-suppliers.

Overcoming these challenges and barriers in order for the MNCs to reap the benefits of R&D offshoring involves significant time and economic resources. R&D offshoring is therefore often not a short-term endeavour, but rather a long-term investment for the MNCs involved. However, in order for R&D offshoring to contribute to accelerate the development and diffusion of climate technologies, it is critical that the above challenge are addressed and overcome.

Based on in-depth firm-level research, we also presented two cases of R&D offshoring in the fields of wind turbine blades and biotechnology undertaken in India and Brazil respectively by two MNCs with headquarters in Denmark. Both of these case studies provide a detailed illustration of how R&D offshoring takes place with regard to climate technologies. The two case studies confirmed the main findings from the literature on R&D offshoring, suggesting that, in relation to climate technologies, such activities generally seem to follow the main trends observed in other industries and countries with regard to the benefits and challenges of R&D offshoring to emerging economies.

7 Policy recommendations

The report clearly indicates that R&D offshoring is a complex phenomenon where much of the inherent dynamics involved take place within individual companies in the private sector. It is therefore not a straightforward matter to extrapolate the findings of the report, which for the most part is based on a non-comprehensive review of firm-level research in the literature, to policy recommendations, especially considering that the academic literature in this field has focused mainly on providing recommendations for management at the firm level.

This circumstance points to the need for further work aimed at improving the interface between research on R&D offshoring and policy advice, especially in the field of climate technologies. However, some tentative suggestions can be drawn from the report that national-level policy-makers in the individual EU member states may want to consider in terms of policy formulation and implementation. To this end, we have found it useful to distinguish between two opposing sets of suggestions for policies that could work either in favour of or by limiting R&D offshoring in relation to the development and diffusion of climate technologies. The recommendations are made from a European perspective.

In terms of policies aimed at promoting and facilitating R&D offshoring, European government agencies could consider developing a policy framework specifically targeted at supporting national MNCs in offshoring R&D activities to emerging economies. Such a framework could benefit from engaging in a dialogue with the potential MNCs and relevant industry associations in order to tailor policies to their specific demands and needs. It would be advisable to conduct national-level assessments of R&D offshoring across various industries as part of the preparatory work for this policy framework. Active support provided by government agencies could also take the form of the establishment of local centres providing various types of consultancy and extension services to MNCs in the emerging economies being targeted. Such promotional activities could be included in bilateral trade agreements or government-to-government programs aimed at promoting private-sector R&D cooperation in the development of various climate technologies. The challenges that have been identified to the MNCs involved could therefore be addressed, for example, by facilitating linkages enabling them to tap into local knowledge systems while protecting their IPR.

An opposite perspective involves the suggestion that government agencies should rather seek to discourage R&D offshoring. Such an approach could involve adopting policies aimed at increasing the supply of skilled knowledge workers, especially in science and technological disciplines, in order to provide a sufficient basis for retaining R&D in the MNC's home country. Furthermore, increasing public investment in R&D could contribute to sustaining R&D activities in the home country, although this would require going against the widespread tendency of government-funded R&D programs to promote internationalisation. Another approach involves adopting economic measures aimed at reducing the costs of conducting R&D in the home country, for example, through dedicated grants, tax breaks or government-funded investment packages. Finally, support for the establishment and nurturing of specialised local and regional clusters and knowledge systems in the home country could contribute to discouraging MNCs from seeking new knowledge and ideas abroad. The strengthening of such localised knowledge

systems could take the form of preferential treatment, economic incentives and various services provided to companies and research institutes that place R&D activities in these areas.

Notwithstanding whether R&D offshoring to emerging economies is considered worthwhile promoting or impeding from the perspective of national policy makers, it is evident that R&D in relation to climate technologies is often an issue of high national economic interest. Not least due to concerns about sustaining industrial leadership and competitiveness in core sectors as reflected in measures to protect and nurture domestic industries, such as the wind turbine industry in Denmark. Hence, national development priorities will be important elements in the policy considerations concerning the offshoring of R&D in climate technologies to emerging economies undertaken by MNCs based in industrialised countries.

In the context of global efforts to mitigate climate change, and for climate policy at the international level, R&D offshoring may generally be considered to involve significant opportunities for accelerating the development and diffusion of climate technologies. Accordingly, the topic of R&D offshoring to emerging economies, and the globalisation of R&D more broadly, could receive greater recognition and prominence in international climate negotiations and technology-related initiatives under the UNFCCC. Such negotiations have been characterised by a long-standing perspective focusing on the importance of transferring technologies to developing and emerging economies based on R&D conducted in industrialised countries (Haselip et al., 2015). However, as pointed out in this report, given the increasing importance of various actors and organisations from emerging economies in the global innovation activities of MNCs, this focus on technology transfer from the North to the Global South should be broadened.

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