The Resource Commitment of Multinational Enterprise R&D Activities

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Niels le Duc

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The Resource Commitment of Multinational Enterprise R&D Activities

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Abstract

English

This dissertation analyses the significance of resource commitment to the ability to access co-location advantages and to innovate for MNEs' geographically dispersed R&D subsidiaries. It refines the definition of resource commitment by aggregating conceptions highlighted by the resource-based view, transaction cost economics and institutional theory, and assesses the characteristics and antecedents associated with varying R&D resource commitment positions. The analyses show that the external environment, the purpose of R&D activities and firm experience influence the resource commitment position of a firm's R&D activities. Both qualitative and quantitative methods are adopted to establish the effects of various resource commitment positions on (a) an R&D subsidiary's access to co-location advantages and (b) the innovation output of R&D subsidiaries. Both are important to the success of the R&D subsidiary and to the long-term competitiveness of the MNE. Distinguishing resource levels and commitment levels, the latter are especially important to the subsidiary's ability to access co-location advantages, a finding that lends more support for the institutional theory-related dimensions of resource commitment than the resource-based view-related ones. Finally, the dissertation shows that the commitment level is positively related to the total patent output by subsidiaries. The positive relationship holds for inventions that contribute to technological fields in which the MNE is specialised. It does not hold for subsidiaries' inventions in technological fields in which the MNE is not specialised. The results demonstrate the importance of adopting the resource commitment concept to the study of MNE R&D activities and provide scholars with a better understanding of MNE dispersed R&D behavior.

Dansk

Denne afhandling analyserer betydningen af ressourceforpligtelse (resource commitment) for evnen til at tilgå samlokaliseringsfordele (co-location advantages) og til at innovere for multinationale selskabers (MNS'ers) geografisk spredte forskning- og udviklingsdatterselskaber (FoU-datterselskaber). Den nuancerer definitionen på ressourceforpligtelse ved at sammensætte begrebsliggørelser fra det ressourcebaserede perspektiv, transaktionsomkostningsøkonomi og institutionel teori og vurderer egenskaber og forudsætninger forbundet med forskellige FoU-ressourceforpligtelsespositioner. Analyserne viser, at de eksterne omgivelser, FoU-aktiviteternes formål og virksomhedens erfaring påvirker ressourceforpligtelsespositionen for en virksomheds FoU-aktiviteter. Både kvalitative og kvantitative metoder anvendes for at fastslå effekterne af forskellige ressourceforpligtelsespositioner på (a) et FoU-datterselskabs adgang til samlokaliseringsfordele og (b) innovationsproduktionen af FoU-datterselskaber. Begge er vigtige for FoU-datterselskabets succes og for den langsigtede konkurrenceevne af MNS'et. Når man skelner mellem ressourceniveauer og forpligtelsesniveauer, er sidstnævnte særligt vigtige for datterselskabets evne til at tilgå samlokaliseringsfordele, et resultat der i højere grad underbygger de institutionel teori-relaterede dimensioner af ressourceforpligtelse end de ressourcebaseret teori-relaterede. Endelig viser afhandlingen, at forpligtelsesniveauet er positivt forbundet med datterselskabers samlede patentproduktion. Den positive sammenhæng holder for opfindelser, der bidrager til teknologiområder, i hvilke MNS'et er specialiseret. Den holder ikke for datterselskabers opfindelser i teknologiområder, som MNS'et ikke er specialiseret i. Resultaterne demonstrerer vigtigheden af at anvende ressourceforpligtelsesbegrebet i studiet af MNS'ers FoU-aktiviteter og giver forskere en bedre forståelse af MNS'ers spredte FoU-adfærd.

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List of acronyms

FDI	Foreign Direct Investment
IB	International Business
MNE	Multinational Enterprise
SMEs	Small and Medium-sized Enterprises
R&D	Research and Development
IPR	Intellectual Property Right
RBV	Resource-Based View
TCE	Transaction Cost Economics
IT	Institutional Theory
GUO	Global Ultimate Owner
RTA	Revealed Technological Advantage
NB	Negative Binomial model

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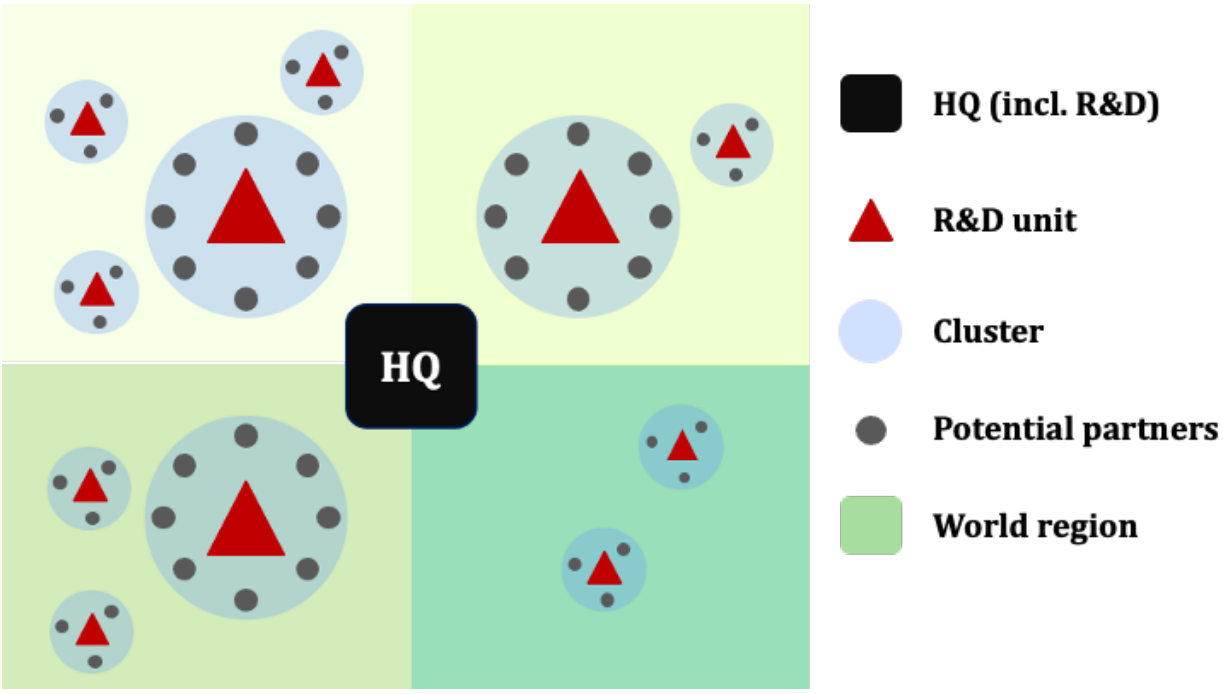
Introduction

The creation, transfer and utilization of knowledge are arguably the primary factors upon which sustained economic prosperity is built in today's world economy. With the increasing rate of technological change in most competitive industries, research and development (R&D) activities have assumed a key role in many firms. It is safe to say that to stay competitive in the long run, firms need to indulge in search behavior: seeking out new knowledge and possibilities to combine existing knowledge about markets and technologies in new ways. Multinational enterprises (MNEs) in particular have long been pursuing the knowledge-generating capabilities needed for technological development (Cantwell 1989) and now control more than three-quarters of the world's technical and scientific resources (Håkanson 2014). Pressured by heightened competition, firms have invested heavily in R&D. Between 2005 and 2018, the world's top 1,000 innovation-leading companies increased their R&D spending by 75 percent, to USD 702 billion, with a mean compound annual growth of 4.8 percent (Jaruzelski, Staack, and Chwalik 2017).

In line with the importance of seeking out new knowledge and the increase in R&D spending, the MNE R&D footprint has changed. Historically, corporate R&D has typically been located in a firm's home country, close to its center of operations (Ana Colovic 2010; Kuemmerle 1997). Foreign technological activity by MNEs, if any, mostly exploited their domestic strengths abroad, aiming to achieve refinement, efficiency, production, and execution benefits in response to local demand conditions (Benner and Tushman 2003; Cantwell and Piscitello 2000; Gammeltoft 2006). However, for several decades now, both scholars and policymakers have observed that foreign technological activities are taking on a bigger role. As competition is becoming more technology-intensive and knowledge sources more dispersed, MNEs that successfully expand their innovation capabilities internationally may gain an important competitive advantage (Awate, Larsen, and Mudambi 2015). Firms are investing abroad partly to gain access to new, local knowledge in centers of excellence (Ambos and Ambos 2009; Cantwell 1989; Florida 1997). Cantwell (1989,

1995) argues that successful innovators tend to invest in innovation activities in several local centers of excellence across countries, because each offers something unique. As a result, corporate R&D has moved towards an open network of geographically dispersed R&D subsidiaries (Cantwell and Iammarino 2003; Guimón 2013; Zanatta and Queiroz 2007). A study by PricewaterhouseCoopers (Jaruzelski et al. 2017) revealed that 94 percent of the largest R&D spenders followed a global innovation model in 2017. The literature refers to such a complex, diverse and geographically diffused set-up as a 'heterarchy' (Hedlund 1986), 'transnational firm' (Bartlett and Ghoshal 1989), 'metanational' (Doz, Santos, and Williamson 2001), or 'differentiated network' (Nohria and Ghoshal 1997).

Figure 1: MNE Global Innovation Network with geographically dispersed R&D centres



Source: author

Note: *The figure is a stylized example of R&D units in a geographically dispersed Global Innovation Network. It does not show linkages between the headquarters and an R&D unit or among R&D units, since drawing linkages would turn the example into one specific type of MNE R&D organization. Gassmann and Von Zedtwitz* (1999) *identify five different types of MNE R&D organizations, (in part) based on the degree of cooperation (linkages) between individual units.*

The move towards global innovation networks fits into a broader trend of firms moving away from the traditional vertically integrated corporation (Chandler 1990; Mintzberg 1979) towards network organizational forms. This is also referred to as the rise of 'alliance capitalism' over 'hierarchical capitalism', enabled by technological, institutional and managerial innovations (Dunning 1995). Alongside global innovation networks, various forms of hybrid governance forms have proliferated, e.g., organizational networks (Nohria and Eccles 1992; Powell 1990), strategic alliances (Doz and Hamel 1997; Dyer and Singh 1998; Gulati 1998), global value chains/global production networks (Gereffi 2018; Henderson et al. 2002), and global factories (Buckley and Ghauri 2004). Figure 1 above provides an example of an MNE's global innovation network.

Befitting the importance of MNE R&D, a broad and variegated literature has emerged (for an overview, see Papanastassiou, Pearce, and Zanfei 2019). Part of this literature focuses on the characteristics of MNE R&D subsidiaries. Already in the 1970s, researchers started paying attention to the various types of overseas MNE R&D subsidiaries and, by the 1990s, taxonomies of MNE R&D subsidiaries really proliferated (for an overview, see Medcof 1997). Classifications of R&D subsidiaries were based on criteria such as underlying motives, geographical scope, complexity, relationships between units, and level of technological competence (Gammeltoft 2006; Perri 2015).

However, limited attention has been paid to the resource commitment of MNE R&D subsidiaries. This is surprising, considering that innovation processes are often complex and require the costly and risky transfer of large amounts of resources over long periods of time. These challenges are compounded when research units are spatially dispersed. Further, when innovation processes involve external partnerships, effective collaborations often are premised on trust and legitimacy, which can hinge on mobilizing and committing sufficient amounts of resources (Kuemmerle 1997; Mellahi et al. 2016; Wagner and Bukó 2005). On the other hand, *ceteris paribus*, firms have a general interest in reducing resource commitment to maintain efficiency and flexibility. Hence, aligning resource commitment with effectiveness, efficiency and flexibility of innovation processes and the contingent trust and legitimacy with external partners is a major strategic challenge in organizing international R&D. Firms that are capable of striking this balance can achieve superior performance (Kulkarni and Ramamoorthy 2005; Richey, Genchev, and Daugherty 2005). However, it is also true that mismatches between available resources, required resources, and decisions to commit resources can result in persistently inferior performance. This also applies to long-term performance, as existing resource commitments are also the basis for future decisions (Santangelo and Meyer 2017).

In addition, there are observable differences in resource commitment of R&D subsidiaries. For example, many MNEs successfully operate both large and established R&D centres (suggesting high resource commitment) and small R&D subsidiaries (ranging from 2 to 25 people, indicating low resource levels) that are relatively flexible (indicating low commitment). The literature discusses such smaller R&D subsidiaries as listening posts (Gassmann and Gaso 2004, 2005), monitoring units (UNCTAD 2005), sensing units (Patel and Vega 1999), innovation labs and innovation antenna (Onetti and Marinucci 2017).

Arguably, resource commitment to R&D activities is more relevant than ever. This is mainly because of two trends: 1) a vast rise in the number of countries offering destinations with attractive science and technology bases and the correspondingly broader geographical dispersion of corporate R&D (Cantwell and Iammarino 2003; Duga and Studt 2006; Guimón 2013), stretching limited MNE resources, and 2) R&D activities becoming more globally fragmented as MNEs are increasingly fine-slicing their value-adding activities (D'Agostino and Santangelo 2012; Mudambi 2008), in ways that allow MNEs to focus on narrower activities within the value chain, while outsourcing other, lower-value-added activities (Ernst and Kim 2002). Unsurprisingly, this has led to a steady increase in R&D outsourcing since the turn of the century (Lewin, Massini, and Peeters 2009; Manning, Massini, and Lewin 2008). This adds to the importance of an MNE's decisions regarding resource commitment to R&D activities along the value chain.

Research question

Considering the above, this PhD dissertation seeks to analyze the significance of resource commitment to MNE R&D units. More specifically, it pursues three inquires, *viz*. to uncover the determinants of resource commitment to MNE R&D units, to discern the effects of different resource and commitment levels on the ability of the R&D unit to access co-location advantages, and to assess the number and nature of an R&D unit's innovative outputs. Both an R&D unit's access to co-location advantages and its inventions are important to the success of the R&D unit and to the long-term competitiveness of the MNE, as will be expanded upon below. Thus, the main research question of the dissertation is as follows:

What are the determinants of resource commitment to R&D activities by multinational enterprises and how does resource commitment influence a subsidiary's inventions and access to co-location advantages?

A subsidiary's inventions are important to consider as they are one of the main outputs of R&D activities. In this dissertation, subsidiary inventions are conceptualized as both a subsidiary's innovative output and the subsidiary's diversification/specialization. The latter captures whether the subsidiary is expanding into a broader range of technologies or limits its effort to technological areas in which the MNE is already active. This is an important distinction. It is argued here that the level of resource commitment to R&D activities depends on the specialization/diversification nature of those activities. The terms diversification and specialization are analogous to the distinction between competence-exploiting and competence-creating activities (e.g. Cantwell and Mudambi 2005), and exploitation and exploration in organizational learning theory (Danneels 2002; March 1991). However, it is important to note that specialization activities are not necessarily competence-exploiting or exploitative in nature. They may also involve the creation of new competences within in a field the MNE already specializes in.

Co-location advantages refer to the advantages gained from access to local actors' assets, both intangible (localized knowledge) and tangible (e.g. equipment, shared facilities). These advantages derive from spatial proximity to other actors, but proximity is not sufficient: relationships also are required for access (Narula and Santangelo 2009). Access to local knowledge/resources is considered to be of critical importance for MNEs, which increasingly are in need of external resources to cope with growing global competition, intense technology interrelatedness, and increasing product complexity (Gammelgaard et al. 2012; Perri, Scalera, and Mudambi 2017; Wang and Kafouros 2020). The co-location advantage concept is strongly related to 'open innovation', an idea that is increasingly prominent in MNE R&D strategies (albeit with significant differences across industries). Open innovation is about not just co-locating, but also opening up the firm's R&D centres and laboratories to collaborations with universities, technology institutes, start-ups, and small and medium-sized enterprises (SMEs) to accelerate internal innovation (Chesbrough, Vanhaverbeke, and West 2006; Jaruzelski et al. 2017). The rationale behind the concept of open innovation is straightforward: not all smart people in a particular industry work for one firm. By opening up the firm and cooperating with externals, the firm expects to increase its innovativeness and reduce time to market (Enkel, Gassmann, and Chesbrough 2009). The importance of the access to co-location advantages fits into the rise of network organizational forms versus more vertically integrated, hierarchical organizations.

Naturally, there is a relationship between co-location advantages and subsidiary inventiveness. Baptista and Swann (1998) show that co-location in strong clusters does increase a firm's likeliness to innovate, and Almeida (1996) and Frost (2001) find that co-located firms tend to cite each other's patents more frequently. It is important to note, however, that these findings pertain to co-location in the sense of geographical proximity. The argument presented here is that proximity creates an opportunity to establish relationship that can lead to innovative success, but the dynamics are relationship-driven rather than proximity-driven. Earlier work acknowledges that local innovation processes rely heavily on the exchange of information and knowledge between various actors and are frequently based on learning-by-interacting (Howells 2002).

The following section introduces the resource commitment concept, answering questions such as: what is resource commitment (and what is it not), what is the background of the concept, and who determines resource commitment? Next, the three papers of the dissertation are introduced. Each paper provides a part of the answer to the main research question, but can be read independently. The summary of the three papers is followed by reflections on contributions to the literature, implications of the findings for managers and policymakers, and suggestions for future research.

Introduction to resource commitment

What is resource commitment?

As hinted at above, resource commitment is composed of two factors: the amount of resources allocated to a specific location and the degree of commitment (sometimes also referred to as the irreversibility) associated with the resources that are allocated (Johanson and Vahlne 1977; Pedersen and Petersen 1998; Randøy and Dibrell 2002). A firm's investment into R&D has several components: capital R&D expenditures include the acquisition of tangible fixed assets (such as buildings and structures, transport equipment, other machinery and equipment) and intangible fixed assets (such as computer software) that are used repeatedly or continuously in the performance of R&D (OECD 2015). Firms may also provide funds to others for the performance of extramural R&D. Labor costs are also tangible, but not fixed, and include all forms of compensation for employed R&D personnel, such as annual wages and salaries (OECD 2015). The arithmetic that identifies a given resource allocation as high or low relates to the sum of tangible and intangible resources allocated to a R&D unit to the size of a firm's global R&D network. After all, an R&D unit of 15 people may be a relatively large investment for some MNEs, while this is a minor investment for firms with multiple large R&D centres around the world.

The level of commitment is based on the irreversibility of deployed resources (resulting in sunk costs). Resource irreversibility is often associated with resource specificity (Williamson 1985). A resource is specific to a usage (a product, an activity, or a location) if its value decreases when a firm applies it differently or redeploys it to another activity or location (Ghemawat and Del Sol 1998).

Many studies that purport to use the resource commitment concept do not adequately define the concept and often equate resource commitment to 'resource allocation', thus only measuring half of the concept. For example, researchers tried to capture resource commitment by using the level of Foreign Direct Investment (FDI) (Hernández and Nieto 2015), R&D expenditure (Kumar 1996) or equity ownership (Delios and Beamish 1999; Pan et al. 2014). These measurements capture only the amount/value of invested resources. Many others measure resource commitment simply by using the type of entry mode (e.g. Brouthers 2013; Elia et al. 2014; Meyer, Wright, and Pruthi 2009). However, these approaches do not capture the actual 'value' of resources. Moreover, one type of entry mode might not always require a higher level of resource commitment than another type.

By also considering the commitment aspect of resource commitment, one can say something not only about how many (or few) resources are invested, but also about how easily these resources can be (re)deployed. This is important, as existing work shows that the irreversibility (commitment) of investments is a key factor in explaining sustained competitive advantage (Ghemawat 1991), while firms, *ceteris paribus*, have efficiency and flexibility incentives to reduce commitment. Thus, commitment as used in this work is not commitment to a specific technology or to a specific strategy, but refers to the commitment level of the allocated resources. However, commitment to building a subsidiary's innovative capabilities does influence the irreversibility of resources a firm deploys. This is because, over time, these resources become more specific to a certain use/product/location, augmenting the irreversibility of these resources.

The commitment concept is based in the economics literature. The significance of irreversibility (commitment) in relation to competitive interactions has been noted by such economists as Porter (1980), Caves (1984), and Ghemawat (1991). Other economists have highlighted the importance of irreversibility in relation to the timing of investment expenditures and their expected returns (Carruth, Dickerson, and Henley 2000) or have used the irreversibility concept to explain why recessions are felt disproportionately in certain sectors (Bernanke 1983). Perhaps due to this background in economics, commitment is mostly conceptualized in terms of potential changes in the value of a resource when it is redeployed in another activity/location (Ghemawat and Del Sol 1998). As mentioned, this conceptualization of commitment is also adopted in this work.

The commitment/irreversibility concept is mostly used in the international business (IB) literature in discussions about the patterns and pace of firm internationalization (see the section 'Resource commitment changes over time', below). This is not to say that commitment is otherwise off the IB radar. IB scholars indirectly acknowledge the importance of commitment to R&D activities. One could think for example of the 'stickiness' of knowledge transfer (Szulanski 1996), referring to the difficulty to pass on tacit knowledge. It is also acknowledged that R&D investments are characterized by a high degree of asset specificity (Williamson 1988), and thus relatively high levels of commitment. After all, R&D activities are often focused on the medium to long-term and are dependent on past innovations (Malerba and Orsenigo 1993), as technological and skill accumulation often occurs through "learning by doing" or "learning by using".

Resource commitment changes over time

Resources invested in R&D activities are likely to become more specific to a certain technology as time passes, due to the abovementioned dependence of R&D activities on past innovations. The increased resource specificity augments the irreversibility (commitment) of investments. Not just commitment levels change over time; resource levels may change, too. That is, the amount of resources invested in R&D activities over time may change in response to changing strategies and/or external developments.

A vast literature considers the internationalization of MNE R&D activities in terms of increasing resource commitment to knowledge-intensive locations. One important approach that has popularized resource commitment to describe firm internationalization is the so-called internationalization process theory (also referred to as the Uppsala Model), associated with Johansson and Vahlne (e.g. 1977). Subsequently, a large body of literature has sought to establish where and why observed patterns of resource commitment are 'stepwise', 'incremental', or 'instantaneous' (Petersen, Welch, and Nielsen 2001). Next to internationalization *patterns,* researchers have also considered the *pace* at which a company builds up resource commitment to a foreign market (Forsgren 2002; Pedersen and Petersen 1998; Weerawardena et al. 2007).

While acknowledging the dynamic nature of (R&D) resource commitment, this dissertation does not seek to study changes in resource commitment over time. Rather, it assesses the characteristics and antecedents associated with varying resource and commitment levels and shows the influence of different resource and commitment levels on subsidiary innovation and access to co-location advantages. Naturally, changes of the antecedents would cause firms to recalculate the appropriate resource and commitment levels for its R&D units, and future work should engage with this dynamic.

Resource commitment and the parent-subsidiary relationship

An often-raised question when discussing the resource commitment of R&D subsidiaries is: who determines the level of resource commitment, the MNE or the subsidiary? Research has typically taken a top-down approach, emphasizing ways through which the headquarters provides capabilities to subsidiaries (Peng 2001). Similarly, resource commitment is generally considered to be the result of a top-down decision, meaning that the parent company determines the nature of resources that are available to its R&D unit (Chen et al. 2020). In this view, foreign subsidiaries are seen as vehicles for parent firms to access new and valuable resources or to exploit their existing ownership- or firm-specific advantages. Specifically, more resource support by parent firms enables foreign subsidiaries to engage more in R&D activities, local markets exploration, and new knowledge and capabilities generation (Chen et al. 2020).

However, some of the (new) resources (knowledge and experience, patents or money, for example) also need to find their way to the parent, creating a second, opposite flow of resources between the subsidiary and the parent. This is in line with the resource-based view, suggesting that an MNE's international strategy depends on its ability to access and transfer valuable resources from their foreign subsidiaries (Ambos, Ambos, and Schlegelmilch 2006; Rabbiosi 2011). Strong internal networks enable MNEs to successfully recombine knowledge from their different locations and to build upon or extend their technological competencies through internally coordinated learning processes (Cantwell 1995). These internal networks make technological accumulation within the firm possible and thus explain why technology is developed in international networks, rather than in separate units (Cantwell 1989). The more resources a parent firm allocates to its subsidiaries, the more likely these subsidiaries will be able to transfer distinct resources and local knowledge to the parent firm (Morgan and Hunt 1994).

Notwithstanding the bi-directional nature of MNE internal networks, resource commitment in this dissertation is viewed as a top-down decision by the parent. After all, while resources may also flow back to the headquarters, it is the headquarters that ultimately allocates resources, thus orchestrating and coordinating the internal MNE network. It is sometimes argued that subsidiaries that are very innovative, or have access to particular technologies, can be seen as resource givers as opposed to resource receivers within the MNE (Andersson and Pahlberg 1997; Gupta and Govindarajan 1991). However, even the knowledge/competencies/other resources from these subsidiaries are ultimately the result of resources the headquarters had previously allocated, in pursuit of its own interests. Thus, the allocation of resources to a subsidiary may follow from a strategic decision from the parent or may be the result of the subsidiary identifying an opportunity and negotiating with the parent regarding the allocation of resources to this opportunity (Birkinshaw 1999; Dörrenbächer and Geppert 2010). The latter approach is discussed in the literature on subsidiary initiatives and subsidiary autonomy (e.g. Birkinshaw, Hood, and Jonsson 1998; Delany 2000).

Resource allocation by the parent to the subsidiaries determines more than a subsidiary's resource level; it also influences a subsidiary's commitment level. This is because the resources a parent chooses to allocate differ in their specificity. Moreover, the parent determines how long resources are invested and, as time passes, resources become more specific to their use, augmenting the irreversibility of investments. The parent thus influences the overall commitment level of the subsidiary. However, the parent does not determine exactly how each resource is used at the subsidiary level. Subsidiary managers also have a say in how resources are used within the subsidiary. Therefore, they also can influence the extent of irreversibility of invested resources. As subsidiaries become larger and develop their own resources, their influence on their commitment level is likely to increase.

The above is a short introduction of the resource commitment concept in relation to the internationalization of MNE R&D. The papers of this dissertation further expand the resource commitment concept. The first paper further explores the two factors (allocated resources and the degree of commitment) that make up the resource commitment concept. The second paper adds to our understanding of the resource commitment concept by observing it through three theoretical lenses: the resource-based view, transaction cost economics, and institutional theory. It shows that to be successful, R&D internationalization involves resource-, transaction- and institution-related dimensions. Finally, both the second and the third paper show how resource commitment can be measured. The following section provides a summary of the three papers included in this dissertation.

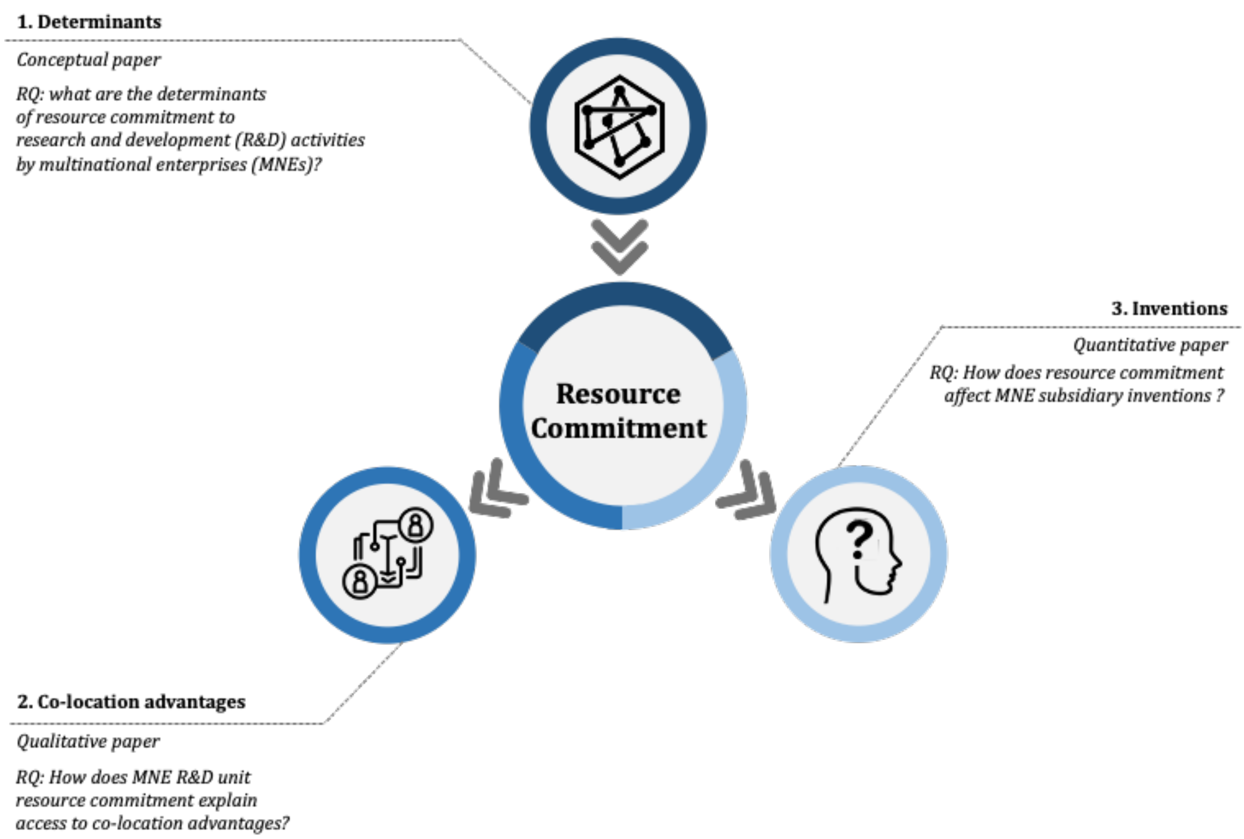
Structure of the dissertation

This dissertation includes three self-contained papers, each of which may be read either independently or as a component of the answer to the main research question. The three papers are briefly summarized below.

The first paper seeks to answer the question: what are the determinants of resource commitment to R&D activities by MNEs? The paper introduces and advocates the concept of resource commitment to better understand R&D behavior within an MNE. Adopting a theory adaptation research design (Jaakkola 2020), the paper assesses the characteristics and antecedents associated with varying resource commitment positions. The paper introduces a framework for assessing differences in resource commitment are more nuanced than expected. For example, large investments (involving a relatively large amount of resources) are not necessarily specific to a use or a location and may thus be low-commitment in nature. Large investments in saleable equipment, for example, do not necessarily imply a strong commitment as the resources involved can easily be moved. The evaluation of antecedents shows that the external environment, the purpose of R&D activities, and firm experience influence the resource commitment position of a firm's R&D activities.

This paper makes several overall contributions. By clearly delineating resource commitment, the paper builds on the literature (Ghemawat 1991; Ghemawat and Del Sol 1998; Maitland and Sammartino 2009) and provides scholars with a better understanding of MNE R&D behavior and R&D resource commitment positions. In so doing, the paper lays the groundwork for new research on the consequences of different positions to firms and locations, which is of interest, considering the importance of resource commitment, as emphasized by the resource-based view. Finally, the framework generates insights that are valuable to both MNE managers and policymakers. MNE managers may use the framework to establish what resource commitment position would be most appropriate. Policymakers can gain insight into the types of activities and the companies they need to attract to maximize the added value of a firm's investments in their country/region.

Figure 2: Relationship between the papers



The second paper, written with Peter Gammeltoft, analyses the relationship between resource commitment and access to co-location advantages through a cross-case study of two MNEs in high-tech industries. First, we disaggregate the composite concept of resource commitment and demonstrate how the resource-based view, transaction cost economics and institutional theory each accentuate certain dimensions of the concept. Next, we analyse empirically the relationship between resource commitment and co-location advantages for 11 R&D subsidiaries of the two MNEs. Based on this analysis, we discuss the relationships between the empirical findings and the theoretically differentiated resource commitment dimensions. The study finds that high resource levels are less important for access to co-location advantages than conventionally assumed, while commitment levels appear to be consistently important, lending more support for the institutional theory-related dimensions of resource commitment than the resource-based view-related ones. We also find support for the claim that more flexible governance arrangement promote access to co-location advantages in asset exploration.

The third and final paper is written together with Björn Preuß and Björn Jindra. This paper conceptualizes the relation between innovation and resource commitment by MNE subsidiaries. Innovation, in this paper, refers to both innovative output (number of patents) and a subsidiary's specialization/diversification compared to the technological competences of their parent company. We exploit a dataset for 7,149 multinational enterprises and 33,541 subsidiaries, which filed in total 4,080,661 priority patent applications (2010–2019). We explain subsidiary patent counts by employing negative binomial regression models with measures for resources allocated and the commitment of these resources, along with controls for other subsidiary-, parent- and location-specific variables. The results show a positive relation between commitment and subsidiaries' patent output. Further inspection indicates that this relationship is non-linear and follows an inverted U-shaped form. Thus, a subsidiary's patent output increases with its commitment level only up to a threshold, beyond which higher commitment levels are associated with declining numbers of total priority applications.

We find that the positive relationship between subsidiary commitment level and patents applied for holds also for the absolute number of priority applications by subsidiaries in technological areas its parent MNE specialises in. Yet, this is not true for the absolute number of priority applications outside technological areas of MNE specialisation.

A robustness analysis indicates a positive but non-linear relationship between subsidiary commitment levels and the share of priority applications by multinational subsidiaries related to technological areas with a technological advantage of the MNE in its total priority applications ('relative specialisation'). The functional form follows, as in the case of subsidiaries' total priority patent applications, an inverted U-shaped form.

Our main findings confirm a positive relationship between MNE resources allocated to subsidiaries and the subsidiaries patenting output, in line with previous findings, yet we also find evidence of decreasing returns. We contribute to the state-of-the-art by introducing resource commitment into research on MNE subsidiary innovation.

Table 1 below provides an overview of the three papers, showing the investigated relationship, data used, method, and main findings.

Table 1: Summary of papers

Paper	Relationship	Data	Method	Main findings
1	Determinants → Resource commitment	NA	Theory adaptation	• Deductively constructed framework suggests that resource commitment positions of MNE R&D activities are influenced by: ○ the purpose of the R&D activity; ○ the external environment; and ○ the international and local experience of the MNE.
2	Resource commitment → co-location advantages	Semi-structured Interviews	Qualitative: embedded multiple-case study	• High resource levels are less important for access to co-location advantages than conventionally assumed. • Commitment levels are consistently important, lending more support for the institutional theory-related dimensions of resource commitment than the resource-based view-related ones. • Support for the claim that more flexible governance arrangements promote access to co-location advantages in asset exploration.
3	Resource commitment → innovation	Firm level financial data	Quantitative: negative binomial regression	• An inverted U-shaped relationship between commitment level and total patent output by subsidiaries • A positive relationship between MNE resources allocated to subsidiaries and the subsidiaries patenting output. • A positive relationship between subsidiary commitment level and absolute number of patents applied for by subsidiaries in technological areas its parent MNE specialises in.

Implications of findings

Implications for the study of MNE R&D activities and resource commitment

Combined, the three papers show the value of the resource commitment concept to the study of an MNE's geographically dispersed R&D activities. The dissertation provides scholars a better understanding of MNE R&D behavior by breaking the concept down into its two building blocks: resources and commitment. In addition, it demonstrates how the resource-based view, transaction cost economics and institutional theory each bring different dimensions of the composite resource commitment concept into the fore. It is shown that resource commitment can arise from a firm's allocation of assets to its R&D subsidiaries, as well as from governance arrangements established to manage costs and risks in transactions across firm boundaries, and that the regularization of norms, values and routines through recurrent external interaction represents both application and commitment of resources. The literature usually approaches resource commitment from behavioral and operational perspectives. Thus, by disaggregating the concept into its component parts, the dissertation contributes to the resource commitment literature (Ghemawat and Del Sol 1998; Johanson and Vahlne 1977; Pedersen and Petersen 1998; Randøy and Dibrell 2002). Moreover, the analytic power of the re-conceptualization presented here has been demonstrated in two of this dissertation's papers.

Adding to this theoretical contribution, the dissertation presents a novel framework that can explain the observable differences in resource and commitment levels of R&D subsidiaries. Besides offering insight into R&D resource commitment positions, the framework enables thinking about R&D units' resource commitment in general. This paves the way for new research on the consequences of different positions to firms and locations (also see suggestions for future research below). Emergent insights yield implications of immediate interest to those who organize international R&D, because identifying the appropriate alignment of resource commitment, including the development of contingent trust and legitimacy with external partners, with general corporate interests in effectiveness, efficiency and flexibility of innovation processes is a major strategic challenge (Kulkarni and Ramamoorthy 2005; Richey et al. 2005).

Another set of implications for research is linked to insights into the ways access to co-location advantages is a strong driver of explorative R&D by MNEs. As this access is conditioned by resource commitment to R&D units, the relationship between resource commitment and co-location advantage access has important strategic implications. The findings on the influence of resource levels on the access to co-location advantages differ from those found in the literature (Kuemmerle 1997; Perri 2015; Perri and Andersson 2014). According to the literature, high resource levels are needed to allow MNE units to gain legitimacy and trust (crucial for accessing co-location advantages), as it allows them to reciprocate benefits of local knowledge/resources with some of their own knowledge/resources. In addition, the literature suggests (relatively) high resource levels are needed to achieve frequent and deep external linkages (Kuemmerle 1997; Mellahi et al. 2016). While respondents indicated the usefulness of high resource levels for gaining access co-location advantages, they also signaled that low resource/high commitment units are able to access knowledge/resources of multiple local external actors. These findings contribute insights into the ties between actors (in terms of their establishment and effectiveness), which is important, considering the fact that the success of firms often is linked to the depth of their ties to other organizations (Powell 1998). Investigating the conditions under which such ties are most likely to be established and/or most fruitful may help scholars to better understand MNE behavior.

As for an MNE subsidiary's inventions, this dissertation demonstrates a positive relationship between subsidiary commitment levels and the number of priority applications by subsidiaries. Higher specificity, irreversibility, and sunk costs related to a subsidiary's assets are associated with higher patent output. This is in line with theoretical literature that suggests the irreversibility of investments is a key factor in explaining sustained competitive advantage (e.g., Ghemawat 1991; Pindyk 1991; Williamson 1985, 1988). However, further inspection revealed that this relationship between commitment and patent output follows an inverted U-shaped form. This might reflect cognitive barriers to learning from trial and error (Liu et al. 2018). The impact of commitment/irreversibility on the inventiveness of the subsidiary and therefore a firm's competitive advantage is more nuanced than previously reported.

Implications for managers and policy-makers

The conceptual framework introduced in this dissertation for assessing differences in R&D resource commitment could have profound implications for the way MNE managers identify appropriate resource commitment positions, considering the type of activity, potential and risk associated with the proposed location, along with the firm's experience. For example, lower risks (e.g., improved intellectual property rights) and/or improved opportunities (e.g., enhanced local competencies) may drive managers to reconsider their R&D resource commitment position. This could entail an increase or decrease in resources or a change in commitment levels (or both). In the case of lower risks and bigger opportunities, it might make sense for firms to shift from keeping all their activities within the firm to setting up collaborations with local actors. This would increase commitment while keeping resource levels relatively unchanged, making the firm less flexible, but allowing it to access more local knowledge.

The dissertation also shows the consequences of different resource and commitment levels to a subsidiary's inventions and access to co-location advantages. Both are important to the success of the R&D unit and to the long-term competitiveness of the MNE. Through analysis of both relationships, this dissertation contributes to striking the balance between the strategic rigidities and excess costs of over-commitment and the ineffectiveness and value dissipation of under-commitment in MNE's R&D decisions. This necessitates a deep look into the future. Commitment explicitly suggests a need for looking before leaping; for trying to peer into the future before it becomes the present.

Policymakers concerned with knowledge-intensive clusters and/or boosting their country or region's knowledge-intensive economy may benefit from the R&D resource commitment framework. Policymakers, arguably, are most interested in attracting high-commitment R&D activities. Such activities are less likely to be relocated or to be discontinued, potentially adding value to the (local) economy over longer time-periods (compared to lower-commitment activities). The R&D resource commitment framework provides policymakers insight into the type of activities and the companies they need to attract to maximize the commitment level of new investments. It shows, for example, that exploitative activities are generally more committed than explorative activities and that firms with existing local experience are likely to be more committed to a location.

Suggestions for future research

The findings and insights from this dissertation bring about new pathways for future research. To begin with, there is a need to conduct empirical studies to determine the strength of the relationships identified theoretically in the first paper. The second and third papers of this dissertation consider the consequences of various resource commitment positions to the subsidiary (its inventions and its access to co-location advantages). However, it would be interesting to identify the effects of different resource commitment positions to the subsidiary's host location. An implication of this dissertation is that high-resource, high-commitment R&D investments are most beneficial to the host location, but this expectation has not been tested, and the idea that low-resource, low-commitment R&D activities also add value to a knowledge cluster.

The second paper of this dissertation takes an MNE-central perspective as it considers the effect of an MNE's resource commitment on its access to co-location advantages. However, co-location advantages stem mainly from the development of local relationships, and one needs two or more actors for a relationship to exist. This means that an MNE's (potential) partners also influence that MNE's access to co-location advantages. From this foundation, it would be interesting to better understand how much of an MNE's access to co-location advantages may be explained by the self-interest, or perhaps shared interest in the MNE's performance, of the MNE's suppliers, customers and other partners. Furthermore, our evidence suggests that physical distance impacts how (potential) partners perceive MNE commitment levels. It would be of interest to study whether there is a difference between actual and perceived commitment levels with increasing physical distance. Perhaps other types of distance, such as cultural, economic, and administrative distance, could also affect this relationship. Distance has been central to international business research since the inception of the field and the suggested research would add to this literature.

Lastly, it would be of interest to consider R&D resource and commitment levels over time. As mentioned in this introduction, this dissertation did not seek to study changes in resource commitment over time. However, it would be interesting to determine whether there are specific patterns in R&D resource and commitment levels over time. Moreover, the paper on co-location advantages reports that local actors respond to decreasing resource and commitment levels, but does not identify the mechanisms that constrain these responses. Understanding this dynamic would be a worthwhile goal of future research.

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Chapter 1

Understanding resource commitment to R&D in multinational enterprises: A novel conceptual framework

Abstract
This paper introduces and advocates the concept of resource commitment to better understand multinational enterprise (MNE) Research and Development (R&D) behavior. Adopting a theory adaptation research design, this paper assesses the characteristics and antecedents associated with varying resource commitment positions. It does so in relation to MNE R&D activities, considering their importance to firm competitiveness and the recent increases in the number of locations and innovative activities a firm might choose to invest in. The paper presents a framework showing that differences in resource commitment are more nuanced than expected. The evaluation of antecedents shows that the external environment, the purpose of R&D activities, and firm experience influence the resource commitment position of a firm's R&D activities. The paper provides a pathway toward understanding of MNE R&D behavior, explaining observable differences in resource and commitment levels of R&D units. The presented framework offers MNE managers insight into when to adopt which resource commitment positions. It offers policymakers insights into the type of activities and the companies they need to attract to maximize the added value of firm's investments in their country/region.

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1. Introduction

What are the determinants of resource commitment to research and development (R&D) activities by Multinational Enterprises (MNEs)? Answering this question is perhaps more important than ever, considering the increasing rate of technological change in most industries), the increasing number of attractive science and technology locations, the correspondingly broader geographical dispersion of corporate R&D (Cantwell and Iammarino 2003; Duga and Studt 2006; Guimón 2013), and the inherent limits of firm resources. Moreover, existing research asserts that MNE resource commitment can facilitate the process of acquiring knowledge and can improve innovation performance (Isobe, Makino, and Montgomery 2000; Kanwal, Zafar, and Bashir 2017).

Despite the importance of resource commitment, the literature has paid limited attention to the determinants of resource commitment to MNE R&D activities. This despite observable differences in resource and commitment levels of R&D units. Instead, scholars have focused mostly on classifying MNE R&D units based on criteria such as underlying motives, geographical scope, complexity, relationships between units, and level of technological competence (Gammeltoft 2006; Perri 2015). The use of such criteria has resulted in many typologies of R&D activities (for an overview, see Medcof, 1997), focusing mainly on the many 'shapes' of MNE R&D activities and not on the different sizes (resources) and levels of commitment of MNE R&D units. Some existing work does examine how the resource commitment intensities and patterns are influenced by environmental conditions (Liedong et al. 2020; Luo 2004), entry strategy (Gollnhofer and Turkina 2015; Johanson and Vahlne 1977, 1990; Nadkarni and Perez 2007), and subsidiary initiatives (Birkinshaw and Morrison 1995; Lee, Chung, and Beamish 2019). However, most of this work is limited to the firm level or to specific conditions.

This paper evaluates the concept of resource commitment, assessing the characteristics and antecedents of resource commitment related to R&D activities. It argues that the main factors that shape R&D resource commitment positions are: (1) the purpose of the R&D activity, (2) the external environment, and (3) international and local experience. Together these three factors provide a framework explaining the resource commitment of MNE R&D activities. The framework is also a response to the call to further our thinking on the influence of contextual factors on subsidiaries' characteristics (Nguyen 2011). By seeking to introduce a new theoretical lens, this paper adopts a theory adaptation research design. This is a common design for a conceptual paper (Jaakkola 2020).

Overall, this paper makes several contributions. By clearly delineating resource commitment, the paper builds on the literature (e.g., Ghemawat 1991; Ghemawat and Del Sol 1998; Maitland and Sammartino 2009) and provides scholars a better understanding of MNE R&D behavior by explaining the difference between R&D resource commitment positions. In addition, the paper enables new research on the consequences of different positions to firms and locations, which is of interest, considering the importance of resource commitment, as emphasized by the resource-based view. Finally, the framework generates insights that are valuable both to MNE managers and to policymakers. MNE managers may use the framework to establish what resource commitment position would be most appropriate, and policy-makers can gain insight regarding the type of activities and the companies they need to attract to maximize the added value of a firm's investments in their country/region.

2. Theoretical foundation

2.1 Existing research

A broad range of existing research addresses the link between resource commitment on the one hand and organizational dynamics and market conditions on the other. Factors that are shown to influence resource commitment include: entry strategy (Gollnhofer and Turkina 2015; Johanson and Vahlne 1977, 1990; Nadkarni and Perez 2007; Pedersen and Petersen 1998), global value chain integration (Gupta and Govindarajan 1986), environmental conditions (Liedong et al. 2020; Luo 2004), firm's owner's personalized motivations (Hermans and Borda Reyes 2020), and subsidiary initiatives (Birkinshaw and Morrison 1995; Lee et al. 2019). However, most studies that link these factors to resource commitment limit themselves to the firm level; They thus fail to adopt the resource commitment concept, which would provide a more nuanced understanding of business functions (such as R&D). In addition, many studies that purport to use the concept do not adequately define it, or, even more problematic, equate resource commitment to 'resource allocation', thus measuring only half of the concept. The resource commitment concept, properly understood, refers to the product of (1) the amount of resources allocated and (2) the level of irreversibility of these resources (commitment).

2.2 Resource-based view and R&D internationalization

The importance of resource commitment is anchored in the resource-based view (RBV) of the firm. The RBV emphasizes the importance of resources in creating value for firms (Barney 1991; Grant 1991; Wernerfelt 1984). It perceives firms as a "collection of productive resources" (Penrose 1959:24) and argues that firms that effectively create, apply, and (re-)allocate their resources are thereby able to create a (sustained) competitive advantage (Barney 1991). In other words: a firm that can match and commit resources to specific innovative activities may achieve superior performance. R&D activities (basic research, applied research, and development) are important contributors to the learning process that characterizes such innovative activities (OECD 2015).

In this view, it seems 'natural' for firms to locate their activities where resources are, such that they can add value to firms' existing firm resources and operations. This implication of the RBV is in line with Dunning's discussion of asset-seeking locational advantages (e.g., Dunning, 2001), and our understanding of MNEs as pursuers of global learning, knowledge acquisition, and upgrading (Yves L., Jose, and Peter 2001). In the context of R&D internationalization, MNEs will (re-)locate some of their R&D activities to geographical locations based on the resources present in those locations (Ervits 2018; Mudambi 2008). The increasing geographic dispersion of knowledge and technological innovation is thus considered one of the main drivers of the internationalization of MNE R&D activities (Cantwell 1995; Castellani 2018).

The internationalization of R&D allows firms to develop knowledge using both internal and external networks (Castellani and Zanfei 2006). Firms that are able to tap into different knowledge stocks by utilizing external networks with other firms and knowledge institutes in host locations can achieve competitive advantages that other firms will find difficult to duplicate or imitate, much less surpass (Kogut and Zander 1993; Martin and Salomon 2003). Strong internal networks, on the other hand, enable MNEs to successfully recombine knowledge from their different locations and to build upon or extend their technological competencies through internally coordinated learning processes (Cantwell 1995). These internal networks make technological accumulation within the firm possible and thus explain why technology is developed in international networks, rather than in separate units (Cantwell 1989).

The internal and external generation, absorption, and transmission of knowledge is crucial to the extraction of economic value from an MNE's increasingly dispersed R&D activities. These capabilities are referred to in the literature as 'dynamic' capabilities, as they enable firms to create, deploy, integrate, and upgrade resources in pursuit of sustained competitive advantages in the ever-changing global marketplace (Luo 2002; Teece, Pisano, and Shuen 1997). In other words, competitive advantages of firms stem not only from their distinctive resources (or from the resources available to them by internationalizing), but also from the manner in which firm resources are deployed (Luo 2004). This speaks to the importance of resource commitment.

2.3. Different resource commitment positions

The large variety of internationalized MNE R&D activities and organizational forms reflect the fact that MNEs have the freedom to adapt the manner in which resources are deployed. Penner-Hahn (1998) categorizes the organizational choices for a firm that undertakes foreign R&D into three basic types: controlled research, collaborative research, and funded research. Even though these categories are rather broad and non-mutually exclusive, they may be used to indicate the adoption of different resource commitment positions. R&D activities within the three categories differ in terms of firm ownership, financial involvement, and day-to-day involvement of the firm.

Controlled research can either be acquisitions or Greenfield investments that include anything from large R&D centers to so-called 'listening posts'. Listening posts are focused on monitoring scientific and technological developments in a specific location and are usually limited in size (Gassmann and Gaso 2005). Generally speaking, controlled research activities involve relatively high levels of ownership and firm 'involvement'. Collaborative research projects may involve the exchange of information on products, technologies, and/or regulatory affairs in public-private partnerships or the participation of a firm's employees in a collaborative research activity. Collaborations can either be equity or non-equity based. Funded research projects are those in which a firm funds research at a university, independent research organizations and other firms (usually start-up companies) (Chatterji 1996). Funding research in this way allows firms to sow many seeds with relatively small sums of money (Gulbrandsen and Smeby 2005; OECD 2009). Such projects generally do not involve company research staff, but do require internal capability to evaluate results and assimilate promising technology.

The need to take one or another resource commitment position (as implied by the variety of organizational forms) can partly be explained by resource constraints faced by MNEs. All firms operate under resource constraints and thus need to make resource commitment decisions regarding their R&D activities. Indeed, previous work describes how the stock of firm resources influences R&D activities (Del Canto and González 1999; Cho and Kim 2017). In addition, Dellestrand and Kappen (2011) state that, due to resource constraints, firms are less likely to allocate resources to all their positive net present value R&D projects.

The following sections describe the main factors that influence MNE R&D resource commitment positions. First, however, the resource commitment concept is delineated.

3. Characteristics of resource commitment

Resource commitment is composed of two factors: (1) the amount of resources allocated to a specific location and (2) the degree of commitment (Johanson and Vahlne 1977; Randøy and Dibrell 2002). Both factors are further explored in this section, starting with a description of the different resources that firms may allocate to a location or activity.

3.1 Resources

Resources are all the factors firms use to produce their goods or services (Ghemawat and Del Sol 1998). Resources can be divided into two categories: tangible and intangible resources. Tangible resources (also referred to as assets) include those factors containing financial or physical value (Galbreath 2005). Intangible resources include those factors that are non-financial and non-physical in nature. Following Hall (1992), intangible resources are considered to fall into two subcategories: assets and capabilities. Assets (both tangible and intangible) are owned and controlled by the firm. Capabilities are intangible bundles of skills and accumulated knowledge exercised through organizational routines (Galbreath 2005; Teece et al. 1997). The difference between intangible assets and capabilities is simplified by Hall (1992), who describes an intangible asset as something the firm ‘has’ and referring to a capability as something the firm ‘does’. In reality, however, there appears to be a fine line between intangible assets and intangible capabilities.

Approaching the concept from a different angle, several scholars have sought to classify resources in broader categories. Four frequently suggested resource categories are: (1) technological resources, (2) managerial resources, (3) financial resources, and (4) physical resources (Das and Teng 1998; Hofer and Schendel 1978). Some of these categories include both tangible and intangible resources. Table 2 below provides some categorized examples of resources that are related to R&D activities. Managerial resources have been changed into 'human resources' in Table 2 to also include employees, next to managers.

Table 2: Types of resources

Resource	**Tangible**	**Intangible**	
	Assets	*Assets*	*Capabilities*
Technological	Capital equipment	Intellectual property	Scientific capabilities
Human	Scientists/engineers	Managers time	Work routines
Financial	Capital	Borrowing capacity	Generate internal funds
Physical	(Research) facilities	-	-

Source: author, based on categorizations by Hall (1992, 1993), Das and Teng (1998), and Hofer and Schendel (1978).

Note: *The table is by no means exhaustive.*

It is important to note that what constitutes high or low resource allocation cannot only be based on adding up the allocated resources from each of the categories described above. Resource allocation is also relative to the size of a firm's global R&D network and its individual R&D units. An R&D unit of 15 people may be a relatively large investment for some MNEs, while this is a minor investment for firms with multiple large R&D centers across the world.

3.2 Commitment

The second factor of resource commitment is the degree of commitment, sometimes also referred to as the 'irreversibility' of a resource allocation (Kulkarni and Ramamoorthy 2005; Pedersen and Petersen 1998). The irreversibility of deployed resources is often a consequence of asset/resource specificity (Teece 1986; Williamson 1985). Resources can either be specific to the firm employing them or to a particular application or use (a product, an activity, or a location) (Ghemawat and Del Sol 1998). An asset is specific to a firm if its value to the firm exceeds its value to any other firm. An asset is specific to a usage if its value decreases when a firm applies it differently or redeploys it to another activity or location. Thus, asset specificity refers to the presence of a significant level of sunk costs (Worthington 1995).

Firm-specific resources tend to be 'sticky' in the sense that there are significant costs involved in separating them from the firm that possesses them. The decision to invest or disinvest in them thus implies an irreversible commitment by the firm (Ghemawat and Del Sol 1998). For example, a brand name is considered firm-specific and 'sticky'.

Usage-specific resources, on the other hand, tend to restrict a firm's internal resource allocation. Both the characteristics of specific activities and/or locations may influence the allocation of usage-specific resources. For example, highly knowledge-intensive activities tend to be difficult to relocate due to the internal stickiness of knowledge (Szulanski 1996). As another example, engineers (resources) in a firm's central engineering department might be easily directed to development and production in other markets, but cannot always be profitably used there (Johanson and Vahlne 1977). Their transfer would thus result in a lower economic value of these resources (engineers) to the firm: these engineers constitute a sunk or lock-in cost based on their usage-specificity. The maintenance of public-private partnerships is another activity-related example. Resources invested into the creation and management of such partnerships are to a large extent relationship-specific (usage specificity). Redirecting these relationship-specific resources could cause the firm to lose access to potentially relevant knowledge. Thus, these resources cannot be redeployed to alternative uses without the loss of value, resulting in irreversibility. A location-related example of usage-specificity is the irreversibility that may arise because of government regulations or institutional arrangements. For example, capital controls may make it impossible for investors to sell assets and reallocate their funds (Pindyk 1991). This is expanded upon in Section 4.

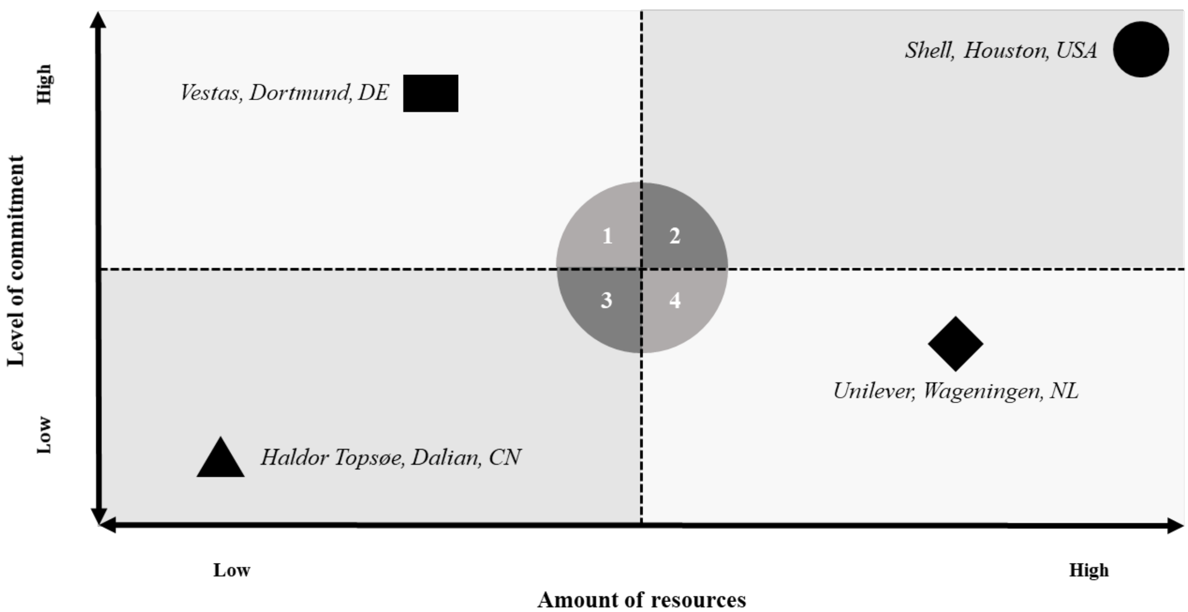
R&D investments are characterized by a high degree of asset specificity (Williamson 1988). R&D activities tend to focus on the medium to long-term and are dependent on the firm's past innovations (Malerba and Orsenigo 1993). This dynamic is clearly expressed by the mean lag in returns from expenditures on R&D, which tends to be on the order of four to six years (Cohen and Levin 1989).

The above description and examples of asset specificity show that: the higher the asset specificity, the higher the degree of commitment, the less flexible an R&D unit is. This may result in over-commitment in certain locations or in certain activities. In contrast, when asset specificity is low, resources can be applied relatively quickly to a large range of alternative uses without substantial costs or difficulty. Low asset specificity thus implies low commitment, or alternatively: high 'resource flexibility' (Sanchez 1995).

3.3 Resource commitment

The preceding sections on 'resources' and 'commitment' (the two building blocks of resource commitment) show that differences in resource commitment are more nuanced than might be expected. For example, large investments (involving a relatively large amount of resources) are not necessarily specific to a use or a location and may thus be low-commitment in nature. Large investments in saleable equipment, for example, do not necessarily imply a strong commitment as the resources involved can easily be moved. Such 'High resource, Low commitment' investments can be placed in quadrant four of Figure 3 below. Figure 3 visualizes the different resource commitment positions that may be adopted by firms.

Figure 3: Level of commitment and amount of resources



Source: author

***Note:** Positioning of examples by approximation*

An example of a ‘High resource, Low commitment’ investment is the shared research facility set-up by the Dutch-British MNE Unilever in Wageningen, The Netherlands. This facility houses expensive, specialized equipment that is shared with the local university and others. Equipment is replaced every 3–5 years in order to stay up-to-date. Funding for these replacements is provided by all involved partners. While the investments in this equipment represent a ‘high resource’ allocation, the firm’s commitment is relatively low as it can choose to opt out every 3–5 years.

The third quadrant in Figure 3 refers to the allocation of a relatively low amount of low commitment resources (‘Low resource, Low commitment’). An example of such an investment is an R&D unit of Danish catalysis company Haldor Topsøe in Dalian, China. The company located 3 employees (‘low resource’) in Dalian, seeking to collaborate with the local university. However, within three years, the company moved their employees to a newly established joint venture on the other side of China. This move shows the flexibility and thus ‘low commitment’ of the allocated resources.

Quadrant one is home to activities that are low in resources but high in commitment (‘Low resource, High commitment’). The R&D unit of Danish wind power company Vestas in Dortmund, Germany may be placed in this quadrant. Vestas has approximately 17 R&D employees in Dortmund. While their number is relatively small, the unit in Dortmund has strong and important relationships with large local suppliers, indicating a high level of commitment.

The final quadrant, number two, is home to R&D activities that require a large amount of dedicated resources (‘High resource, High commitment’). All large corporate R&D centers fit in this quadrant. An example of such a center is one of the main R&D hubs of oil and gas company Shell in Houston, USA. The Shell Technology Center Houston has 44 buildings housing around 2,000 scientists and engineers.

Now that the components and characteristics of the resource commitment concept have been explored, the next section discusses the determinants of resource commitment positions.

4. Antecedents of resource commitment

Resource commitment positions of MNE R&D activities are mainly influenced by three factors: (1) purpose of the R&D activity, (2) the external environment, and (3) international and local experience. The relationship between these factors and both the amount of resources and the commitment levels are discussed below.

4.1 Purpose of R&D activity

Resource commitment is shaped partly by the underlying 'purpose' of the specific R&D activity that the firm seeks to perform. Broadly speaking, R&D activities may serve two types of purposes: exploitation and exploration (March 1991; Kuemmerle 1997). The purpose of exploitative activities is to achieve refinement, efficiency, production, and execution benefits (Benner and Tushman 2003). They are primarily concerned with the local adaptation of existing processes and products, and the creation of peripheral products (Cantwell and Piscitello 2000; Gammeltoft 2006). These activities are thus less related to research (in a strict sense) and more to design, development, and/or engineering (Gammeltoft 2006). The aim of explorative R&D activities, on the other hand, is to augment a firm's knowledge base (Cantwell 1989; Florida 1997). Thus, explorative R&D activities play a crucial role in the generation of new ideas and capabilities (Frost 2001).

It is important to note that the distinction between exploitation and exploration is often a matter of degree and should therefore be viewed as a continuum: R&D units (often) do not employ only one or the other. A firm's ability to both exploit existing competencies and explore new opportunities is referred to in the literature as ambidexterity (Raisch et al. 2009). Moreover, the notion of exploration-exploitation is subject to relativity because it must be defined from the viewpoint of a given MNE or unit. After all, certain knowledge, technology, or markets may be familiar to one firm or R&D unit but new to another (Lavie, Stettner, and Tushman 2010).

Both exploration and exploitation activities are essential for firms. Exploration without exploitation results in experimentation costs without the benefits, while exploitation without exploration may result in the loss of competitive advantage in the long term. While both types of activities are essential, they compete for scarce resources (Levitt and March 1988; March 1991). Over time, firms demonstrate a natural tendency towards exploitation (Chen and Katila 2008). They become grounded in a series of common routines that facilitate the exploitation of existing skills/knowledge/products (Helfat 1994). Such routines generally suppress a firm's capacity to absorb new information by spelling out behavior that hinders searches for new ideas that diverge from prior learning (Hutzschenreuter, Pedersen, and Volberda 2007). In other words: past exploitation activities in a given domain tend to make further exploitation in that domain even more attractive, because these efforts are believed to make more efficient use of existing intangible resources (Levinthal 1995). This dynamic is also referred to as path dependency and resonates with the aforementioned built-in biases towards inertia that lead to irreversibility and hence to higher levels of commitment.

Explorative activities, on the other hand, are less associated with common routines and inertia, and more with uncertain, distant, and often negative returns (March 1991). The uncertainty associated with explorative activities lowers the likelihood of setting-up an explorative activity abroad, as opposed to an exploitative activity (Ambos and Ambos 2011). In addition, this uncertainty causes lower levels of commitment (at least initially) to explorative activities. After all, high commitment constitutes an exit barrier, limiting the strategic flexibility of the firm in case no useful knowledge or partners can be found in a particular location, or in case useful relations have run their course. The need for flexible explorative activities is also highlighted by Geiger and Makri (2006), who find that only enough 'slack resources' (resources that are readily available, as they are not in use) would provide firms with the flexibility needed for explorative activities.

Looking at the amount of allocated resources per activity, the roles seem to be reversed. R&D activities that are generally small in scale (suggesting relatively few resources) are mostly exploitative in nature. These are (1) units focusing on adapting products, processes, and materials to foreign markets, and (2) units providing technical support to offshore manufacturing plants (Patel and Vega 1999). Activities seeking to generate entirely new products and core technologies (explorative activities) tend to be large in size by Patel and Vega (1999). After all, such R&D units need relatively large, long-term investments of resources in order to conduct their research (Williams and Nones 2009). Explorative R&D units also receive higher levels of autonomy (compared to exploitative units) (Cantwell and Mudambi 2005), gaining a mandate or specific area of responsibility for the parent company. Such autonomy also comes with the required resources to launch or progress further in their work (Keupp 2008). Not all explorative units have access to a (relatively) large amount of resources. Exceptions are units focused on monitoring scientific and technological developments (referred to earlier as listening posts). Although these are technically explorative activities, they are generally small in scale, as it would be illogical for firms to use high commitment levels just to identify knowledge. Based on the above discussion, the following propositions are formulated:

Proposition 1(a): *Generally, more resources are allocated to more-explorative R&D locations than to more-exploitative R&D locations ('monitoring' explorative activities being an exception).*

Proposition 1(b): *Generally, more-exploitative activities maintain higher commitment than more-explorative activities.*

4.2 External environment

Consistent with the concept of Location (L) advantages from the eclectic paradigm (Dunning 1993), the external environment has an important influence on resource commitment positions. L advantages are a set of complementary assets associated with a location (thus external to the firm) that are based on resources, formal and informal institutional structures, or other location-specific factors (Dunning 1988, 1993, 2001; Narula and Grazia D Santangelo 2009).

The (re)location of R&D activities requires a very strong offer of complementary L advantages. Firms display inertia when it comes to relocating their R&D activities, due to the nature of innovation (Narula 2002), and the strategic long-term significance of R&D activities to the firm (Narula and Zanfei 2004). In addition, centripetal forces such as economies of scale and concerns regarding control, communication, and security compel firms to limit the number of R&D locations (Pearce 1989).

Location advantages that attract R&D to peripheral sites are referred to as centrifugal forces. Exploitative and explorative R&D activities differ in terms of the importance of specific L advantages. Exploitative R&D activities, for example, are subordinate to the MNE's market-seeking activities. They follow the location of other MNE activities, such as production and sales (Narula and Grazia D Santangelo 2012). Thus, exploitative activities are primarily determined by the same L advantages (mostly market-specific) that shape other MNE activities. Nevertheless, the availability of expert pools (e.g., highly qualified engineers, software developers, etc.) is an important factor for some exploitative R&D activities (Lewin and Peeters 2006).

Explorative R&D activities are influenced primarily by knowledge infrastructure-related L advantages and the L advantages that derive from other firm R&D activities based at the same location (Narula and Grazia D Santangelo 2012). The former relates to the presence of tertiary education institutes and public research institutes. The latter are also referred to as co-location advantages (Narula and Grazia D Santangelo 2012). Co-locating with other high-tech firms might provide access to appropriately skilled and experienced workers. In addition, co-locating offers the possibility of knowledge spillovers, as these are often spatially bounded (Malmberg, Sölvell, and Zander 1996).

Location characteristics not only influence the location choice of MNE R&D activities; they also strongly influence MNE R&D resource commitment positions. These resource commitment positions may either be the result of firms' decisions in light of perceived opportunities and risks that certain location characteristics offer, or they are the direct result of government regulations. The direct impact of government regulations on resource commitment positions may follow one of two paths. First, as shown by previous studies, host country governments may require firms to upgrade their investments and to conduct R&D activities locally (Håkanson and Nobel 1993). Such policies may lead firms to adopt resource commitment positions that they would otherwise not have adopted. An example of this would be Japanese policies to promote R&D and technology importation between the 1950s and the late 1970s. As a result of these policies, foreign firms felt the need to set-up local R&D units in Japan (resource allocation). While these policies have since been lifted, some firms still have R&D units in Japan (due to their aforementioned locational inertia), even though Japan might no longer be the ideal location for them. This reflects the high level of commitment of some of the allocated resources.

Second, government regulations may adjust a firm's commitment without (or despite of) firm decisions. In such cases, an adjustment in commitment is the result of a change in the potential redeployability (sunk cost) of resources due to changing government policies (Santangelo and Meyer 2017). For example, changing government regulations regarding capital controls, exchange rate policy, or trade policy may affect a firm's ability to sell assets or reallocate funds.

Perceived locational risks and opportunities influence a firm's resource commitment decisions more directly, as resource deployment is an important mechanism for balancing both risks and opportunities. After all, risk can be conceptualized as the product of uncertainty (in this case of the external environment) and the level of commitment undertaken in a specific location (Johanson and Vahlne 1977). The uncertainty of an environment may be defined as the extent to which a location's characteristics threaten the stability of business operations (Gatignon and Anderson 1988). Two often-cited factors that influence uncertainty experienced by firms when locating their R&D activities are: (1) weak institutional environments and (2) weak knowledge bases of local competitors. Both of these factors may cause the 'leakage' of deployed resources, as weak institutional environments are less likely to provide strong protection of industrial and intellectual property rights, and weak local firms may copy propriety knowledge or recruit employees. Although local firms may possess a lower absorptive capacity (the capacity to recognize the value of new external information, assimilate it, and apply it (Cohen and Levinthal 1990), MNEs may still fear potential leakages to such firms to be higher than potential knowledge inflows (Mariotti, Piscitello, and Elia 2010).

According to the conceptualization of risk, firms are expected to lower their level of commitment to an uncertain environment in order to minimize the risk of negative knowledge leakages (Gatignon and Anderson 1988; Luo 2002; Williamson 1985). Studies of MNE equity ownership levels support this argument, showing that as location risk increases, foreign firm's level of commitment decreases (Ahmed et al. 2002; Henisz and Delios 2001). However, some scholars argue that when expected benefits from opportunities are stronger than risks posed by the local environment, higher levels of commitment are necessary (Luo 2000). The argument is that when factor markets are volatile and underdeveloped (causing uncertainty), firms need to commit their own resources in order to reduce their dependence on host location inputs (Luo 2002). In such cases, commitment allows MNEs to obtain and maintain competitive advantages vis-à-vis local firms and other MNEs. In addition, commitment allows MNEs to mitigate the disadvantages of foreignness and newness (which include a shortage of market power, company image, and institutional support).

Arguably, it is more difficult for firms that conduct more-explorative R&D activities to lower their dependence to host location input, as their success is linked in large part to their access to these inputs. It is, therefore, expected that explorative MNE R&D activities require lower environmental risks and larger opportunities to commit resources than is the case for exploitative activities.

Potential opportunities not only affect commitment levels but also MNE resource allocation. After all, in trying to limit the firm's dependence on host location inputs, the firm is bound to allocate more of its own resources. However, as the R&D investments in higher risk environments are expected to include mostly relatively small exploitative R&D activities (see Section 4.1), this suggests a relatively low amount of allocated resources to locations that pose (affordable) risks. The following propositions emerge from this discussion:

Proposition 2(a): *A relatively low amount of R&D resources is allocated to locations with affordable risks, as R&D investments in these locations mostly include relatively small exploitative R&D activities.*

Proposition 2(b): *More-explorative activities require lower environmental risks and larger opportunities to commit resources than is the case for more-exploitative activities.*

4.3 Experience

It is a dominant view in MNE theories that MNE experience influences decisions about commitment levels and subsequent activities. Both experience with international activities in general and experience in a particular host location are argued to have a positive impact on resource commitment (Johanson and Vahlne 1977; Li 1995; Wells 1998). These two types of experience may be linked to external and internal networks that promote knowledge development.

From an evolutionary perspective, location-specific experience (knowledge about and experience in a host location) facilitates the gradual increase of an MNE's local resource deployment (Chang 1995; Kogut 1983). This is related to the effect of locational uncertainty (as described in Section 4.2), as firms that have experience in a specific local market perceive such familiar markets as less uncertain (Delios and Henisz 2003). After all, they are already familiar with the local consumer (relevant for exploitative R&D activities), formal and informal institutions, and local actors. Experience with local actors has been shown to be a result of prior R&D experience in a specific location, and to facilitate networking and social proximity (Blanc and Sierra 1999).

As a result of increased local familiarity, firms are more prepared to assume higher commitments in and allocate more resources to the location in question (Chang and Rosenzweig 2001). In addition, firms with local market experience have developed the capability to operate in that specific market, making it easier for them to deal with increasing levels of commitment and resources (Gao and Pan 2010).

Experience gained in a location is not necessarily location-bound. Experience with how to interact with external actors, how to deal with foreign institutions, and experience with high resource commitment configurations, may also be used elsewhere. Local experiences, therefore, help build a firm's international experience. It could be argued that experience is in fact a firm-specific resource (capability) in itself, being a valuable, unique and hard-to-imitate resource (Peng and York 2001). Experienced MNEs are able to transfer this capability (their knowledge about how to operate foreign activities) across national borders (Petersen and Pedersen 1999). This body of knowledge influences the allocation of resources and their commitment level, as firms become more confident about their ability to deal with uncertainty, the liability of newness, and/or the liability of foreignness. The relationship between international experience and R&D resource commitment is hinted at by Penner-Hahn (1998), who suggests that firms with foreign market knowledge perceive lower barriers to foreign R&D and therefore tend to establish high commitment R&D activities (collaborative and controlled activities as opposed to sponsored activities). Based on the above discussion, the following propositions are formulated:

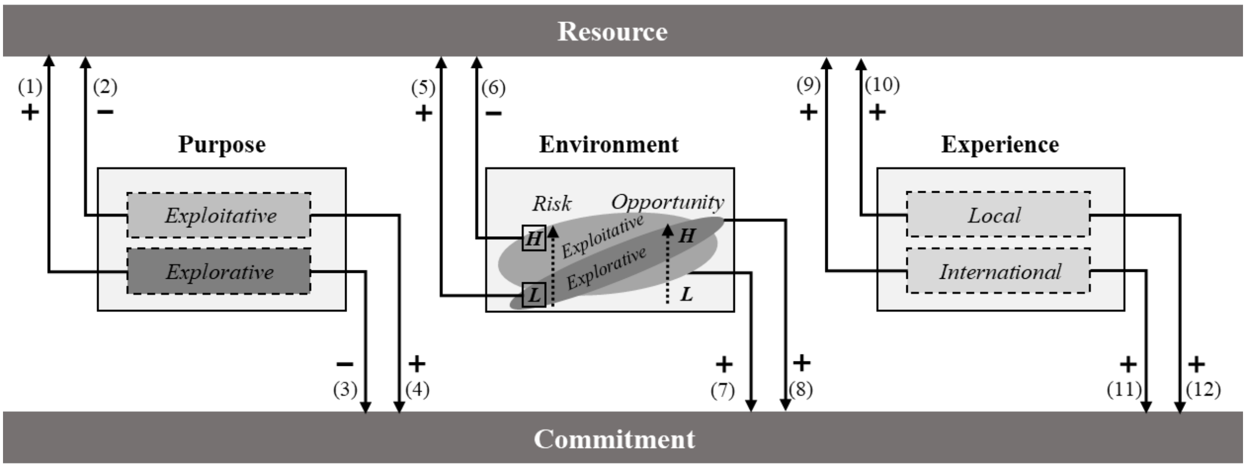
Proposition 3(a): *Both international and local experience positively influence resource allocation.*

Proposition 3(b): *Both international and local experience positively influence commitment levels.*

5. Discussion

The previous sections support the idea that resource commitment positions of MNE R&D activities are influenced by (1) the purpose of the R&D activity, (2) the external environment, and (3) the international and local experience of the MNE. Together, these three factors provide a framework (see Figure 4) explaining the resource commitment of MNE R&D activities. It is argued that, generally, more resources are allocated to more-explorative R&D locations (1) than to more-exploitative R&D locations (2). At the same time, more-explorative activities are argued to maintain lower commitment (3) than more-exploitative activities (4). It is also argued that R&D investments to locations with affordable risks are dominated by relatively small exploitative R&D activities, indicated a low amount of allocated R&D resources (5, 6). Furthermore, explorative activities require lower environmental risks and larger opportunities to commit resources than is the case for exploitative activities (7, 8). Finally, it is argued that both international and local experience positively influence resource allocation (9, 10) and commitment levels (11, 12).

Figure 4: R&D resource commitment framework



Source: author

5.1 Contributions

The above framework allows us to understand why MNE R&D units adopt certain resource commitment positions. By breaking down the resource commitment concept into its constituent parts (resources and commitment), the framework builds on the literature concerning resource commitment (e.g., Ghemawat 1991; Ghemawat and Del Sol 1998; Maitland and Sammartino 2009) and provides scholars with a better understanding of MNE behavior. Besides offering insight into R&D resource commitment positions, the framework enables thinking about R&D units' resource commitment in general. This paves the way for new research on the consequences of different positions to firms and locations, which is of interest considering the importance of resource commitment, as emphasized by the resource-based view.

Further, the framework offers MNE managers a tool they can use to establish what resource commitment position would be most appropriate, considering the type of activity, potential and risk associated with the proposed location, and the firm's experience. For example, lower risks (e.g., improved intellectual property rights) and/or improved opportunities (e.g., enhanced local competencies) may drive managers to reconsider their R&D resource commitment position. This could entail an increase or decrease in resources or a change in commitment levels (or both). For example, in the case of lower risks and bigger opportunities, firms could set up collaborations with local actors. This would increase commitment while keeping resource levels relatively unchanged, making the firm less flexible, but allowing it to access more local knowledge. However, it is important to note that there are other antecedents of R&D resource commitment. Differences in industry, firm's owner's personalized motivations (Hermans and Borda Reyes, 2020), subsidiary initiatives (Birkinshaw and Morrison, 1995; Lee *et al.*, 2019), and top management involvement (Kleinschmidt *et al.*, 2007) are a few examples of factors that may also influence resource commitment to R&D activities. The presented framework should therefore not be used on in its own.

Finally, policy-makers concerned with knowledge-intensive clusters and/or boosting the knowledge-intensive economy may also benefit from the R&D resource commitment framework. Policy-makers are, arguably, most interested in attracting high commitment R&D activities. Such activities are less likely to be relocated or to be discontinued, potentially providing added value to the (local) economy over a longer period of time (compared to lower-commitment activities). The R&D resource commitment framework provides policy-makers insight in the type of activities and the companies they need to attract to maximize the commitment level of new investments. It shows, for example, that exploitative activities are generally more committed than explorative activities and that firms with existing local experience are more likely to be more committed to a location.

5.2 Limitations and future research

This paper is presented as a first step in thinking about resource commitment as concept that enables more nuanced understandings of MNE R&D internationalization behavior. The major limitation of this work is that it is purely conceptual; it offers a roadmap for the development of a theoretical framework and propositions for further testing, but in itself does not achieve those milestones. At least three directions for future research are identified here. Firstly, there is a need to better understand MNE innovation networks in terms of resource commitment and to conduct empirical studies to determine the strength of the relationships identified in this paper. Secondly, while the discussion in this paper might imply a rather static view of resource commitment, it would be interesting to determine whether there are specific patterns in resource and commitment levels over time. The third, and final, suggestion would be to identify the effects of different resource commitment positions on host locations.

6. Conclusion

This paper has sought to evaluate the concept of resource commitment and use the concept to better understand differences between global MNE R&D activities. It breaks down the resource commitment concept into its two building blocks: resources and commitment. In so doing, it corrects the misunderstanding that resource commitment is the same as 'resource allocation'. The subsequent discussion highlights three main factors (antecedents) that are argued to influence the resource commitment positions of MNE R&D activities. These are: (1) the purpose of the R&D activity, (2) the external environment, and (3) international and local experience of the MNE. Based on these antecedents, a novel framework is presented that is able to explain the observable differences in resource and commitment levels of R&D units.

Understanding R&D resource commitment is crucial for firms as it impacts firm embeddedness (Kuemmerle 1997), innovation, and performance (Isobe et al. 2000; Kanwal et al. 2017). MNE managers who use the framework presented can strike a balance between commitment and flexibility in their R&D activities to achieve these benefits. It provides them with a clear understanding of the factors and relationships that come into play when determining resource commitment to R&D activities. It also provides policy-makers insight into the type of activities and the companies they need to attract to maximize the added value of firm's investments in their country/region.

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Chapter 2

The role of R&D resource commitment in accessing co-location advantages

Niels le Duc and Peter Gammeltoft

Abstract

In a globalized economy, multinational enterprises (MNEs) pursue competitiveness through cross-border knowledge exploitation and exploration in international R&D. It is conventionally assumed that for subsidiaries to effectively access co-location advantages in knowledge milieus abroad, high levels of resource commitment are required. This paper analyses the relationship between resource commitment and access to co-location advantages, first theoretically and then through a case study of two MNEs in high-tech industries. We disaggregate the composite concept of resource commitment and demonstrate the dimensions accentuated, respectively, by the resource-based view, transaction cost economics and institutional theory. Next, we analyse the relationship between resource commitment and co-location advantages for 11 R&D subsidiaries of the two MNEs. Based on this analysis, we discuss the relationships between the empirical findings and the theoretically differentiated resource commitment dimensions. The study finds that high resource levels are less important for access to co-location advantages than conventionally assumed, while the level of commitment associated with allocated resources appears consistently to be important, lending more support for the relevance of institutional theory-related dimensions of resource commitment than the resource-based view-related ones. We also find support for the claim that more flexible governance arrangements promote access to co-location advantages in asset exploration.

1. Introduction

Access to external local knowledge and the ability to absorb it are of critical importance to the innovative performance of multinational enterprises (MNEs) (Chesbrough, 2006; Figueiredo and Brito, 2011; Laursen and Salter, 2006; Perri *et al.*, 2017). To access and absorb local knowledge, MNEs are required to mobilize internal or relational assets and commit them over time. When innovation processes involve external partnerships, crucial trust and legitimacy can be strengthened by a parent company that mobilizes and commits sufficient amounts of resources to the endeavour (Kuemmerle, 1997; Mellahi *et al.*, 2016; Wagner and Bukó, 2005). R&D units that do not receive such resource commitments are argued to be less able to access so-called co-location advantages: advantages gained from the access to intangible (localized knowledge) and tangible (e.g., equipment, shared facilities) resources of local actors. On the other hand, *ceteris paribus*, firms have a general interest in reducing resource commitment to maintain efficiency and flexibility. Hence, aligning resource commitment with effectiveness, efficiency and flexibility of innovation processes and the contingent trust and legitimacy with external partners is a major strategic challenge in organizing international R&D.

It is conventionally assumed that to be successful, international R&D requires relatively high levels of resource commitment (Kuemmerle, 1997; Perri, 2015). However, some MNE R&D units seem to be able to access local knowledge/resources by adopting low resource commitment configurations (le Duc and Lindeque, 2018; Gollnhofer and Turkina, 2015; Li and Xie, 2016) and many MNEs successfully operate small R&D units (ranging from 2 to 25 people, indicating low resource commitment) that are relatively flexible. Examples of such units in the literature are listening posts (Gassmann and Gaso, 2004, 2005), monitoring units (UNCTAD, 2005), sensing units (Patel and Vega, 1999), innovation labs, or innovation antenna (Onetti and Marinucci, 2017). Considering the inherent limit to firm resources and the differences in resource commitment to MNE R&D units, it is of interest to better understand how differences in resource commitment influence the access of MNE R&D units to local knowledge/resources, especially considering the critical importance of such local knowledge for MNEs (Gammelgaard *et al.*, 2012; Perri *et al.*, 2017). Considering the above, this paper seeks to answer the following research question:

How does MNE R&D unit resource commitment explain access to co-location advantages?

The literature rarely specifies concretely what constitutes resource commitment or why and how it is important. We contribute to better specifying and disaggregating the concept of resource commitment and its relationship with co-location advantages by observing it through three theoretical lenses: the resource-based view, transaction cost economics, and institutional theory. Each theoretical perspective focuses on different aspects and accords them with different significance. By implication, heterogeneity in cognitive, normative and valuative dispositions towards these perspectives, at the levels of organizations and managers, is likely to produce different governance and resource commitment preferences and modalities for international R&D. We show that resource commitment has substantive, transactional, and institutional dimensions and that the relationship between resource commitment and co-location advantages is approached differently in the resource-based view, transaction cost economics and institutional theory.

We combine a theoretical discussion of resource commitment dimensions with findings from a qualitative, embedded, multiple-case study research design. Data were collected by interviewing R&D managers from two companies, both large MNEs from small developed-market countries (Sweden and Denmark) that produce high-tech equipment and sell it to other companies. R&D managers from both headquarters and eleven R&D units, each with its own resource commitment position, were interviewed.

The findings suggest that the influence of an R&D unit's resource level on its access to co-location advantages is less important than previously reported and seems to be affected by the R&D unit's commitment level. This lends more support for the institutional theory-related dimensions of resource commitment than the resource-based view-related ones. We also find support for the claim that more flexible governance arrangements of R&D units promote access to co-location advantages in asset exploration. These findings contribute additional insights to the ties between organizations (in terms of their establishment and effectiveness), which may help scholars to better understand MNE behaviour. These findings also contribute to literature that emphasizes the relationship between resource commitment and firm insidership in local networks (Johanson and Vahlne, 2009; Vahlne and Bhatti, 2019; Valentino *et al.*, 2018). Lastly, the findings may provide policy-makers new insight regarding the type of MNE activities that would both benefit from and deepen the potential of networks they are trying to establish in their country/region.

The next section discusses co-location advantages and how the resource-based view, transaction cost economics and institutional theory each accentuate different dimensions of the concept of resource commitment. Next, the study's research design is described (Section 3), before the cross-case findings are presented (Section 4). The study concludes with a discussion of these findings and their implications.

2. Resource commitment dimensions and co-location advantages

To be successful, R&D internationalization involves resource-, transaction- and institution-related dimensions. Correspondingly, resource commitment has substantive, transactional, and institutional dimensions. It can arise from a firm's internal allocation of assets, e.g., investment in (specialized) equipment. It can also arise from durable governance arrangements established to manage costs and risks in transactions across firm boundaries, e.g., contracts, joint ownership, or putting-out systems. Finally, the regularization of norms, values and routines through recurrent (value-adding) external interaction involves both application and commitment of resources. Or more succinctly, resource commitment is manifested in assets, governance arrangements and external relationships. The overall resource commitment is constituted by the combination of these types of commitment.

In the following, we first define co-location advantages, which are argued to be a special subgroup of location advantages, and then consider the constitution of the relationship between resource commitment and co-location advantages in the context of R&D internationalization for three theoretical perspectives: the resource-based view, transaction cost economics, and institutional theory.

2.1 Co-location advantages

MNEs are organizationally and spatially complex systems with the ability to take advantage of differences in availability, quality, and price of location-bound assets (Dunning, 1977). Location-bound assets are a set of characteristics associated with a location, and thus external to the firm, and may be resources, formal and informal institutional structures, or other location-specific factors (Dunning, 1988, 1993, 2001; Singh and Kundu, 2002). Location-bound assets that are relevant to a firm are also referred to as location or 'L' advantages (Dunning, 1977, 1979).

Co-location advantages are a special type of L advantages, as they are derived from their spatial proximity to other actors such as institutes of higher education, research institutes, or other firms. More specifically, co-location advantages are gained from the access to assets of local actors, both intangible (localized knowledge) and tangible (e.g., equipment, shared facilities). Access to local knowledge is often equated to the concept of local knowledge spillovers, which occur when localized knowledge leaks beyond a local actor's organizational boundaries and is internalized and used by other local actors (Perri, 2015). The term makes no distinction between flows that are the outcome of free sharing agreements, economic transactions, or some agent's failure to secure the outcome of their own innovation efforts (Breschi and Lissoni, 2001). The latter may cause harm and may therefore represent a co-location disadvantage (Alcácer, 2006; Perri *et al.*, 2013; Santangelo, 2012). Access to the indivisible goods of local actors (which may lower costs and/or risks) also constitutes a co-location advantage.[1]

Co-location advantages are only available to those that have invested time in a location to acquire knowledge of institutions and actors (Forsgren *et al.*, 2005; Narula and Santangelo, 2009; Tallman *et al.*, 2004). That is, benefitting from proximate innovation network relationships requires intentional investments in such relationships (Maskell, 2002) and building up relationships with proximate actors (analogous with trust and relational capital) is time-consuming and expensive. However, once created, these relationships can be maintained at a low marginal cost (Mudambi *et al.*, 2018). Since co-location advantages mainly stem from the development of local relationships, being co-located does not automatically result in meaningful co-location advantages (Lorenzen, 2007; Maskell and Lorenzen, 2004; McCann and Mudambi, 2005).

The investments needed to access and exploit co-location advantages seem to be highly related to the concept of 'network insidership'. It is argued that local firms are better positioned to access L advantages as they are 'insiders' in the local network. Their 'insidership' provides them with significantly more market power compared to foreign

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[1] Sometimes other agglomeration externalities, besides knowledge spillovers and the sharing of goods, are also referred to as co-location advantages. These include the availability of specialized inputs (services, infrastructures) or the presence of skilled labour due to the co-location of many actors. However, we consider these to be 'public goods' L advantages, as access to them does not require the development of particular relationships.

firms (Hennart, 2012). Foreign firms may be able to achieve an advantageous local network position, but this is assumed to be a slow process requiring social relationships (Johanson and Vahlne, 2009). While both co-location advantages and 'network insidership' are associated with investments in local relationships, there are two differences: (1) access to 'regular' L advantages requires agency from the firm; access to co-location advantages requires agency from both the firm and at least one other local actor. Moreover, (2) 'network insidership' only enables a levelling of the playing field to access 'regular' L advantages in relation to other firms in a location, while investing in specific relationships in order to benefit from co-location advantages differentiates firms, as not all firms are equally well connected (Bathelt, 2005; Giuliani, 2007; Uzzi, 1997).

In the following sections we analyse how the relationship between resource commitment and co-location advantages is perceived differently when observed with the resource-based view, transaction cost economics and institutional theory, respectively.

2.2 Resource-based view

The resource-based view of the firm emphasizes firm-internal resources, broadly perceived, as the central enabler and constraint of firm evolution and hence the central role they play in firm strategies, growth and competitive advantage (Barney, 1991; Grant, 1991; Penrose, 1959; Wernerfelt, 1984). Firms are defined by their resources; their competitiveness, growth and survival hinge on safeguarding and refining them. Resource heterogeneity across firms produces distinct rent-creating potentials and path dependencies. Resources are diverse, e.g., physical, human, and financial (Barney, 1991) as well as technological and reputational (Grant, 1991), tangible vs intangible, property-based vs knowledge-based (Miller and Shamsie, 1996), and regular vs higher-order, the latter enabling integrating, building and reconfiguring resources over time (Teece *et al.*, 1997). The firm itself is often perceived as a bundle of resources.

Applying a resource-based perspective to resource commitment for the internationalization of corporate R&D highlights resources as both means and ends: resources are the central driver/rationale of R&D internationalization, whether it is motivated by exploiting existing strengths abroad, further refining or complementing existing resources, or acquiring or developing resources that are lacking, and whether the resources deployed or sought are tangible assets or intangible routines or practices. As a means, the process of R&D internationalization aims to augment the size or value of firm resources by identifying opportunities and capturing them by allocating resources and bundling them with complementary locational assets. Yet, committing resources represents both assets, liabilities and imperatives: to generate value locally, whether through exploration or exploitation, invariably requires a certain investment of resources. Given value-generating opportunities through the bundling of firm resources with local assets, the firm benefits from committing resources. At the same time, commitment introduces opportunity costs, sunk costs and rigidities as the firm forecloses alternative future growth opportunities, particularly when path dependencies are pronounced.

Within RBV, the primary focus is on the assets R&D internationalization is intended to acquire or augment, and on requisite initial resource provision and further acquisition, augmentation and opportunity generation through bundling with local complementary resources, while less focus is on external relationships. In this sense, RBV is more concerned with the resource than the commitment dimension of resource commitment.

2.3 Transaction cost economics

Observing resource commitment from the perspective of transaction cost economics (TCE) accentuates other dimensions. TCE enables analyses of governance choices based on the relative costs of interacting in markets vs. hierarchies, including analyses of the existence of the firm (Coase, 1937; Williamson, 1975, 1985, 2000). It is reductionist in the sense that it considers institutions to be fully reducible to underlying economic principles and the firm is often perceived as a nexus of contracts. Behaviourally, TCE assumes bounded rationality and often-contested opportunism (Alchian and Woodward, 1988; Conner and Prahalad, 1996; Donaldson, 1990; Foss and Weber, 2016). The governance form that prevails for a given transaction is contingent on its frequency, uncertainty, and asset specificity.

Much of the strength of TCE resides in its succinct and parsimonious specification, which concurrently limits its scope. Hence, with its (unilateral) focus on cost, efficiency, risk mitigation and control, it has little to say about value creation (Zajac and Olsen, 1993). It is widely argued that its behavioural assumptions may imply governance forms that do not properly incentivize learning, innovation and creativity (Bartlett and Ghoshal, 1993; Conner and Prahalad, 1996; Ghosal and Moran, 1996; Madhok, 2002; Mayer and Argyres, 2004). Its delimitation to transactions and their governance, rather than value-adding activities, facilitates only a partial outlook on the internationalization of corporate R&D and resource commitment, as it applies mainly to activities that involve transactions.

Hence, as opposed to RBV, TCE has little to say about the ends of R&D internationalization. Rather, presupposing the ends, it offers certain insights on the means. Transactions, internal as well as external, are costly and expose the firm to contracting and appropriability hazards, so fewer and cheaper transactions are better and entail less risk. This is, however, only a partial perspective on the value creation potential of international R&D, which can require frequent and rich interaction, especially when it is collaborative. In TCE, transactions that are frequent, uncertain and involve specific assets should be internalized rather than be relational. This would disfavour, for example, instances where assets are mutually developed through incremental co-specialization. Asset-augmenting international R&D is usually expressly collaborative and, particularly when it involves radical and basic R&D, can require frequent, highly uncertain interactions and joint investments in assets whose alternative uses, or uses altogether, are often opaque. In fact, R&D expenditures are usually considered sunk costs (Stiglitz, 1987), which in turn are specific assets, and hence TCE would generally underscore the benefits of internalizing such activities. Thus, the transactions and relationships promulgated by TCE, while supporting efficiency, control, and risk reduction, may be less conducive to asset augmentation than to exploitation.

In TCE, resource commitment emerges mainly as a liability since asset specificity, assuming bounded rationality and opportunism, brings about unforeseeable risks and costs. TCE focuses on the costs of transacting at the expense of the benefits, e.g., learning and innovation. Pertaining to firms' R&D internationalization, failures in markets for knowledge have a prominent place in explaining firms' boundary choices in units abroad (Buckley and Carter, 1999; Kogut and Zander, 1993; Teece, 1998). In other words, in a TCE perspective, knowledge-related activities abroad primarily emerge as costly and risky, both of which incentivize firms to internalize.

Presupposing value-enhancing outcomes of activities, TCE is concerned with how governance forms such as hierarchies, contracts or hybrids can be devised unilaterally in ways that reduce costs and risks for given transactions. Resources and their augmentation, especially jointly, are not a main concern and more weight is attached to the commitment dimension of resource commitment, mainly as a liability.

2.4 Institutional theory

Unlike RBV and TCE, institutional theory (IT) is not a single theoretical approach but comprises an eclectic set of perspectives that emphasize the importance of institutions in economic activities (DiMaggio and Powell, 1983; Meyer and Rowan, 1977; North, 1990; Scott, 1995). In International Business (IB), IT typically focuses mainly on institutions in a firm's environment and economic activities are perceived as a nexus of relationships. In a broader conception, IT includes firm-internal institutions, in which case IT becomes a superset encompassing (most of) RBV and (all of) TCE, even though TCE operates with institutions primarily as explanandum and IT as explanans. The breadth of the concept of institutions contributes to both the appeal and the intractability of IT approaches. In institutional theory, social life is mediated by institutions, which are emergent and irreducible to any underlying plane. North (1990) considers institutions 'humanly devised constraints that shape human interaction' but in terms of definition, it is perhaps easier to consider the inverse, what institutions are not: institutions are not phenomena, which are non-anthropocentric (e.g., a material good), non-relational (e.g., a person's capabilities), or non-regularized (e.g., random or one-off).

Hence, an institutional perspective on resource commitment tends to focus on a firm's external relationships, and the often intangible but also tangible assets invested in them. The intent to institutionalize external relationships supporting the acquisition, exploitation or development of assets is often an important goal of international R&D, particularly of augmentative R&D, perhaps even the most pervasive one. The literature identifies institutions as an important enabler of successful performance outcomes in international R&D (Doh *et al.*, 2005; Inkpen and Tsang, 2005; Li and Xie, 2016). Successful collaboration or co-specialization with local agents, particularly in R&D activities that often do not lend themselves well to formalization or contracting, is promoted developing relatively stable and durable relationships.

While both formal and informal institutions are crucial to all business activities, informal institutions assume relatively greater importance when formal institutions do not apply well (Gollnhofer and Turkina, 2015). This is the case in R&D, for example, particularly in explorative and more basic R&D, where activities cannot easily be formalized and are more prone to institutional voids and market failures (not least information and coordination failures, and appropriability issues). Achieving successful outcomes in international R&D is hence promoted by investment in local embeddedness, legitimacy, and norm and trust formation (Zaheer and Venkatraman, 1995), which are inherently long-term and durable, and accumulate into social capital (Putnam, 1993). Legitimacy derives partly from adaption to the local environment through isomorphic pressures (Meyer and Rowan, 1977; Zaheer, 1995), which can in turn produce tensions between internal and external embeddedness (Andersson and Forsgren, 1996; Zanfei, 2000).

While a few assets relevant for international R&D can be acquired in spot transactions, the significant assets firms aspire to obtain and develop through R&D internationalization are usually institutions themselves, or are preconditioned by institutions and institution-building as indispensable enablers. With learning and trust-building, successful institutionalization promotes effectiveness and efficiency and can substitute for formal contracting (Poppo and Zenger, 2002; Ring and van de Ven, 1992), even at greater efficiency (Dyer and Singh, 1998; Gulati, 1998). On the other hand, institutionalization processes are complex, uncertain and potentially costly, and can also lead to overembeddedness and ensuing rigidities and inflexibilities (Granovetter, 1985; Uzzi, 1997). With its focus on regularization of interactions across firm boundaries without presumptions of specific (resource-related) rationales, IT is more focused on the (bi- or multilateral) commitment dimension of resource commitment, as antecedent as well as outcome.

The above sections show that each theoretical perspective accentuates a different dimension of resource commitment. As both an imperative and an outcome of successful R&D internationalization, RBV accentuates resources that are the rationale for internationalization; IT the relationships involved in creating, deploying and maintaining them; and TCE ways of organizing the firm and its relationships efficiently. Having established theoretically distinct dimensions in the relationship between resource commitment and access to co-location advantages, we proceed to empirically investigate the impact of resource commitment on this access. The next section explains the data collection method and subsequent approach to the analysis, after which the findings are presented.

Table 3: Theoretical perspectives on co-location resource commitment

	RBV	TCE	Institutional theory
Explanans	Firm-internal resources and routines; heterogeneity; exploitation and augmentation of firm resources; firm growth	Transaction costs; economic efficiency; market imperfections; incentive alignment	Extra-firm institutions (cognitive, normative, regulative; formal vs informal/distant vs proximate); institutional failure/voids; embeddedness
Explanandum	Spatial resource distribution; operation modes	Firm governance forms; corporate governance; market vs. hierarchy; operation modes	Legitimacy; isomorphism; firm behaviour
Ontology			
Firm	Resource and revenue growth; profit maximization	Efficiency	Co-evolution
Agency	Bounded rationality; asymmetric information	Bounded rationality; uncertainty; asymmetric information; moral hazard, opportunism	Collective rationality; bounded rationality; imperfect information
Theories	OLI paradigm; resource-based view/knowledge-based view; ownership advantages; resource dependence theory	Transaction cost economics; internalization theory; agency theory; capital market theory	New institutionalism; institutional economics; innovation system; cluster theory; economic history
Resource commitment			
Ontology	Resource augmentation Complementarity/synergy	Liability	Relational asset
Imperatives	Resource bundling	(Discrete agent) exchanges; incentive alignment	Socialization; co-evolution
Assets	Resource augmentation and acquisition	-	Trust; differentiation; efficiency
Liabilities	Commitment costs; resource dependency; path dependency	Costs and risks of opportunism and asset specificity	Over embeddedness; lock-in; determinism
Example studies	(Bercovitz *et al.*, 1996; Hutzschenreuter *et al.*, 2007; Kuemmerle, 1997; Mellahi *et al.*, 2016; Wagner and Bukó, 2005)	(Brown *et al.*, 2000; Grover and Malhotra, 2003; Heide and Stump, 1995; Klein *et al.*, 1978; Lui *et al.*, 2009; Parkhe, 1993; Rokkan *et al.*, 2003; Wang, 2002)	(Bureth *et al.*, 1997; Heide and John, 1990; Kang *et al.*, 2009; Larson, 1992; Lin *et al.*, 2012; Lui *et al.*, 2009; Parkhe, 1993; Perri, 2015; Perri and Andersson, 2014; Uzzi, 1997; Yoshino and Rangan, 1995; Young-Ybarra and Wiersema, 1999)

3. Data and methods

A qualitative, embedded, multiple-case study research design (Eisenhardt, 1989; Eisenhardt and Graebner, 2007; Piekkari *et al.*, 2009; Yin, 2013) has been adopted. This design is well suited for this exploratory study, which seeks to understand the relationship between resource commitment and access to co-location advantages. Reflecting IB disciplinary convention (Piekkari *et al.*, 2009), the case study design tends towards a more post-positivist positioning (Guba and Lincoln, 2005). This paper follows a ‘deductive bottom-up theorising' approach (Shepherd and Sutcliffe, 2011), which favours a sound a priori conceptualization of the main constructs (Gioia and Pitre, 1990; Ridder *et al.*, 2014; Yin, 2013). This integration of the literature contributes to the study's internal validity by supporting the thematic coding of the data and its external validity, through analytical generalization (Yin, 2013).

A literal replication logic (Yin, 2013) was used to select two companies for intensive study. Both are large MNEs that produce high-tech equipment, both are business-to-business companies, and both are headquartered in small, developed-market countries (Sweden and Denmark). These characteristics are linked to strong R&D internationalization (Gammeltoft, 2006; Gerybadze and Reger, 1999), which increased the likelihood of identifying at least one R&D unit for each resource commitment configuration. Despite following a literal replication logic, the case companies do differ in their locations, products, and knowledge base, as is typical for case research.

R&D units (embedded units of analysis) were selected within each company following a theoretical replication logic (Yin, 2013) based on differences in both resource levels (high/low) and commitment levels (high/low) (see Table 4). What constitutes a high or low resource level is based on the tangible and intangible resources (financial, physical, and human resources) that are allocated to an R&D unit, accounting for the relative size of the allocation to the size of a firm's global R&D network. After all, an R&D unit of 15 people may be a relatively large investment for some MNEs, while this is a minor investment for firms with multiple large R&D centres around the world. The level of commitment is based on the irreversibility of deployed resources (resulting in sunk costs) (Ghemawat and Del Sol, 1998; Williamson, 1985). Commitment levels are often measured by asking interviewees directly about the extent to which investments lose value if they are re-deployed (Pedersen and Petersen, 1998; Randøy and Dibrell, 2002; Tan *et al.*, 2007). Other common methods are determining the number of years a company is active in a location (Petersen and Pedersen, 1999) or determining the annual change in R&D expenditure (Neelankavil and Alaganar, 2003). See Table 5 for a more detailed overview of commitment measures.

The selection and first assessment of the resource and commitment levels of R&D units was based on exploratory interviews with R&D managers at the headquarters of both companies and an analysis of publicly available information about the R&D activities of the companies. Only explorative R&D units were selected, as the potential of co-location advantages is more important to such units than to exploitative R&D units. Exploitative R&D activities are often subordinate to the MNE's market-seeking activities (although some exploitative activities are efficiency-seeking). They follow the location of other MNE activities, such as production and sales (Narula and Santangelo, 2012). It is important to note, however, that the distinction between exploitation and exploration is often a matter of degree and should therefore be viewed as a continuum: R&D units rarely employ only one or the other (Criscuolo *et al.*, 2005; Gammeltoft, 2006).

Table 4: Units of analysis and interviewees

	Location	Country	Resource	Commitment	Interviewee
Company 1	*HQ 1*	Denmark	-	-	Research Management Specialist
	Location 1.1	Germany	Low	High	Manager
	Location 1.2	USA	High	Low	Technology Director
	Location 1.3	Denmark	Low	Low	Director
	Location 1.4	India	High	High	Director
	Location 1.5	Portugal	High	High	Head of Engineering
Company 2	*HQ 2*	Sweden	-	-	Corporate Director Research
	Location 2.1	Italy	Low	High	Research & Innovation Manager
	Location 2.2	Canada	High	Low	Manager of Operations
	Location 2.3	Japan	Low	Low	General Manager Research Japan
	Location 2.4	USA	High	High	Head of Research
	Location 2.5	Hungary	High	High	Head of Technology and Innovation
	Location 2.6	India	High	High	Head R&D operations

Note: to ensure anonymity of the interviewees, sources are not provided.

Data were collected through semi-structured interviews, ensuring that key topics were covered while allowing themes to emerge, in conversation, in a relatively broad and flexible way (Fylan, 2005). This cross-sectional interview-based data collection reflects IB disciplinary convention in case study research (Piekkari *et al.*, 2009). A total of fifteen interviews were conducted, with R&D managers from the headquarters and each R&D unit (see Table 4). Headquarters officials were interviewed both at the beginning of the study, to help in the selection of the R&D units, and also at the end, to achieve stronger construct validity through data triangulation. The use of such archival data as company annual reports and corporate news releases served a similar purpose. In addition, the use of this secondary data helped to fill in some blanks as some interviewees were not able to supply more technical data.

The interviewees were purposively sampled using a snowballing strategy (Biernacki and Waldorf, 1981). This allowed for the identification and access to even the smallest R&D units. To compensate for potential biases with snowball sampling, the interviewees were matched by type across the cases, reflecting a theoretical sampling logic for interviewee types (Morse, 1995). Interview questions were designed to uncover the resource commitment position of the specific unit and the unit's access to co-location advantages.

Measurements for resource levels, commitment levels, knowledge sharing, and goods sharing (the latter two being co-location advantages) were partly adopted from existing measures. Table 5 lists all the identified measurements. Some identified measurements were adapted for use in the semi-structured interviews, while others were discarded as their direct measurements were impossible (e.g., managerial experience and transferred property rights) or because they were deemed less relevant (e.g., professional expatriates intensity). Table 6 shows the measurements adopted for this study. A few example interview questions are provided. The full interview question protocol is available upon request. All interviews were recorded (with permission), transcribed and subsequently thematically analysed using NVivo (Payne and Payne, 2004; Ryan *et al.*, 2003; Saldana, 2012). Due to the large geographical distribution, most interviews were conducted using video-conferencing software. Initial interviews in Denmark and Sweden were conducted face-to-face. However, due to the coronavirus outbreak, follow-up interviews were conducted online as well.

Leveraging the strengths of a deductive bottom-up case study design (Shepherd and Sutcliffe, 2011), initial thematic codes for the analysis were derived from theories on resource commitment and co-location advantages, while others emerged from the data (Bourque, 2004). Each of the two individual cases was first analysed separately, after which a cross-case analysis was performed with a view to analytical generalization (Eisenhardt, 1989; Eisenhardt and Graebner, 2007), thereby increasing external validity (Yin, 2013).

Table 5: Existing measurements

Variable	Measurement	Used by	Operationalisation
Resource level	# of employees in a location (as proportion of total employment)	Pedersen and Petersen (1998) Petersen and Pedersen (1999)	Survey question
	Economic involvement	Randøy and Dibrell (2002)	The firm's economic involvement in a given country (1–5 scale)
	R&D intensity	Hung and Chou (2013), Luo (2004)	R&D expenditure/sales
	Resources invested in specific activities	Wagner and Bukó (2005)	Resources spent on: search for partners, confidence building, coordination, relationships, monitoring, adaptation (1–5 scale)
		Kleinschmidt et al. (2007)	On average, sufficient resources are committed so that [different activities] can be undertaken (1–5 scale)
	Managerial experience	Özsomer and Gençtürk (2003)	International and local experience of interviewed managers
	Transferred property rights intensity	Luo (2004)	The value of property rights transferred from the MNE to the subsidiary during the past three years divided by start-up investment
Commitment level	# of years active in location	Petersen and Pedersen (1999)	Which year did the first contact with the market take place?
	Irreversibility	Pedersen and Petersen (1998)	To what extent has the firm dedicated assets in a given country that cannot be re-deployed without the loss of value (1–5 scale)
		Randøy and Dibrell (2002) Tan et al. (2007)	To what extent can investments not be transferred to other markets? (1–5 scale)
	Investment intensity in a location	Luo (2004)	New investment in the subsidiary during the past three years/start-up investment
	Annual change in R&D expenditure	Neelankavil and Alaganar (2003)	Annual increase/decrease (%) of money spend on R&D in different locations
	Relationship-specific investments	Maitland and Sammartino (2009)	Frequency of the sample firm investing in equipment specific to its local long- term suppliers (4 point scale) and human capital investments specific to its suppliers (4 point scale)
	Professional expatriates intensity	Luo (2004)	Total salaries of expatriates divided by a subsidiary's total salary
Sharing of knowledge	Perceived knowledge sharing performance	Lefebvre et al. (2016)	How well performed the 'network' with regard to the extent of knowledge sharing between network members (1–7 scale)
	Degree of knowledge sharing	Wagner and Bukó (2005)	Degree of knowledge sharing with suppliers, customers, and research institutions. Separately measured (1–5 scale)
Sharing of goods	Resource sharing	Bouty (2000)	Past experiences of resource exchanges (incl. equipment and facilities) with external partners (interview)
	Special equipment	Melin (2000)	What was the major reason for the collaboration? (incl. special data/equipment) (survey)

Table 6: Adopted measures

Variable	Measurement	Adapted from	Example interview question
Resource level	# of employees in a location (as proportion of total employment)	Pedersen and Petersen (1998) Petersen and Pedersen (1999)	How many people work in R&D here? How many people work in R&D in the entire firm?
	R&D intensity	Hung and Chou (2013), Luo (2004)	How much of the total R&D expenditure of the firm is allocated to this R&D unit?
	Resources invested in specific activities	Wagner and Bukó (2005)	How much of the total expenditure of this location are salary costs? What kind of equipment does this unit operate? Does the R&D unit have the resources to build and maintain relations with local actors?
Commitment level	# of years active in location	Petersen and Pedersen (1999)	When was this unit set-up?
	Irreversibility	Pedersen and Petersen (1998) Randøy and Dibrell (2002) Tan et al. (2007)	How difficult would it be to relocate or sell the equipment that is currently used in this R&D unit?
	Investment intensity in a location	Luo (2004)	Could you tell about the investments made in this locations and any planned investments?
	Annual change in R&D expenditure	Neelankavil and Alaganar (2003)	Is there a fluctuation in R&D expenditure in this location over the last five years?
	Relationship-specific investments	Maitland and Sammartino (2009)	How much has the firm/R&D unit invested in local relations?
Sharing of knowledge	Knowledge sharing	Lefebvre et al. (2016) Wagner and Bukó (2005)	With which local actors does this unit maintain relations? How would you characterize the knowledge sharing with these actors?
Sharing of goods	Resource sharing	Bouty (2000) Melin (2000)	Does this R&D unit make use of resources (laboratories, equipment, and data) of local actors? Does this R&D unit share resources with local actors?

Note: *As the access to knowledge is difficult to observe from an external perspective, inferences regarding knowledge spillovers must be made indirectly by examining less detailed patterns of close spatial interactions. The perceived access of insiders is considered a fair way of measuring* (Yu *et al.*, 2010).

4. Resource commitment and co-location advantages in selected R&D units

In this section, the findings from the four resource commitment positions across the two case companies are presented. This is followed by a cross-case analysis (Eisenhardt, 1989; Yin, 2013) in which the implications of the comparison are discussed in light of the existing literature on co-location advantages and resource commitment. This section starts by establishing the resource commitment positions of each R&D unit.

4.1 Establishing resource commitment positions and governance structures

The R&D units were selected on the basis of an initial assessment of their resource commitment positions. Using the gathered data on the different resource and commitment measurements, the resource commitment positions of the R&D units have been formally established (see Table 7). The units are grouped on the basis of their established resource commitment positions. Each of the four groups are analysed separately in the following sections.

In addition to differences in resource commitment to the selected R&D units, the governance of local relationships also varies. These governance structures are important to consider, since the way resources are committed is a key dimension of resource commitment. Table 8 provides an overview of the types of governance structures, as well as the type of R&D performed and the main goal of the firm at each location. The overview shows a large variety in the governance of resource commitments of the selected R&D units. On a scale of 'strictness', at one end of the spectrum are arrangements that involve strict contracts concerning the use of equipment, invested resources, and intellectual property rights (IPR). A good example is the contract that unit 2.1 has with the local university: "our research contract with [the university] stipulates some specific activity they do for us and anything that is generated within this agreement is owned by [Company 2], in terms of patents". Company 1 works with similar research contracts, as is mentioned by the manager from unit 1.1: "we cover any risks by agreeing on intellectual property rights with our partners".

Towards the other end of the scale, we find fellowships and funding of local university staff members. Collaborative research agreements fall somewhere in the middle of the scale, depending on the specific agreements regarding mutual benefits and funding.

Table 7: resource commitment per R&D locations

	Location	Resource	Illustrative quote	Commitment	Illustrative quote
Company 1	*Unit 1.1 (Germany)*	Low	- "It's small. We are 13 people in total" - "We have no hardware in the office".	High	- "It now exists for 12 years… It is definitively bigger than in the beginning". - "We invested a lot in those relationships, … and they also did. We need each other in the long-term". - "I see a strong commitment to the region, … therefore I would say it is hard to transfer this department".
	Unit 1.2 (USA)	High	- "We invested a lot in it and one of the [equipment] belonged to us".	Low	- "The activities have not been overwhelmingly large for a period". - "It is still running today, but we don't have any activities at that site anymore".
	Unit 1.3 (Denmark)	Low	- "We started with 5 people, and at its peak we had about 8 to 10 people" - "It is mostly an office site".	Low	- "There was no management for about 6 months, … It was like a kind of administrative peddling around in a vacuum, … The budgetary things also went from growing to no direction".
	Unit 1.4 (India)	High	- "This office oversees the work of around 700 people, … Maybe 30 per cent are consultants".	High	- "This R&D office opened in 2007". - "We have gained dedicated ownership of areas that only take place here".
	Unit 1.5 (Portugal)	High	- "It's 335 people, of which 330 are engineers and researchers". - "We have a test wall, … and a cyber security lab".	High	- "… grown from 0 to 335 in less than 3 years". - "These are not things you can sell again. There is no market".
Company 2	*Unit 2.1 (Italy)*	Low	- "A small centre with 20 people".	High	- "..launched in 2007, ... We multiplied by a factor of four". - "I do not exclude another period of growth, because we are investing in other areas as well".
	Unit 2.2 (Canada)	High	- "I have about 50 people here" - "[company name] invested close to 1.3 billion USD in this brand-new centre"	Low	- "We opened barely one year ago, but we will be closed again at the end of the year". "We will try to find a buyer for the equipment". - "The lifespan of the equipment is 3 to 5 years, ... so it is very easy to take away too".
	Unit 2.3 (Japan)	Low	- "At the peak, there were about 12 people. … Salary cost is the major part of the expenditures". - "We do not have any large assets"	Low	- "The unit was set up in 1998–1999". - "We abandoned measurement equipment when we downsized". - "My colleagues could be relocated within Japan".
	UNit 2.4 (USA)	High	- "There are roughly 200–230 people" - "We have testbeds and do trials. But it is not much"	High	- "Research activities were established here in 2008–2009" - "We used to be a lot bigger. Four years ago there were 1500–1600 people here. Now only 230". - "A super-important part of what we are doing here is our work with local partners, customers, and universities, and so forth".
	Unit 2.5 (Hungary)	High	- "[We number] about 1700".	High	- "R&D was founded in 1992". - "We just moved into a brand new building made for us".
	Unit 2.6 (India)	High	- "Now we are about 400". - "The majority of the expenditure would be salaries, and some IT infrastructure".	High	- "Migrating to a different place, going out of [city name], cannot be thought of". - "We are looking to build again". - "We started in 2010, ... we have been here for more than 10 years already".

Like the stricter research contract, these collaborative agreements have clauses on topics like IPR and investments. However, in the case of unit 1.2, the interviewee indicated that the MNE "does not have a deciding say" in the collaboration. Yet another governance structure that may be placed towards the middle of the scale is the use of engineering consultancy companies. The director of unit 1.4 stated: "we use consultants to quickly ramp up and scale down. Between 20 and 40 per cent of our department consists of external consultants".

Table 8: Types of governance, research, and goals per location

	Unit	Country	R*	C*	Governance	Type of research	Goal
Company 1	*1.1*	Germany	Low	High	Contracts and legal agreements	Technology development	Developing/improving critical parts
	1.2	USA	High	Low	Collaborative research agreement	Exploratory research projects	Incubator for new ideas
	1.3	Denmark	Low	Low	Ad hoc fellowships and project-based contracts	Exploratory research projects	(Re-)engaging with local university and attracting talent
	1.4	India	High	High	Engineering consultancy companies	Engineering solutions and feasibility/concept studies	Gaining competencies at the right cost level
	1.5	Portugal	High	High	-	Engineering solutions and feasibility/concept studies	Gaining competencies at the right cost level
Company 2	*2.1*	Italy	Low	High	Research contract	Basic research	
	2.2	Canada	High	Low	-	Testing	Cost-saving by combining testing equipment in one site
	2.3	Japan	Low	Low	Funding	Exploratory research projects	Developing and strengthening R&D relationships with customers
	2.4	USA	High	High	Contract for shared-use research facility	Technology outpost: working with customers and partners	Bringing learnings from interaction with (potential) customers to the development organization
	2.5	Hungary	High	High	Contracts and legal agreements	Product/technolog y development	New business opportunities by developing technology domains
	2.6	India	High	High	Fellowships and project-based contracts	Product/technolog y development	New business opportunities by developing technology domains

* *R = Resource, C = Commitment*

There does not seem to be any clear relationship between the governance structures of local external R&D relationships, the resource commitment to R&D units, and the main type of research activity performed. Furthermore, the adopted governance structures are similar for both case companies. However, the data seem to indicate that most low-commitment units are focused on exploratory research projects. Furthermore, the R&D activities in emerging economy locations are less related to research in a strict sense and more to design, development and/or engineering, which is in line with existing research (Cantwell and Piscitello, 2000; Gammeltoft, 2006). This is probably one of the reasons why we see engineering consultancies used only for low-risk activities in emerging economies.

4.3 Low resource/high commitment R&D units

Managers of the low resource/high commitment R&D unit (units 1.1 (Germany) and 2.1 (Italy)) provided insights suggesting that commitment levels in particular are important for accessing co-location advantages (see Table 9). Despite low resource levels, both units actively explore and exploit the knowledge and resources of local partners. In both locations, these partners include several universities (local and regional), and knowledge institutes. In the case of unit 1.1, these partners also include six important suppliers. Both units share and absorb knowledge while working with their partners on new products and/or while conducting basic research.

Interviewees expressed their belief that their commitment to their partners and their parents' commitment to the location in general was important, as it smoothed access to local resources and thus enabled them to do more with less. They regard the people and equipment of their partners as extensions of themselves. Both units work with equipment from their local partners which is important for their work. This is especially the case for unit 1.1, as most of the work conducted at this location involves the co-development of products that Company 1 buys from suppliers in this location. Company 1 and its local suppliers thus have a shared interest. Relatedly, employees of unit 1.1 spend a relatively large amount of their time visiting these suppliers to discuss and work on new product development. Clearly, these local relationships are a key reason for Company 1 to have a unit in Germany. This is also apparent from the interview with the manager of unit 1.1, who spoke about the importance of the local relationships and the need to maintain these relationships for the long-term: "We invested a lot in those relationships, in time and money. And they did, too. We need each other in the long-term."

While unit 2.1 also depends on the equipment of its local partners, its local relationships differ from those of unit 1.1. Unit 2.1 does not work with suppliers, but with several higher education and research institutes. More than unit 1.1, unit 2.1 is focused on basic research. The Research & Innovation Manager at unit 2.1 projected a resource-based view as he explained that the high competence level of his team, in combination with the strong research ecosystem in the region, enables the R&D unit to innovate successfully. This, despite the lack of a critical mass of employees. The same manager also stressed the importance of local networks (an IT perspective), saying, "we have strong local networks … we basically merge our network with the university's network of relationships. This is key."

Table 9: Analytical table – Low resource/high commitment locations

Factor	Main findings	Illustrative quotes
Knowledge sharing	- Low resource levels do not seem to negatively affect knowledge sharing - Relation-specific investments (increasing commitment) are important to access knowledge	- "Our local suppliers act like development partners, we co-develop [product] together with them" (Manager, unit 1.1). - "We have very strong collaboration with them [universities], not just for hiring" (Manager, unit 1.1). - "We meet and work with professors and researchers on a daily basis" (Research & Innovation Manager, unit 2.1). - "They [the universities] have their network, we have our network, and we basically merge the two" (Research & Innovation Manager, unit 2.1).
Resource sharing	- Despite low resource levels, the locations are able to use equipment of partners. - Established relationships are important in order to access external resources.	- "The hardware we work with all belongs to our local partners" (Manager, unit 1.1). - "Even though we do not have a critical mass of [company name] employees here, we have kind of a joint lab with the university, ... we can use their lab" (Research & Innovation Manager, unit 2.1). - "Especially in [discipline], labs are quite expensive, ... exploiting their lab is a huge advantage" (Research & Innovation Manager, unit 2.1). - "Good relationships can facilitate the funding of research activity" (Research & Innovation Manager, unit 2.1).

4.3 High resource/low commitment R&D locations

Managers of the high resource/low commitment R&D units (units 1.2 (USA) and 2.2 (Canada)) provided evidence suggesting that large amounts of resources do not necessarily result in meaningful local interaction (see Table 10), which again is consistent with literature (Lorenzen, 2007; Maskell and Lorenzen, 2004; McCann and Mudambi, 2005). The evidence suggests that a lack of commitment, however, does inhibit access to local knowledge/resources.

While units 1.2 and 2.2 occupy similar resource commitment positions, their background and main goals differ. Through unit 1.2, Company 1 has invested resources (expensive equipment and knowledge) to a research program run by a government agency. If necessary, the company could sell or relocate their equipment relatively easily, hence the low commitment level. The company is hoping to profit from whatever new insights come out of the research program. In the past, the company successfully implemented an improved design of its product based on the research conducted at this location. However, the interviewee, who is in charge of the collaboration, acknowledged that progress is slow, in part because the company does not have any employees on the site. They used to have engineers relatively nearby, but these engineers had been let go a couple of years ago (signalling low commitment).

Table 10: Analytical table – High resource/low commitment locations

Factor	Main findings	Illustrative quotes
Knowledge sharing	- High resource levels do not necessarily lead to knowledge sharing - The level of knowledge sharing used to be higher in location 1.2, when the company had some engineers stationed nearby (signalling more commitment). - Low commitment is a barrier to knowledge sharing.	- "We do not have a deciding factor in it. It is their site and we just leverage the partnership" (Technology Director, unit 1.2). - "The whole idea of building this shared research facility was for it to act as an incubator for ideas, ... some of the work that has been done in [unit 1.2] was leveraged back into our system" (Technology Director, unit 1.2). - "Things are going slower than it was supposed to go, ... it is obviously difficult since we do not have people there" (Technology Director, unit 1.2). - "The centre's main goal is to provide added-value to our own engineers all over the world", (Manager of Operations, unit 2.2).
Resource sharing	- Unit 2.2 does not share resources locally. This is explained partly by the specialized nature of their activities and partly by their low commitment level. - Unit 1.2 is able to use resources from their partner because they also allocated (relatively uncommitted) resources themselves.	- "The cost-sharing with U.S. entities is another aspect, ... the idea you can cost-share your research, ... It's a shared effort" (Technology Director, unit 1.2). - "We bought one of the [equipment] and they bought the other two" (Technology Director, unit 1.2). - "The centre's main goal is to provide added-value to our own engineers all over the world, ... we are self-sufficient" (Manager of Operations, unit 2.2). - "Our customers are able to connect remotely to our [equipment], ... we do not have any local partners using our [equipment]" (Manager of Operations, unit 2.2). - "We internally discussed some options to open up our centre to partners or others, but we did not have enough time" (Manager of Operations, unit 2.2).

Unit 2.2, on the other hand, houses expensive equipment (including test walls and a large data centre) that is mostly used by the engineers and customers of Company 2. As such, this unit is less focused on sourcing/sharing knowledge or resources locally. Despite having invested USD1.3 billion into setting up unit 2.2, Company 2 announced its closure barely one year after it opened. At the time of data collection, the unit was set to close in eight months. This is a strong signal of low commitment. The company cited rapid technology development as the reason for the closure, as the company believes new technology will enable it to consolidate test activities to two other centres. The company expects the closure to save the equivalent of USD46 million a year. The short lifespan of the unit has made gaining access to co-location advantages basically impossible. After all, such access requires relationships with proximate actors and building these relationships takes time, which unit 2.2 has not had. Perhaps as a result, the interviewee at unit 2.2 mostly focussed on the resources invested in the unit over its short life, taking an RBV perspective on resource commitment.

4.4 Low resource/low commitment R&D locations

Interviewees at unit 1.3 (Denmark) and unit 2.3 (Japan) provided evidence suggesting that low resource/low commitment R&D units struggle to access co-location advantages, even over longer time periods (see Table 11).

Both units scaled down over the last few years, decreasing their already low resource levels while also signalling lower commitment. Both units have collaborations with local universities and the Japanese units also has R&D collaborations with (potential) customers. Due to its lowered resource level, the Japanese unit (2.3) has been forced to prioritize some external relationships over others. According to the interviewee, the unit is increasingly focussing on its (potential) commercial partners. With this change, the unit is moving from more explorative R&D to more exploitative R&D. For example, the interviewee frequently has meetings with customers to discuss how to incorporate new technologies into existing systems. Knowledge spillovers from the university are limited and are mostly through direct contact with the headquarters, not through the unit. The Danish unit (1.3) does not need to prioritize relationships as it works predominantly with just one partner (the local university). Nevertheless, the interviewee from unit 1.3 also indicated lower levels of local knowledge sharing after their resource level was lowered. The collaboration with the university initially revolved around one major project and the unit's decrease in resources coincided with the end of this project. Afterwards, no new substantial collaborative projects were started, due to a lack of resources from Company 1. The location choice was, in part, based on "long historical cooperation with the research site and the university." In fact, according to the Research Management Specialist at Company 1 headquarters, "the whole idea of establishing the unit was to get more collaboration and more cooperation with [local university]." When the collaborations stopped, Company 1 only retained a small office, which was used "as a kind of meeting room for our people visiting the site, needing to collect and analyse data, or analyse problems with the [equipment] and go back and fix it."

Table 11: Analytical table – Low resource/low commitment locations

Factor	Main findings	Illustrative quotes
Knowledge sharing	- Low resource levels require prioritization of external projects/partners. - Units 1.3 and 2.3 gain knowledge from their local collaborations. This is limited to theoretical discussions and has decreased since resources were decreased. - Low commitment levels partly explain the decrease in partner commitment and knowledge transfer.	- "I would open the window and yell over to the [university] researcher in the building next to me" (Director, unit 1.3). - "The intention was to be close to the university, ... but it only worked for a short time" (Research Management Specialist, HQ 1). - "We locally discussed with customers and potential customers to try and find new joint projects or research collaborations, ... They [local partners] could give their views and outside-in requirements" (General Manager, unit 2.3). - "We have a lot of collaboration going on with [unit], but that was not because or with the local office" (Director, unit 1.3). - "We have some problems with less resources and insufficient headcount, ... we had to prioritize" (General Manager, unit 2.3). - "What we do is particularly theoretical discussions" (General Manager, unit 2.3).
Resource sharing	- Units 1.3 and 2.3 do not have access to substantial external resources. - This is explained partly by the nature of their activities, and partly by the low resource commitment level.	- "We do not and did not use any assets from the university or potential customers" (General Manager, unit 2.3). - "We are not able to do any kind of trials or tests locally" (General Manager, unit 2.3). - "We occasionally use some sensors from the university, although we now do most of it ourselves, ... and we use their land of course, for our [equipment]" (Director, unit 1.3).

Access to external equipment is limited for both units. This is partly explained by these units' main activities (predominantly working with software and data), but can also be linked to their low resource commitment positions. Both units have insufficient resources to get involved in projects that involve the shared use of equipment. The Japanese unit's local access is limited to theoretical discussions with external partners, while all testing is done at the headquarters. The Danish unit has just enough people to work on their own projects and to have similar theoretical discussions with the local university. Their projects are explorative in nature.

The decrease in knowledge sharing and the limited use of external resources seems to be caused partly by low resource levels. However, the reported decrease in knowledge sharing is greater than would be expected from a resource-based view, since the overall decrease in resource level has been relatively limited. The impact of the R&D units' decrease in commitment may explain this difference. Interviewees report that, increasingly, local external parties are directly contacting the headquarters of their respective companies. This indicates that commitment from external partners to the local R&D unit has decreased, while they are still committed to the corporation. This is in line with findings from Bureth et al. (1997), showing that low commitment makes it difficult to secure partner commitment.

4.5 High resource/high commitment R&D locations

Insights provided by managers of the high resource/high commitment R&D units (units 1.4 (India), 1.5 (Portugal), 2.4 (USA), 2.5 (Hungary) and 2.6 (India)) suggest their high resource commitment position has a positive impact on their ability to access co-location advantages (see Table 12). Most selected high resource/high commitment units have multiple partners (universities, customers and suppliers) and/or many collaborations with just one or two partners. Insights from the interviews suggest that their R&D units were able to set up and maintain so many relations/projects because they have the resources to contribute to these partnerships. This is consistent with theories on the importance of reciprocity for access to co-location advantages (Perri, 2015; Perri and Andersson, 2014).

Generally, the high resource/high commitment units are long-time locals and that continue to invest in local partnerships (such investments are highly usage-specific), signalling commitment to the location and partners. Several managers mentioned that investing in relationships takes time and is not always straightforward. For example, the director of unit 1.4 (India) stated that building relationships "was not without problems because we have a lot of cultural clashes and a lot of biases and opinions from Denmark. It has been a longer journey; it has taken years". The unit in Hungary (2.5) employs fifteen people to support collaborations with local universities and knowledge institutes.

Naturally also, high resource/high commitment units differ in the degree to which they can access co-location advantages. Two units (1.4 and 1.5) seem to have limited access to external actors' knowledge and resources. However, this has little to do with adopted resource commitment positions. For example, unit 1.5 (in India) performs a relatively high number of more exploitative R&D activities next to its explorative R&D activities. Co-location advantages are therefore less relevant to this location. Unit 1.5 (in Portugal) was only recently set up and therefore has not yet had the opportunity to develop deep relations with local partners. After all, building meaningful relationships is a time-consuming process (Maskell, 2002).

Table 12: Analytical table – High resource/high commitment locations

Factor	Main findings	Illustrative quotes
Knowledge sharing	- High/high locations are able to set up and maintain many different partnerships/projects in part because of their high resource levels and long-term commitment.	- "We have access to the research knowledge of the universities and we have colleagues cooperating with them, ... There is sharing from both sides" (Head of Technology and Innovation, unit 2.5). - "They [local partners] learn from us and we are learning from them" (Head of Research, unit 2.4). - "We have access to these [local] universities, ... we interact, we have discussions and collaboration going on, ... We are sharing some things as well as gaining some knowledge from them" (Head R&D operations, unit 2.6).
Resource sharing	- High/high locations source from and share resources with local partners.	- "We have some collaboration projects which involve hardware, where we are sharing laboratory equipment" (Head of technology and Innovation, unit 2.5). - "We regularly visit the university campus to make use of what they have there" (Head of R&D operations, unit 2.6). - "We have a shared research facility with [name partner]" (Head of Research, unit 2.4).

5. Discussion

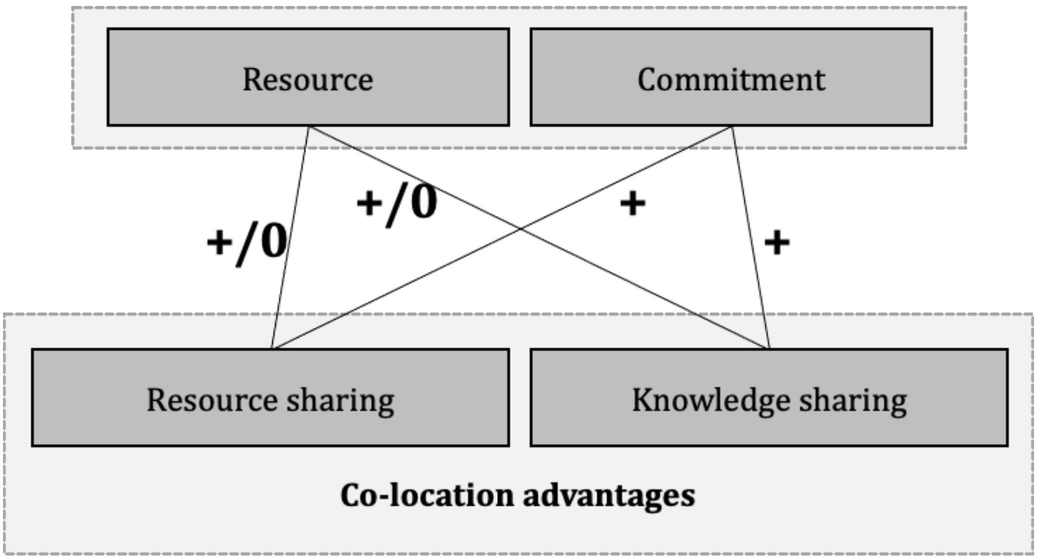
We discussed how three theoretical approaches, the resource-based view, transaction cost economics and institutional theory, accentuate particular aspects of the relationship between resource commitment and co-location advantages. Succinctly put, RBV brings focus to resources applied, developed, and acquired in the venture TCE accentuates the governance arrangements applied to committing the resources, and IT places emphasis on the relationships involved in the commitment. Our empirical analysis sheds light on the validity and, in a managerial context, the utility of the three theoretical perspectives when applied to the relationship between resource commitment and co-location advantage. The empirical findings indicate that the resource level of an R&D unit is less relevant than its commitment level to access co-location advantages. Some units with low resource levels have successfully accessed local knowledge and other resources, yet some units with high resource levels experienced difficulties doing the same. High resource levels do seem to facilitate access to co-location advantages, but by no means guarantee it. In all cases, interviewees provided evidence that commitment is crucial in gaining access to local knowledge/resources.

Abstracting from these observations to a more general theoretical assessment, out of the three theoretical approaches institutional theory offers the most promise for understanding, and producing, value-enhancing outcomes of co-location advantages. Several interviewees echoed the institutional theory perspective on resource commitment as they focused on the relationships involved in creating and maintaining successful R&D internationalization. This is in line with the perceived importance of commitment levels, as we show in the theoretical foundation of this paper that the institutional theory is more focused on the (bi- or multilateral) commitment dimension of resource commitment, as antecedent as well as outcome. Statements indicating that a unit's resource level was relatively low, yet it was able to develop effective collaborative relationships, are in line with these findings. After all, RBV is more concerned with the resources, which R&D internationalization is intended to acquire or augment, and less on the commitment needed to build external relationships.

TCE also attaches more weight to the commitment dimension of resource commitment. However, within TCE, commitment is mainly viewed as a liability. Our data does not indicate a clear relationship between the governance structures of local external R&D relationships, the resource commitment to R&D units, or the main type of research activity performed. However, we do find support for the claim that more flexible governance arrangements promote access to co-location advantages in asset exploration. This aligns with the need for corporate flexibility in explorative activities. A firm needs to be able to relocate or shut down an R&D unit if no useful knowledge or partners can be found in a particular location, or after useful relations have run their course. The need for flexible explorative activities is also highlighted by Geiger and Makri (2006), who find that 'slack resources' (resources that are readily available, as they are not in use) provide firms with the flexibility needed for explorative activities.

Our findings on the influence of resource levels on the access to co-location advantages differ from those found in the literature (Kuemmerle, 1997; Perri, 2015; Perri and Andersson, 2014). According to the literature, high resource levels are needed to enable MNE units to gain legitimacy and trust (crucial for accessing co-location advantages), as they allow for reciprocation of benefits received from local partners with some of their own knowledge/resources. In addition, the literature suggests that (relatively) high resource levels are needed to achieve frequent and deep external linkages (Kuemmerle, 1997; Mellahi *et al.*, 2016). While interviewees indicated the usefulness of high resource levels to access co-location advantages, they also signalled that low resource/high commitment units are able to access the knowledge and resources of local external actors. This suggests that the influence of an R&D unit's resource level on its access to co-location advantages is less important than previously reported and seems to be affected by the unit's commitment level. While resources facilitate reciprocity, commitment may be more effective in attaining legitimacy and trust (an IT perspective). The relationship between an R&D location's resource level and co-location advantages in Figure 5 below is therefore marked with a '+/0' sign.

Figure 5: Influence of resource commitment on the access to co-location advantages



Inferring from the data, a potential reason for the contrasting findings regarding the influence of resource levels on the access to co-location advantages is that a company's suppliers or customers may benefit from a strong relationship with the corporation. Such self-interest (or perhaps shared interest in the company's performance) may explain why the company's local resource level can be less of an issue. Data from unit 1.1 in Germany provides evidence of this alternative logic. The unit works mostly with direct suppliers whose businesses rely heavily on Company 1 as a customer. The fact that Company 1's R&D unit in Germany has a low resource level does not influence their perceived legitimacy much. Unit 2.3 in Japan also offers evidence of a self/shared-interest logic at play. The unit mostly works with (potential) customers that rely in large part on Company 2 to stay competitive. Collaboration with unit 2.3 is thus of importance to these firms despite its low resource/low commitment status.

5.1 Contributions to the literature

Access to co-location advantages is a strong driver of explorative R&D by MNEs. As this access is conditioned by resource commitment to R&D units, the relationship between resource commitment and co-location advantage access is an important strategic concern. Through analysis of this relationship, this study contributes to striking a balance between the strategic rigidities and excess costs of over-commitment and the ineffectiveness and value dissipation of under-commitment in an MNE's R&D decisions.

The literature usually approaches resource commitment exclusively from a behavioural and operational perspective. In this study, we extend the understanding of the concept by disaggregating it theoretically into its substantive (resource-based), transactional, and institutional dimensions. This contributes to the existing resource commitment literature (Ghemawat and Del Sol, 1998; Johanson and Vahlne, 1977; Pedersen and Petersen, 1998; Randøy and Dibrell, 2002) and has applicability to academic analyses. Furthermore, we venture that managers' cognitive orientation vis-à-vis these three theoretical perspectives may influence the process and efficacy of MNE R&D units' co-location access.

Our findings contribute additional insights into the ties between actors (in terms of their establishment and effectiveness), which is important because the success of firms is linked to the depth of their ties to other organizations (Powell, 1998). Investigating the conditions under which such ties are most likely to be established and/or most fruitful may help scholars to better understand MNE behaviour.

5.2 Limitations and future research

One limitation of this study is the varied backgrounds of the MNE R&D units selected for analysis. While cross-comparative analysis was possible because units with similar resource commitment positions were selected, each operates in its own niche and focuses on a particular type of local actor. These differences may influence the importance accorded to resource commitment to access local knowledge/resources. Additionally, the relatively small number of interviewees for each resource commitment position limits the extent to which our theoretical inferences can be generalized.

At least three directions for future research are identified here. Firstly, there is a need to better understand how changes in resource commitment over time influence an R&D unit's access to co-location advantages. This study suggests that local actors respond to decreasing resource and commitment levels, and future work could focus on how this specifically works. Secondly, some data suggests physical distance impacts how (potential) partners perceive MNE commitment levels. For example, the unit of Company 1 in the United States seems to suffer from the large geographical distance between itself and both the headquarters and the nearest R&D unit, which are in Europe. Future research should investigate how this works. Finally, it would be interesting to better understand how much of a firm's access to co-location advantages can be explained by the briefly touched upon self/shared- interest logic of its existing or potential customers and suppliers.

6. Conclusion

This study set out to gain a better understanding of the role of MNE R&D units' resource commitment on their access to co-location advantages. The research builds on the literature concerning co-location advantages (Narula and Santangelo, 2012) and the concept of resource commitment (Ghemawat and Del Sol, 1998; Johanson and Vahlne, 1977; Pedersen and Petersen, 1998; Randøy and Dibrell, 2002). We theoretically disaggregated the relationship between resource commitment and co-location advantage access and demonstrated how the resource-based view, transaction cost economics and institutional theory each accentuate dimensions of the relationship. We show that it is affected by a firm's allocation of assets to its R&D units, by governance arrangements established to manage costs and risks associated with transactions across firm boundaries, and by the regularization of norms, values and routines through recurrent external interaction.

We combined the theoretical discussion of the different resource commitment dimensions with findings from a qualitative embedded multiple-case study research design. The empirical analysis of the relationship between resource commitment and co-location advantages indicates that high resource levels are less important for access to co-location advantages than conventionally assumed, while commitment levels consistently appear to be important, lending more support for the institutional theory-related dimensions of resource commitment than the resource-based view-related ones. With respect to governance arrangements, which are of greatest interest to TCE, we find support for the claim that more flexible arrangements promote access to co-location advantages in asset exploration.

This study's findings are of interest to MNEs that are increasingly in need of external resources to cope with growing global competition, intense technology interrelatedness, and increasing product complexity. Access to co-location advantages is, therefore, considered to be of critical importance for MNEs. This paper's findings are also relevant to policy-makers and managers concerned with knowledge-intensive clusters and/or boosting the knowledge-intensive economy. There is a need to attract MNE R&D activities utilizing committed resources, and this study suggests that units with such resources are, indeed, able to develop long-term mutually beneficial relations with local actors.

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Chapter 3

Resource commitment and inventions by multinational enterprise subsidiaries

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Abstract

This article conceptualises the relationship between innovation and resource commitment by multinational enterprise (MNE) subsidiaries. We advance the state-of-the-art by differentiating between resources allocated by an MNE and the degree of an MNE's commitment, which is reflected by the irreversibility of the allocated resources. We exploit a dataset for 7,149 MNEs and 33,541 subsidiaries, which filed in total 4,080,661 priority patent applications (2010–2019). We explain subsidiary patent counts by employing negative binomial regression models with measures for resources allocated and resource commitment, along with controls for other subsidiary-, parent- and location-specific variables. The results show a positive relation between resource commitment and total patent output by subsidiaries. Yet, we also find evidence of decreasing returns. The positive relationship also holds for inventions exclusively within technological areas characterised by a specialisation of the multinational enterprise. It does not hold for subsidiaries' inventions reflecting technological diversification. Further inspection reveals an inverted U-shaped relationship between resource commitment and a firm's share of patents, which reflects the technological specialisation of an MNE's subsidiaries.

1. Introduction

A substantial body of research focuses on the determinants of innovation by subsidiaries of multinational enterprises (MNEs) (e.g., Ciabuschi, Dellestrand, and Holm 2012; Eberhardt, Helmers, and Yu 2017; Reilly and Sharkey Scott 2014). Many of these studies directly or indirectly consider the role of resources such as research and development (R&D) expenditure, availability of human capital, or access to external or internal knowledge flows. Although extant research deals with resource allocation to subsidiaries or access to resources by subsidiaries, it fails to capture resource *commitment*. Resource commitment, as used in this article, refers to the level of irreversibility of tangible and intangible resources allocated to a subsidiary (Le Duc 2020). By considering resource commitment explicitly, one can say something not only about how many (or few) resources are available to an MNE's subsidiary, but also about how easily these resources can be (re)deployed elsewhere in the multinational organisation.

The relationship between a subsidiary's resource commitment and its ability to create innovations has not received much attention, which is surprising considering that: 1) a large theoretical literature suggests that the irreversibility of investments is a key factor in explaining sustained competitive advantage of firms (e.g., Ghemawat 1991; Pindyk 1991; Williamson 1985, 1988); 2) previous research shows that there are significant inter- and intra-industry differences in commitment levels (Folta, Johnson, and O'Brien 2006; Helfat 1994); and 3) the fact that R&D investments – a key resource for innovations – are high-commitment by their very nature (Williamson 1988). After all, commitment to building a subsidiary's innovative capabilities influences the irreversibility of a firm's deployed resources, as these resources become more specific to a certain use/product/location. Relatedly, R&D activities tend to focus on the medium- to long-term and are dependent on past innovations (Malerba and Orsenigo 1993).

This article contributes to our understanding of the relationship between a subsidiary's resource commitment level and innovation outcomes. Specifically, we focus on patented inventions of MNE subsidiaries. We argue that the importance of irreversibility when building a subsidiary's innovative capabilities implies that the higher a subsidiary's overall commitment level, the higher its output of inventions. However, we also suggest that there is probably a point at which higher commitment does not lead to even more inventions, due to cognitive barriers, a lack of flexibility and/or systemic lock-in. Finally, we argue that the role of resource commitment could differ depending upon whether the subsidiary invents within or beyond its parent MNE’s areas of technological specialisation. Specifically, we expect higher resource commitment levels for inventions related to technological specialisation, since these rely upon more extensive and sustained development efforts.

In the empirical analysis of this article, we exploit a dataset for 7,149 multinational enterprises and 33,541 subsidiaries, which filed 4,080,661 priority patent applications (2010–2019). We explain subsidiaries’ patent count by employing negative binomial models with measures for resources allocated and resource commitment, along with controls for other subsidiary-, parent- and location-specific variables. The results show a positive relation between resource commitment and total patent output by subsidiaries. Yet, we also find evidence of decreasing returns. The positive relation also holds for inventions exclusively within technological areas the multinational enterprise specialises in. The same does not hold for subsidiaries’ inventions that reflect technological diversification. Further inspection reveals an inverted U-shaped relationship between resource commitment and patent share, which reflects the technological specialisation of an MNE’s subsidiaries. Our main findings confirm a positive relationship between MNE resources allocated to subsidiaries and the subsidiaries’ patenting output, in line with previous findings. However, we contribute to the state-of-the-art by introducing resource commitment of subsidiaries into research upon MNE subsidiary innovation.

2. Theoretical foundation

2.1 Resources and innovation

Previous research on the determinants of firms’ inventions focusses primarily on resources invested into R&D, the creative and systematic work undertaken in order to increase the stock of knowledge and to devise new applications of available knowledge (OECD 2015). It covers basic research, applied research and experimental development (Ibid.). Extant research documents a positive relationship between a firm’s R&D spending and its output of inventions, which is consistent with the argument that internal research capabilities are key to enabling a firm to generate creative outputs (e.g., Ahuja and Katila 2001; Bound et al. 1984; Hagedoorn and Duysters 2002; Mairesse and Mohnen 2005; Pakes and Griliches 1984; Peeters and Van Pottelsberghe De La Potterie 2006).

Yet, there is also evidence that this relationship is characterised by decreasing returns to R&D expenditures (Graves and Langowitz 1993). Thus, the effectiveness decreases with increasing R&D effort and, by association, with firm size (Ibid.). This corresponds to findings suggesting that smaller firms (implying lower resource levels) are more 'efficient', gaining a larger number of patents per invested R&D dollar than larger firms (implying higher resource levels) (Acs and Audretsch 1990; Bound et al. 1984). This could be related to a reduction in the amount of 'entrepreneurial attention' devoted to creating new inventions, which has been found to constrain the overall innovative capability of larger firms (Acs and Gifford 1996) or less efficient decision making, coordination, and resource allocation processes in large firms.

It is important to highlight that the resources required for a firm to generate creative and novel outputs for commercialisation cannot be restricted solely to R&D. For example, Bell (2009) distinguishes between production and innovation capability at the firm level. Both include knowledge or technology in various kinds of capital stock: physical capital, knowledge capital, human capital, and organisational capital. Physical capital corresponds to a firm's tangible assets. Knowledge and human capital are among a firm's intangible assets. Organisational capital encompasses internal firm procedures, but also a firm's external relationships and networks (Ibid.). The latter have been recognised as important elements of firm-level strategies as they search for innovative inputs from external sources such as suppliers, clients, competitors, and universities (e.g., Chesbrough 2003; Grimpe and Sofka 2009; Katila and Ahuja 2002; Laursen and Salter 2006).

Extant research on an MNE's subsidiaries' inventions (and innovation more broadly) pays attention to resources such as research intensity (Mudambi and Navarra 2004), extent of government support (Tse et al. 2021), availability of qualified technical personnel (e.g., Demirbag and Glaister 2010; Miravitlles et al. 2013; Li, Wang and Liu 2013), nature of local knowledge (Almeida and Phene 2004; Hegde and Hicks 2008; Porter and Stern 2000) access to local networks of universities, R&D labs and suppliers (e.g., Damijan, Kostevc, and Rojec 2010; Phene and Almeida 2008), and political-institutional framework (Fischer, Fröhlich, and Gassler 1994; Giroud et al. 2012). It also considers organisational aspects such as parent involvement (Bouquet, Morrison, and Birkinshaw 2009; Ciabuschi et al. 2012), self-determination and autonomy over business functions (Beugelsdijk and Jindra 2018; Ciabuschi, Forsgren, and Martín 2011; Magelssen 2020; Iwasa and Odagira 2004, Mudambi et al 2007), internal embeddedness (Ciabuschi, Dellestrand, and Martín 2011; Ferraris, Bogers, and Bresciani 2020; Garcia-Pont, Canales, and Noboa 2009) as well as the mode of overseas R&D (Mudambi and Navarra 2004; Tse et al. 2021; Wang et al. 2017).

2.2 Resource commitment and innovation

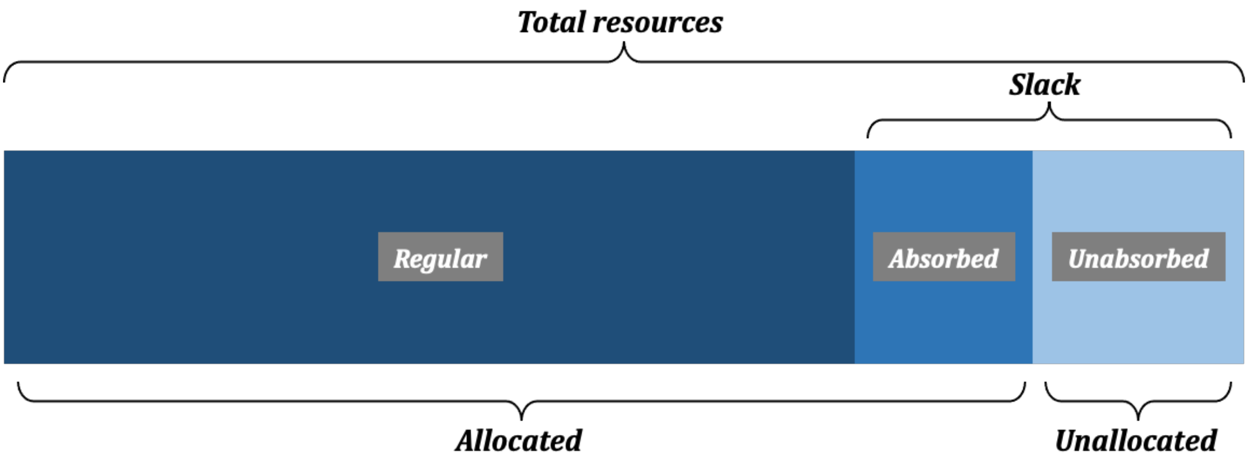
While the relationship between a subsidiary's resources and its inventive activity has been studied extensively, the focus has mostly been on resource allocation (or access to resources) rather than resource *commitment*. This is an important distinction, since it has been suggested in international business theory that resource commitment is composed of two factors: (1) the amount of tangible and intangible resources allocated and (2) the degree of commitment of a resource allocation (Johanson and Vahlne 1977; Pedersen and Petersen 1998; Randøy and Dibrell 2002). In this article, we define the commitment level of a subsidiary's resources on the basis of the irreversibility of these resources resulting in sunk costs (Le Duc 2020). Resource irreversibility is often associated with resource specificity (Williamson 1985). By definition, a resource is 'specific' to a firm/location/use/activity if its value decreases when a firm applies it differently, redeploys it to another activity or location, or sells it to another company (Ghemawat and Del Sol 1998). Naturally, an MNE's commitment to building a subsidiary's innovative capabilities influences the irreversibility of the resources the MNE deploys to the subsidiary. After all, these resources become more specific to a certain use/product/location, augmenting the irreversibility of these resources.

The importance of resource commitment in creating value for firms is anchored in the resource-based view of the firm (Barney 1991; Grant 1991; Wernerfelt 1984). It perceives firms as a "collection of productive resources" (Penrose 1959:24) and argues that firms that effectively create, apply, and (re-)allocate their resources are thereby able to create a sustained competitive advantage (Barney 1991). In other words, a firm that can match *and* commit resources to specific innovative activities may achieve a superior (innovation) performance.

Despite the importance of commitment to innovative activities, and a large theoretical literature on commitment and irreversibility (e.g., Ghemawat 1991; Pindyk 1991; Williamson 1985, 1988), we lack insights into how commitment levels explain differences in innovative output by MNE subsidiaries. While the relationship between commitment and subsidiary innovation is arguably understudied, the relationship between innovation and slack resources is one of the central issues in management theories (e.g., Bourgeois 1981; Chandler et al. 2011; Huang and Chen 2010; Kim et al. 2017; Nohria and Gulati 1996; Yang, Wang, and Cheng 2009). Slack resources refer to "the pool of resources in an organization that is in excess of the minimum necessary to produce a given level of organizational output" (Nohria and Gulati 1996). Previous research argues that slack resources have an inverse U-shaped relationship with innovation performance (e.g., Herold, Jayaraman, and Narayanaswamy 2006; Tan 2003). This is true for both absorbed and unabsorbed slack resources (Geiger and Cashen 2002), a finding that is relevant to this study because both types of slack resources vary in the extent of their (re)deployability.

Absorbed slack is organizational slack that is allocated to particular usages, or "absorbed into the system design as excess costs" (Bourgeois and Singh 1983:43). Examples of absorbed slack include excess inventory, excess machine capacity, and indirect staff. Unabsorbed slack, on the other hand, is comprised of unallocated resources. Since these resources are not assigned to any particular usages, they are more readily deployable (Bourgeois and Singh 1983; Singh 1986). Examples of unabsorbed slack are cash and marketable securities. Because absorbed slack resources are allocated to a particular usage, their commitment level is higher than those of unabsorbed slack resources, which are relatively easy to deploy in a discretionary manner (Tan and Peng 2003; Voss, Sirdeshmukh, and Voss 2008).

Figure 6: Regular resources, absorbed slack, and unabsorbed slack



Source: authors

Note: *For illustration purposes only. The size of the different groups may differ significantly case-by-case.*

The existing literature has not fully clarified the extent to which the relationship between slack resources and innovation is the result of their 'slack nature', or the extent to which commitment levels influence the relationship with firm innovation. Moreover, the focus on slack resources considers only a certain percentage of a firm's total resources (see Figure 6). 'Regular' resources are not considered by existing studies, while these too can vary in terms of their commitment.

2.3 Hypothesis development

2.3.1 Resource commitment and innovation

In this article, we argue that the importance of commitment to building a subsidiary's innovative capabilities implies that the higher a subsidiary's overall commitment level, the more innovative the subsidiary is likely to be. We know that R&D, a key factor for firm-level innovation, is characterised by a high degree of asset specificity (Williamson 1988). R&D activities are often focused on the medium to long-term and they are dependent on past innovations (Malerba and Orsenigo 1993). As time passes, resources allocated to R&D in subsidiaries become more resource-specific, augmenting the irreversibility of such investments. The firm-specific nature of R&D investments positively influences the ability of firms to earn returns on R&D efforts (Helfat 1994).

A firm's investment into R&D has several components: Capital R&D expenditures include the acquisition of tangible fixed assets (such as buildings and structures, transport equipment, other machinery and equipment, etc.) and intangible fixed assets (such as computer software) that are used repeatedly or continuously in the performance of R&D (OECD 2015). Firms may also provide funds to others for the performance of extramural R&D. Labour costs comprise compensation for employed R&D personnel, such as annual wages and salaries (Ibid.). The higher the specificity, irreversibility, and sunk cost of a firm's investment in such assets, the higher the firm's commitment level. This, in turn, is likely to be associated with higher and more persistent innovative output by the subsidiary, compared to subsidiaries whose R&D-related assets reflect lower commitment levels.

As outlined above, subsidiaries' innovation capability draws upon assets beyond R&D. Therefore, our principal argument applies to tangible and intangible assets of the subsidiary more broadly. For example, there is evidence of a positive effect of training, which contributes to human capital formation, on a firm's patenting output (Ballot, Fakhfakh, and Taymaz 2001; Gallié and Legros 2012). Extant research also points to the relevance of foreign R&D to support local production and adaptation of centrally developed products to local market conditions (Håkanson and Nobel 1993). This signals a positive relationship between fixed (tangible and intangible) assets in the area of production, later investment into R&D, and innovative outputs by MNE subsidiaries. Thus, we can hypothesise:

H1: There is a positive relationship between the commitment level of a subsidiary's resources and its innovative output.

2.3.2 Decreasing returns to resource commitment

We argue that there is probably a point at which higher commitment does not lead to more innovations. High levels of irreversibility are argued to raise cognitive barriers to learning from trial and error or other technological adaptations (Liu et al. 2018). Moreover, a certain amount of flexibility is needed to enable the subsidiary to bear the costs of instituting innovations and exploring new ideas in advance of an actual need (Rosner 1968). Slack resources may partly provide this flexibility, as can 'regular' resources that are less committed to a certain use or activity. Radical innovations or technological discontinuities may require new institutions and resources, but systemic lock-in of R&D activities in a particular location may prevent a rapid response (Narula 2002). Thus, very high commitment levels to a specific location may be associated with decreasing returns for a subsidiary's innovation capability. Thus, we can hypothesise:

H2: There are decreasing returns, in terms of innovative output, from very high commitment levels of a subsidiary's resources.

2.3.3 Resource commitment for technological specialisation and diversification

This article posits that the effect of the commitment level of a subsidiary's resources on the subsidiary's inventive output depends on whether it is contributing to the technological specialisation or diversification of its MNE. MNEs focusing their activities in a small number of technological fields can profit from specialisation that enhances economies of scale associated with the learning process, facilitates the transfer of knowledge between the core technologies, and benefits from the MNE’s technological comparative advantages (Breschi, Lissoni, and Malerba 2003; Garcia-Vega 2006). However, MNEs may also benefit from diversification due to higher cross-fertilization between different technologies and related economies of scope (Granstrand 1998; Piscitello 2000; Suzuki and Kodama 2004). Since a firm’s engagement in technological fields does not change rapidly, diversification is often into related assets that establish patterns of corporate coherence (Piscitello 2004; Teece et al. 1994; Teece and Pisano 1994).

Extant research argues that more resources are required for technological diversification than for specialisation (Cantwell and Mudambi 2005). Not only does entering a new technological area directly tax a firm’s resources more, but additional complementary resources are also often required to mitigate the increased risks and uncertainties linked to technological diversification (Chiu et al. 2008). By contrast, specialisation tends to require a more extensive and continuous succession of development efforts by subsidiaries (Cantwell and Mudambi 2005). This can have a self-reinforcing effect: past specialisation in a given domain tends to make further specialisation in that domain even more attractive, because these efforts facilitate more efficient use of existing intangible resources (Levinthal 1995). However, this dynamic, also referred to as path dependency, may lead to inertia. For example, firms may find it difficult to move away from current technologies because of costs related to switching away from existing R&D equipment and corresponding human capital (Narula 2014). Moving beyond R&D, there is evidence that the existence of highly specific resources encourages development along trajectories that are close or similar to the original trajectory (Chatterjee and Wernerfelt 1991).

In sum, this could suggest that although fewer (additional) resources are required for subsidiaries that innovate in areas of existing technological specialisation, the assets employed would be characterised by relatively high asset specificity and, therefore, by a relatively high commitment level of the subsidiary’s resources. For diversification of MNEs, in turn, new or additional resources might be required, as well as flexibility, when entering a new technological area (Geiger and Makri 2006). Higher flexibility could imply lower commitment levels to corresponding subsidiary resources use for innovation in technological areas outside the existing specialisation of the MNE. Lower commitment levels also enable the MNE to exit new technological domains quickly, which is an attractive option due to the inherently higher risk and uncertainty. Thus, we hypothesise:

H3: Higher subsidiary commitment levels are positively related to innovative output in areas in which the MNE possesses a specialisation advantage.

3. Data and method

3.1 Data

Extant research integrates large, firm-level datasets with patent data (Alkemade et al. 2015; Dernis et al. 2015; EU Industrial R&D Scoreboard 2015, 2016; Laurens et al. 2015; Magelssen 2020) to measure technological activities by MNEs. Our dataset combines three sources, all provided by Bureau van Dijk (BvD): Orbis, Orbis IP, and Orbis-Zephyr, which contain data on general corporate characteristics, patent activity, and mergers and acquisitions (M&A), respectively. The Orbis dataset links subsidiaries to their Global Ultimate Owners (GUOs). We downloaded the three datasets between July 2020 and March 2021. Next, we conducted a bottom-up search that moved from subsidiaries to their immediate parents and then to the global ultimate owners. After extracting all subsidiaries whose shareholders hold at least 25.01 per cent of outstanding shares, the search was extended upwards (subsidiaries that are parents of other subsidiaries) and downwards (parents that are subsidiaries of other subsidiaries). Then, we performed a top-down search for shareholders with subsidiaries and all their subsidiaries. This enabled us to map integrated MNE ownership structures that consist of up to 21 ownership levels. To account for the entry or exit of subsidiaries during the observation period, the ownership structure was calculated backwards and forwards (taking the ownership structure of 2010 as a basis) by adding M&A data from the Orbis-Zephyr database and by accounting for the date of incorporation of subsidiaries. By doing so, we minimize a potential survival bias.[2] For information on the GUO, we relied on 'corporate entities' and excluded financial and individual types of GUO.

Next, a patent dataset was built using information from Orbis IP. We identified all priority filings with priority dates within the period from 1 January 2000 to 31 December 2019. A priority filing is the first patent application filed to protect an invention; it is the identifier for the entire patent family, regardless of spatial protection scope. Using priority

[2] Subsidiaries dissolved completely before 2020 could not be accounted for.

filing reduces country bias, compared to other patent indicators (De Rassenfosse et al. 2013). Finally, the BvD ID of patent owners was used to link this patent dataset to the companies' ownership dataset. The patents are linked to their respective corporate owners on an annual basis. This allows accounting for changes in ownership due to patent or firm acquisitions. Although the ownership structure of MNEs covers the 2011–2020 period, the year 2020 is dropped from the analysis due to incomplete patent data.

3.2 Description of sample

Table 13: Number of subsidiaries, patents, and MNEs per country*

#	Country	#of subsidiaries	# of foreign subsidiaries	% of foreign subsidiaries	Subsidiary priority patent applications	# of MNEs
1	China	9,308	3,691	39.7%	1,584,337	1,484
2	USA	7,426	3,617	48.7%	1,184,432	552
3	Germany	4,387	2,345	53.5%	423,167	1,257
4	UK	1,850	1,552	83.9%	62,177	81
5	France	1,828	879	48.1%	154,027	479
6	Spain	970	354	36.5%	11,106	495
7	Canada	775	477	61.5%	34,024	235
8	Australia	760	539	70.9%	12,164	178
9	Taiwan	748	173	23.1%	157,113	228
10	Netherlands	641	554	86.4%	97,114	53
12	Austria	573	258	45.0%	25,357	265
13	Belgium	530	293	55.3%	20,222	179
14	Finland	491	175	35.6%	41,257	252
15	Denmark	439	216	49.2%	18,918	179
16	Sweden	433	290	67.0%	78,919	57
17	Singapore	253	207	81.8%	35,026	17
18	Czechia	237	109	46.0%	4,227	118
19	Hong Kong	197	162	82.2%	14,702	27
20	Ireland	190	157	82.6%	12,948	17
21	Russia	181	95	52.5%	3,634	5
22	Poland	170	150	88.2%	1,906	7
23	India	158	117	74.1%	9,409	29

**Only countries with more than 150 subsidiaries are listed. There are a total of 87 countries in the sample, of these 52 countries have less than 20 subsidiaries.*

We dropped subsidiaries with no information on key variables. We interpolated missing data on the key numerical variables for selected years of a specific subsidiary by taking the average from existing data points for the variable for the respective subsidiary. The final unbalanced panel dataset includes 7,149 MNEs with 33,541 subsidiaries (242,680 observations) and a total of 4,080,661 priority applications between 2010 and 2019. The final sample includes subsidiaries located in 87 countries, 52 of which have fewer than 20 subsidiaries. The top 5 countries in terms of number of subsidiaries are China, USA, Germany, UK and France, which jointly account for 74% of all subsidiaries in the sample (see Table 13). The top two countries (China and the USA) account for 68% of all priority patent applications in the sample. About 28% of subsidiaries are in 'manufacturing', with fairly equal distributions among the different manufacturing sub-categories. This is followed by 'administrative and support services' (8%) and 'transportation and storage' and 'construction', each comprising 5% of the sample.

3.3 Variables and measurements

3.3.1 Dependent variables

Seminal empirical works studying the determinants of inventions have developed models of firms based on investment in discovering new knowledge and/or flows of ideas from existing knowledge to generate a knowledge production function (Criscuolo, Haskel, and Slaughter 2010; Griliches 1979, 1990; Jaffe 1986; Nelson 1987). We followed this approach and use patent information to measure subsidiaries' inventions (see also Dernis et al. 2015; Magelssen 2020; Mudambi, Mudambi, and Navarra 2007). We used three dependent variables to test our hypotheses: First, we approximated innovative output (App) by taking the annual number of priority patent applications by each subsidiary (2011–2019). To classify whether a subsidiary patent application occurs within or outside its MNE's areas of specialisation, we calculated the 'Revealed Technological Advantage' (RTA) index for each MNE for each year (2011–2019) as follows:

$$RTA_{ij} = \frac{\mathrm{P}_{ij} / \sum_i \mathrm{P}_{ij}}{\sum_j \mathrm{P}_{ij} \ / \sum_{ij} \mathrm{P}_{ij}}$$

P_{ij} denotes the number of priority patent applications of MNE in technological field[3] j. We used the initial MNE stock of priority applications in 2010 and added cumulatively the annual applications. An RTA greater than one indicates that the MNE possesses a relative technological advantage in the respective technological field, relative to other technological fields (Cantwell and Mudambi 2000). Thus, the second dependent variable (*SPEC*) is a count of the annual sum of a subsidiary's priority applications within technological fields in which the corresponding MNE possesses a revealed technological advantage (specialisation). The third dependent variable (*DIV*) is an annual count of a subsidiary's priority applications in technological fields in which the corresponding MNE has an RTA below one.

3.3.2 Independent variables

To account for the resources allocated to each multinational subsidiary (*RESL*), we included the annual share of a subsidiary's total assets in its parent's annual total assets. We opted for a relative measure to account for MNE heterogeneity in terms of total assets.[4] In this way, we controlled for the effect of resources allocation to subsidiaries, independent of the size of the MNE,[5] and captured the relative share of MNE resources allocated to a specific subsidiary. We followed previous research (Campa 1993; Li and Li 2010; Wennberg, Folta, and Delmar 2006) for approximating a subsidiary's resource commitment (*COML*) by calculating the ratio of the subsidiary's fixed assets to the subsidiary's total assets (see Annex 1 for a complete overview of commitment level measures). Fixed assets, long-term assets with a lifespan of at least one financial year, consist of both tangible (also called physical) fixed assets (such as buildings and structures, transport equipment, other machinery and equipment, etc.) and intangible fixed assets (such as computer software and mineral exploration rights). Fixed assets are harder to liquidate than other assets, that is,

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[3] Technology fields are inferred from International Patent Classification (IPC) codes. Technology fields refer to a bundle of related classifications from the IPC (e.g., Le Bas and Patel 2005; Leten, Belderbos, and Van Looy 2007). We use the main IPC code of each patent and differentiate the 8 main IPC sections: A) Human necessities; B) Performing operations, Transporting; C) Chemistry, Metallurgy; D) Textiles, Paper; E) Fixed construction; F) Mechanical engineering, Lighting, Heating, Weapons, Blasting; G) Physics; and H) Electricity.

[4] When calculating RESL we subtract intangible fixed assets from total assets, since costs to acquire a patent are recorded as the initial asset cost as part of firms' intangible fixed asset. This costs will include the registration, documentation, and other legal fees associated with the patent application. If the company bought a patent from another party, the purchase price is the initial asset cost.

[5] Due to our theoretical considerations, we do not restrict subsidiary resources to R&D but prefer a more comprehensive resource measure. The correlation between the reported R&D expenditures (2,627 out of the 33,541 subsidiaries) and the RESL variable is 0.59.

they are relatively highly irreversibility. Thus, a high fixed asset ratio of a firm signals high resource commitment. To test for non-linearity, we introduced a squared term of the COML variable (*COML_SQ*). A negative relationship between the dependent variable and the squared term of COML would indicate a concave relationship (Hayes 2015). Please see Annex 3 for a summary of descriptive statistics for the key variables in the final sample.

3.3.3 Control variables

Given the differences in commitment levels between industries (Folta et al. 2006) and the fact that patenting propensity differs across industries (Bound et al. 1984; Schefer 1983), we controlled for subsidiary industry at the 4-digit level of the NACE classification (Cerda, Varoquaux, and Kégl 2018).[6] We also controlled for the years since the subsidiary's establishment, since a firm's experience, often proxied by age (Dai, Eden, and Beamish 2013; Ferraris et al. 2020; Isobe, Makino, and Montgomery 2000) has been associated with commitment levels (Chang and Rosenzweig 2001; Le Duc 2020; Gao and Pan 2010). Following extant research (e.g., Ciabuschi and Martín 2011; Dellestrand and Kappen 2012), we controlled for the size of the subsidiary, accounting for the number of employees, which affects innovative output. We also included a number of MNE-specific controls, including the number of countries in which the MNE is active as a measure of the geographic scope of its internationalisation, the number of MNE subsidiaries outside the MNE home country as a measure of the extent of its internationalisation, the number of priority applications by the MNE parent (excluding all subsidiary priority applications) as a measure of its absorptive capacity, and the total number of MNE subsidiaries as a proxy of size. Finally, location-specific factors may influence the innovation output of subsidiaries (see e.g., Criscuolo, Narula, and Verspagen 2005). In line with previous research (Guimon 2009; Hagedoorn, Cloodt, and Van Kranenburg 2005), we controlled for the level of intellectual property rights protection in the host country of the subsidiary (Heritage Foundation 2021) as well as the 'technological readiness' and the 'innovativeness' index of the respective host country (World Economic Forum 2021). Annex 2 provides an overview of all adopted variables.

[6] Since the sample includes many 4-digit level NACE codes, we used hashing. This method allows us to deal with high cardinal variables, which would be difficult to deal with when using a classical dummy variable approach, which would limit interpretation.

3.4 Regression model specification

The distributions of the three dependent variables are skewed to the left. This is a well-documented characteristic of patent-based count variables. A non-normal distribution implies that analysis can proceed via either a Poisson or a negative binomial (NB) model (Zeileis, Kleiber, and Jackman 2008). We adopted the latter, which can accommodate over-dispersed count data. This type of data is characterised by a conditional variance that exceeds the conditional mean (Ver Hoef and Boveng 2007). If the conditional distribution of the outcome variable is over-dispersed, the confidence intervals for NB are likely to be narrower compared to those from a Poisson regression. The NB model shows a better fit, since it does not assume that the variance is equal to the mean. The formula for the NB regression model is as follows:

$$\frac{\left(y_i - \lambda_i\right)^2 - \lambda_i}{\lambda_i} = \alpha \cdot \lambda_i + 0$$

After fitting the models to the data, we get α. To attain λ_i, we ran the NB regression model, using the [glm.nb] package in R (Zeileis et al. 2008). The performance of the model was interpreted by considering the change in the target variable when the feature variable changes by 1 (Beck and Tolnay 1995). We calculated 1-(residual-deviance / null-deviance) to obtain the pseudo-R^2. Next, we looked at the relation of the residual deviance to the degree of freedom (df). If the degree of freedom is larger than 1, we have an overdispersion; if it is smaller, we have an underdispersion. In all three models, we found the residual deviance slightly above 1.

4. Empirical analysis and results

4.1 Main results

The first model regresses priority patent applications by year (*App*) (see Table 14). All variables are highly significant. We found that subsidiary commitment level (*COML)* is positively associated with the number of priority applications by the annual subsidiary (*App*). In fact, this relationship is the strongest of all the tested relationships. This confirms H1. The squared term of subsidiaries' commitment levels (*COML_SQ)* is negative and significant, which implies that the relationship between a subsidiaries' commitment levels and their priority patent output is concave and non-linear. This confirms H2.

Table 14: Negative binomial model – All priority patent applications (App)

	Estimate	Std.	Error	z	Pr(>|z|)
(Intercept)	-1.202	0.053	-22.660	< 2e-16	***
log1p(RESL)	0.746	0.019	40.204	< 2e-16	***
log1p(COML)	0.951	0.069	13.694	< 2e-16	***
log1p(COML_SQ)	-0.903	0.079	-11.429	< 2e-16	***
log1p(NACE)	-0.005	0.003	-1.858	0.063	***
log1p(Age)	-0.097	0.007	-14.518	< 2e-16	***
log1p(EMP)	0.079	0.001	57.002	< 2e-16	***
log1p(Countries)	-0.093	0.009	-10.652	< 2e-16	***
log1p(NoSub)	0.082	0.005	15.049	< 2e-16	***
log1p(MultiSub)	-0.018	0.003	-5.897	0.000	***
log1p(TP)	0.016	0.001	10.838	< 2e-16	***
log1p(TR)	0.080	0.002	40.629	< 2e-16	***
log1p(Inno)	0.279	0.011	24.876	< 2e-16	***
log1p(IPR)	-0.285	0.005	-63.254	< 2e-16	***
Observations	242,680				
Residual deviance	220,337				
Degrees of freedom	242,586				

*Significant codes: *** p < 0.001, ** p < 0.01, * p < 0.05*

Abbreviations: RESL = Resource level, COML = Commitment level, COML_SQ = Commitment level squared, NACE = Industry Classification, Age = Age of subsidiary, EMP = Employees (Sub), Countries = Number of countries the MNE is operating in, NoSub = Number of MNE subsidiaries, MultiSub = Share of foreign MNE subsidiaries to all MNE subsidiaries, TP = Total Patents (MNE), TR = Technological Readiness, Inno = Innovativeness based on the Global Competitiveness of the host country, IPR = Intellectual Property Rights Index in the host country.

As expected, the variable 'subsidiary resources' (*RESL)* shows a positive relationship with the number of priority patent applications. The relation between the number of employees of the subsidiary (*EMP)* and the count of annual priority patent applications also is positive. We found a small negative relationship between years since the establishment of the subsidiary (*Age)* and the number of subsidiary priority patent applications. For the controls at the level of the MNE, we found that both the number of countries in which the MNE is active (*Countries*) and the number of MNE subsidiaries outside of the MNE home country

(*MultiSub*) have a negative relationship with the number of priority patent applications by subsidiaries, whereas both the number of MNE parent priority applications (*TP*) and the total number of MNE subsidiaries (NoSub) are positively related with the number of priority patent applications of multinational subsidiaries. As expected, we found a positive relationship between the number of priority applications and the innovativeness (*Inno*) and technological readiness (*TR*) of the subsidiary's host country. However, results indicate a negative relationship between *App* and a host country's intellectual property rights (*IPR*).

The second model uses the annual count of priority patent applications by the subsidiary within technological fields in which the MNE poses a revealed technological advantage (*SPEC*) (see Table 15).

Table 15: Negative binomial model – Priority patent applications in areas with MNE specialisation (SPEC)

	Estimate	Std.	Error	z	Pr(>|z|)
(Intercept)	0.095	0.025	3.810	0.000	***
RESL	0.242	0.002	117.493	< 2e-16	***
COML	0.054	0.007	7.474	0.000	***
NACE	-0.045	0.000	-47.738	< 2e-16	***
Age	0.000	0.000	2.995	0.003	**
log1p(EMP)	0.050	0.001	90.165	< 2e-16	***
log1p(Countries)	0.130	0.004	32.202	< 2e-16	***
log1p(NoSub)	-0.081	0.003	-32.026	< 2e-16	***
log1p(MultiSub)	-16.090	0.001	-11.187	< 2e-16	***
log1p(TP)	0.002	0.001	3.003	0.003	**
log1p(TR)	0.011	0.001	12.497	< 2e-16	***
log1p(Inno)	0.180	0.005	34.299	< 2e-16	***
log1p(IPR)	-91.780	0.002	-44.160	< 2e-16	***
Observations	242,680				
Residual deviance	279,434				
Degrees of freedom	242,587				

*Significant codes: *** p < 0.001, ** p < 0.01, * p < 0.05*

Abbreviations: RESL = Resource level, COML = Commitment level, COML_SQ = Commitment level squared, NACE = Industry Classification, Age = Age of subsidiary, EMP = Employees (Sub), Countries = Number of countries the MNE is operating in, NoSub = Number of MNE subsidiaries, MultiSub = Share of foreign MNE subsidiaries to all MNE subsidiaries, TP = Total Patents (MNE), TR = Technological Readiness, Inno = Innovativeness based on the Global Competitiveness of the host country, IPR = Intellectual Property Rights Index in the host country.

The results show that commitment level (*COML*) has a positive relationship with the number of priority patent applications by the subsidiary within technological fields, in which the MNE has a revealed technological advantage. This leads us to confirm hypothesis H3, although the size of the coefficient is low and thus the relationship is rather weak.

As in model one, we also found a positive relationship between a subsidiary's resources (*RESL*) and the number of priority applications by the subsidiary in areas of the MNE's technological specialisation. The number of employees (*Size*) of the subsidiary has a weak but positive relation with the dependent variable. For MNE-specific variables, we found negative coefficients for the total number of MNE subsidiaries (NoSub) as well as the number of MNE subsidiaries outside of the MNE home country (*MultiSub*). The latter is actually very large. We find positive coefficients for the number of countries in which the MNE is active (*Countries*) as well as the number of MNE parent priority applications (*TP*). Thus the sign of the coefficients for *Countries and NoSub* is opposite to the results in model one. The coefficients for host country effects confirm the results from model one.

In the third model we took the number of priority patent applications in areas in which the MNE has no specialisation advantage (*DIV)* as a dependent variable (see Table 16). Here we found no significant relationship between the commitment level variable (*COML)* and the absolute diversification of inventive activities by the subsidiary. As with models 1 and 2, we found a positive relationship between a subsidiary's resources (*RESL*) and also for the number of priority applications by the multinational subsidiary in both technological areas without a technological specialisation advantage by the MNE. The results for subsidiary specific effects (Age and Size), are in line with model two. The results for all MNE-specific variables are in line with model 1. The coefficients for host country effects confirm the results from models one and two.

Table 16: Negative binomial model – Priority patent applications in areas with no MNE specialisation (DIV)

	Estimate	Std.	Error	z	Pr(>|z|)
(Intercept)	-1.495	0.042	-35.829	< 2e-16	***
RESL	0.176	0.005	38.424	< 2e-16	***
COML	0.018	0.012	1.567	0.117	
NACE	0.000	0.000	-39.477	< 2e-16	***
Age	0.000	0.000	0.194	0.847	
log1p(EMP)	0.065	0.001	74.360	< 2e-16	***
log1p(Countries)	-0.030	0.006	-4.847	0.000	***
log1p(NoSub)	0.139	0.004	36.060	< 2e-16	***
log1p(MultiSub)	-0.015	0.002	-6.208	0.000	***
log1p(TP)	0.001	0.001	0.992	0.321	
log1p(TR)	0.014	0.001	10.196	< 2e-16	***
log1p(Inno)	0.309	0.009	35.262	< 2e-16	***
log1p(IPR)	-0.147	0.003	-44.181	< 2e-16	***
Observations	242,680				
Residual deviance	275,754				
Degrees of freedom	242,587				

*Significant codes: *** p < 0.001, ** p < 0.01, * p < 0.05*

Abbreviations: RESL = Resource level, COML = Commitment level, COML_SQ = Commitment level squared, NACE = Industry Classification, Age = Age of subsidiary, EMP = Employees (Sub), Countries = Number of countries the MNE is operating in, NoSub = Number of MNE subsidiaries, MultiSub = Share of foreign MNE subsidiaries to all MNE subsidiaries, TP = Total Patents (MNE), TR = Technological Readiness, Inno = Innovativeness based on the Global Competitiveness of the host country, IPR = Intellectual Property Rights Index in the host country.

4.2 Robustness

4.2.1 Alternative measurement of specialisation

SPEC and DIV, the dependent variables in models two and three respectively, are count variables. They measure separately the extent to which subsidiaries generate priority patent applications in fields with or without revealed technological advantage of their respective MNEs. However, extant literature shows that subsidiaries can engage in both types of activity (see e.g., Criscuolo et al. 2005), and it seems that they do so, given the high correlation between our SPEC and DIV as dependent variables (see Annex Table 4). Therefore, we assessed the robustness of our main results using an alternative measure to test H3. To this end, we calculated the share of a subsidiary's annual priority patent applications within technological fields in which their parent MNE possesses a revealed technological advantage, in total annual priority applications of the subsidiary (*SPEC2*). Given the nature of this alternative dependent variable for the relative specialisation of a subsidiary, we adopted a logistic regression model and followed the model diagnostics for logistic regressions described by Hosmer and Lemeshow (1991). The results indicate a very weak, but significant, negative relationship with a subsidiary's commitment level (see Annex 5). We also tested for non-linear effects, using the squared term of COML (*COML_SQ*) (see Annex 6). The results indicate an inverted U-shape relationship between a subsidiary's relative specialisation and its commitment level (although this relationship also is very weak). Thus, the subsidiary's commitment level increases with the relative specialisation of inventions by the multinational subsidiary. Above a certain threshold of commitment level, the relative specialisation declines again.

4.2.2 Sample bias

In our sample, China hosts the largest number of subsidiaries, and these account for the highest share of priority applications (see Table 1 above). Due to the institutional context of the Chinese IPR framework, our interpretation of the commitment level of a subsidiary's resources might be inaccurate. Specifically, Chinese policies reward businesses that file patents, with the possible effect that some applications are spurious. For example, the National IP Strategy Outline (2008) promotes IP creation, utilization, protection, and management, and the National Patent Development Strategy (2011–2020) by the State Intellectual Property Office (SIPO) further encourages IP creation (Chen, Patton, and Kenney

2016). These IPR policies give rise to a common concern that patent counts measure the quantity but not the quality of inventions (Dang and Motohashi 2015). Against this background, we excluded the Chinese subsidiaries from the sample and re-estimated our main models.[7] The results show that on the three main NB models, the relation of *RESL* and *COML* retain their direction of impact. The *IPR* variable, however, changes its direction. Thus, in the sample without Chinese subsidiaries, the level of IPR protection in the host country of the subsidiary has the expected positive relationship with all three dependent variables of the main analysis.

5. Discussion

To summarize, our main findings show a positive relationship between MNE resources allocated to subsidiaries and the subsidiaries' innovative output measured by their priority patent applications. This is in line with extant research that identifies, for example, a positive relationship for resources invested into R&D and firms' patenting. Our findings show that the relationship holds for the share of an MNE's total assets (minus intangible fixed assets) allocated to its subsidiaries. This measure includes R&D (for example, in particular machinery and equipment) but refers to all current and long-term assets of a firm. This is consistent with the view that, beyond R&D, a firm must commit additional resources, including various kinds of capital stock, in order to generate creative and novel outputs for commercialisation (Bell 2009).

The identified positive relationship applies both for the patenting of subsidiaries in technological areas in which their MNE possess specialisation advantages and for subsidiaries that seek patents in other technological areas. The latter might be surprising given the argument, proposed by Cantwell and Mudambi (2005), that competence-augmenting subsidiaries that are engaged in diversification away from the main lines of their MNE's business activity find themselves more tightly resource-constrained (in the sense of Penrose 1959). However, our data showed a high correlation between the number of priority applications of subsidiaries within and the number outside areas of MNE specialisation (see Annex 4). This is in line with extant research that points to the fact that

[7] Results available upon request.

subsidiaries usually engage in both competence exploiting and competence augmenting activities (Criscuolo et al. 2005; Zander 1999).

The main contributions of this article are in its insights regarding the role of resource commitment. We demonstrate a positive relationship between subsidiary commitment levels and the number of priority applications by subsidiaries, in line with H1. Thus, higher specificity, irreversibility, and sunk costs related to a subsidiary's assets are associated with higher patent output. This is in line with theoretical literature that suggests the irreversibility of investments is a key factor in explaining sustained competitive advantage (e.g., Ghemawat 1991; Pindyk 1991; Williamson 1985, 1988). Our further inspection indicates that this relationship between commitment and patent output is non-linear and follows an inverted U-shaped form, in line with H2. Thus, a subsidiary's patent output increases with its commitment level only up to a threshold, beyond which higher commitment levels are associated with declining numbers of total priority applications. This might reflect cognitive barriers to learning from trial and error (Liu et al. 2018), a lack of flexibility that is needed to enable the subsidiary to bear the costs of instituting innovations and exploring new ideas in advance of an actual need (Rosner 1968), or systemic lock-in of R&D activities in particular locations (Narula 2002).

In line with H3, we find that the positive relationship between subsidiary commitment level and patents applied for holds also for the absolute number of priority applications by subsidiaries in technological areas its parent MNE specialises in. Yet, this is not true for the absolute number of priority applications outside technological areas of MNE specialisation. Finally, the robustness analysis indicates a positive but non-linear relationship between subsidiary commitment levels and the share of priority applications by multinational subsidiaries related to technological areas with a technological advantage of the MNE in its total priority applications ('relative specialisation'). The functional form follows, as in the case of subsidiaries' total priority patent applications, an inverted U-shaped form. These findings support the view that specialisation tends to require not only extensive but also continuous replenishment of development efforts of subsidiaries (Cantwell and Mudambi 2005) and that the existence of specific resources encourages the specialisation of business activity (Chatterjee and Wernerfelt 1991). Yet, the considerations regarding cognitive barriers, inflexibility and systemic lock-in, outlined above, apply in particular to subsidiaries patenting in technological areas with MNE specialisation.

5.2 Limitations

First, we employ a knowledge production function with patent-based dependent variables. Patent statistics are an output indicator for innovation and a reliable measure of innovative activity (Acs, Anselin, and Varga 2002). Codified knowledge represented by patents is closely linked with, and complementary to, tacit knowledge (Mowery, Oxley, and Silverman 1996). Yet, we need to acknowledge that not all innovative activities result in patents, either for strategic reasons (Cohen et al. 2002) or due to the nature of the particular innovative activities (OECD 2015). Therefore, our findings apply (more narrowly) to innovations that take the form of patentable inventions. Corresponding limitations apply when generalising the findings to subsidiaries' innovation more broadly.

Second, the empirical investigation of this article is based on a pooled regression approach using negative binomial models. Thus, we cannot infer a causal relationship between resource commitment levels and patent output, due to potential endogeneity that may result from an omitted variable, simultaneity, measurement error, or selection bias (see Wooldridge 2010 for an overview). However, the effects of a third variable on both resource commitment and inventions at the same time, or whether past inventions also affect resource commitment, remain is theoretically unclear and should be subjected to further investigation. At this stage of the research, our arguments, hypotheses, and interpretations are strictly limited to correlations between the key independent variables and the dependent variables in question.

5.3 Future research

Our research on the relationship between resource commitment levels and inventions by multinational subsidiaries opens several opportunities for future research. First, our investigation focused on resources and their commitment in its most aggregated form, by considering total assets. We did this for good reason, yet future research could consider commitment level variables based on different asset-specificity/irreversibility of resources linked to investments, including physical capital such as machinery and equipment used for R&D, intangible assets such as human capital, or organizational capital related to linkages with the local eco-system of subsidiaries.

Second, our investigation took a holistic view of all subsidiaries of MNEs and did not investigate differences in resource commitment levels between domestic and foreign subsidiaries. Yet, it is possible that location, foreign vs. domestic, could affect the level of resource commitment.[8] For example, stronger enforcement of IPR positively affects the investment of resources associated with knowledge sourcing rather than support-oriented foreign R&D (Ito and Wakasugi 2007). Host country characteristics, such as the institutional environment, influence both the location of MNE R&D activity and the level of MNE resource commitment (Le Duc 2020). Thus, future research could consider how IPR protection moderates the relationship between resource commitment levels and innovative outputs by foreign subsidiaries.

Third, this research considers the relation between resource commitment and inventions by accounting for inventions in technological areas with or without specialisation by the MNE. This could be extended by future work that considers whether there are differences in resource commitment by differentiating diversification into inventions in related and unrelated knowledge areas (Breschi et al. 2003). Perhaps, this could further explain our current finding of no significant relation between resource commitment for diversification-associated inventions. Diversification into related variety might be associated with higher and unrelated variety with lower resource commitment by MNEs.

Finally, future studies could set out to further untangle slack resources and commitment. The extent to which the relationship between slack resources (both absorbed and unabsorbed) and innovation is the result of their 'slack nature' or their differences in commitment levels remains unclear, although some preliminary propositions have been forwarded. This is despite the large literatures on both commitment (e.g., Ghemawat 1991; Pindyk 1991; Williamson 1985, 1988) and slack resources (Bourgeois 1981; Chandler et al. 2011; Kim et al. 2017; Nohria and Gulati 1996).

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[8] In our sample, 74% of the subsidiaries are foreign, 77% of the priority patents belong to domestic subsidiaries. Foreign subsidiaries patent relatively more outside technological areas in which their MNE possess a specialisation advantage, although the difference with domestic subsidiaries is limited.

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Annexes

Annex 1: Existing commitment measurements

Measurement	Used by	Data source	Operationalisation
# of years active in location	Petersen and Pedersen (1999)	Mail survey	Which year did the first contact with the market take place?
Irreversibility	Pedersen and Petersen (1998)	Mail survey	To what extent has the firm dedicated assets in a given country that cannot be re-deployed without the loss of value (1-5 scale)
	Randøy and Dibrell (2002) Tan et al. (2007)	Mail survey	To what extent can investments not be transferred to other markets? (1-7 scale)
	Li and Li (2010)	National Bureau of Statistics of China	Fixed asset ratio at industry level – the ratio of fixed assets to total assets of of all firms in a three-digit industry
	Wennberg, Folta, Delmar (2006)	Statistics Sweden	Fixed assets to total industry assets
	Wennberg, Folta, Delmar (2006)	Statistics Sweden	Intangible assets divided by total assets in each industry
	Folta et al. (2006)	Compustat	Average leverage in the target industry: the inverse of total industry long-term debt divided by total industry assets
Asset redeployability	Kim and Kung (2017)	Bureau of Economic Analysis	Asset redeployability score defined as the sum of weights of industries that use the asset among the industries listed by BEA. Industry weight in a given year is determined by: 1) one over the total number of BEA industries, 2) the number of all public (i.e., Compustat) firms in an industry over the total number of all public firms, and 3) the sum of market capitalization of all public firms in an industry over the sum of market capitalization across all public firms
Investment intensity in a location	Luo (2004)	Mail survey	New investment in the subsidiary during the past three years/start-up investment
Annual change in R&D expenditure	Neelankavil and Alaganar (2003)	Worldscope Disclosure database	Annual increase/decrease (%) of money spend on R&D in different locations
Relationship-specific investments	Maitland and Sammartino (2009)	Mail survey	Frequency of firm investing in equipment specific to its local long- term suppliers (4 point scale) and human capital investments specific to its suppliers (4 point scale)
Professional expatriates intensity	Luo (2004)	Mail survey	Total salaries of expatriates divided by a subsidiary's total salary

Annex 2: Overview of variables and measurements

Type	Variable	Measuring	Operationalisation	Adopted from
IV	*RESL*	Resource level	The share of a subsidiary' total assets minus intangible fixed assets in relation to its MNEs' total assets minus intangible fixed assets.	-
	COML	Commitment level	A subsidiary's fixed assets ratio. The fixed asset ratio is the ratio of fixed assets to total assets. Fixed assets are defined as all non-current assets (Intangible assets + Tangible assets + Other fixed assets) after depreciation.	Campa (1993); Li and Li (2010); Wennberg, Folta, and Delmar (2006)
DV	*App*	Innovative output	Number of priority patent applications[1] of the subsidiary per year	De Rassenfosse et al. (2013)
	SPEC	Absolute specialisation	The 'Revealed Technological Advantage' (RTA) index is used to measure a MNE's technological expertise in each technological field. RTAs are calculated for each year (2010–2019), taking the MNE patent stock in 2010 and cumulatively add patents per year. The annual sum of the MNE's subsidiary patents inside technological fields for which the MNE's RTA is larger than one is taken to reflect specialisation innovative activity by the subsidiary.	Le Bas and Sierra (2002); Zhang, Jiang, and Cantwell (2015)
	DIV	Absolute diversification	The 'Revealed Technological Advantage' (RTA) index is used to measure a MNE's technological expertise in each technological field. RTAs are calculated for each year (2010–2019), taking the MNE patent stock in 2010 and cumulatively add patents per year. The annual sum of the MNE's subsidiary patents inside technological fields for which the MNE's RTA is smaller than one is taken to reflect diversification innovative activity by the subsidiary.	Le Bas and Sierra (2002); Zhang, Jiang, and Cantwell (2015)
	SPEC2	Relative specialisation/diversification	This is the ratio of the sum of a subsidiary's annual priority patent application and the sum of its annual priority patent applications within technological fields, in which the corresponding MNE possesses a revealed technological advantage.	-
Control	*NACE*	Subsidiary industry	Industry Classification (NACE Rev. 2 4-digit level)	Burger et al. (2018)
	Age	Subsidiary experience	Years since establishment	Isobe, Makino, and Montgomery (2000); Ferraris, Bogers, and Bresciani (2020)
	EMP	Subsidiary employees	Total number of employees	Ciabuschi and Martín (2011); Dellestrand and Kappen (2012)
	Countries	MNE geographic scope	Number of countries in which the MNE is active	-
	MultiSub	MNE internationalisation	The number of MNE subsidiaries outside of the MNE home country	-
	TP	MNE absorptive capacity	Total number of priority applications by the MNE parent (excluding any subsidiary applications)	-
	NoSub	MNE size	Total number of MNE subsidiaries	-
	TR	Location	Technological Readiness based on the Global Competitiveness Index in the subsidiary's host country	-
	Inno	Location	Innovativeness based on the Global Competitiveness Index in the subsidiary's host country	-
	IPR	Location	Intellectual Property Rights in the subsidiary's host country	-

Abbreviations: IV = Independent Variable, DV = Dependent Variable

Annex 3: Descriptive summary statistics of used sample

Variable	Count	Min.	Mean	Max.
App	242,680	0	17	26,866
SPEC	242,680	0	88	90,198
DIV	242,680	0	22	19,259
RESL	242,680	0	0	96
COML	242,680	0	0	382
SPEC2	242,680	0	1	1
NACE	87,536	0	0	0
Age	242,680	0	25	442
EMP	242,680	0	4,453	961,000
Countries	87	0	0	0
NoSub	242,680	0	410	14,805
MultiSub	31,548	0	1	1
TP	236,654	0	445,202	1,542,002
TR	20,044	5	6	6
Inno	29	3	4	5
IPR	161,919	5	70	95

Abbreviations: App = Number of priority patent applications, SPEC =Specialisation, DIV = Diversification, RESL = Resource level, COML = Commitment level, SPEC2 = relative specialisation, NACE = Industry Classification, Age = Age of subsidiary, EMP = Employees (Sub), Countries = Number of countries in the dataset, NoSub = Number of MNE subsidiaries , MultiSub = Share of foreign MNE subsidiaries to all MNE subsidiaries, , TP = Total Patents (MNE), TR = Technological Readiness (MNE), Inno = Innovativeness (MNE), IPR = Intellectual Property Rights Index in MNE home country).

Annex 4: Correlation table

	No Sub	Multi Sub	Coun tries	TP	TR	Inno	IPR	EMP	TA_ Sub	FA _Sub	INT	No Pat	App	Age	NACE	FA _MNE	TA _MNE	SPEC	DIV	COML	RESL	COML_ SQ	SPEC2
NoSub	1.00	0.06	0.59	-0.08	0.05	0.02	0.07	0.02	0.04	0.04	0.04	0.01	0.00	0.04	0.05	0.22	0.83	0.00	0.02	0.02	-0.18	0.04	-0.21
MultiSub	0.06	1.00	0.16	-0.31	0.19	0.18	0.28	0.00	0.00	0.00	0.03	0.02	-0.03	0.13	0.05	0.01	0.05	0.00	0.00	-0.03	0.02	-0.03	0.06
Countries	0.59	0.16	1.00	-0.15	0.13	0.08	0.14	0.07	0.07	0.06	0.08	0.07	0.01	0.07	0.09	0.46	0.39	0.05	0.05	-0.05	-0.41	-0.01	-0.27
TP	-0.08	-0.31	-0.15	1.00	-0.57	-0.32	-0.78	0.04	0.01	0.00	-0.02	0.00	0.07	-0.30	-0.23	-0.03	-0.03	0.03	0.05	-0.04	-0.05	-0.06	-0.05
TR	0.05	0.19	0.13	-0.57	1.00	0.06	0.69	-0.02	-0.01	0.00	0.01	0.01	-0.04	0.20	0.16	0.03	0.01	-0.01	-0.02	-0.01	-0.01	0.01	0.01
Inno	0.02	0.18	0.08	-0.32	0.06	1.00	0.59	-0.01	0.00	0.00	0.01	0.04	-0.01	0.23	0.16	0.02	0.00	0.01	0.01	-0.05	0.00	-0.03	0.00
IPR	0.07	0.28	0.14	-0.78	0.69	0.59	1.00	-0.03	-0.01	0.01	0.02	0.02	-0.05	0.32	0.23	0.02	0.03	-0.01	-0.02	0.00	0.02	0.03	0.03
EMP	0.02	0.00	0.07	0.04	-0.02	-0.01	-0.03	1.00	0.75	0.68	0.49	0.34	0.32	0.10	-0.01	0.10	0.02	0.40	0.39	0.09	0.08	0.08	0.01
TA_Sub	0.04	0.00	0.07	0.01	-0.01	0.00	-0.01	0.75	1.00	0.94	0.65	0.34	0.32	0.08	-0.01	0.18	0.04	0.39	0.41	0.12	0.06	0.13	0.00
FA_Sub	0.04	0.00	0.06	0.00	0.00	0.00	0.01	0.68	0.94	1.00	0.71	0.31	0.30	0.08	-0.01	0.19	0.04	0.36	0.38	0.16	0.06	0.17	0.01
INT	0.04	0.03	0.08	-0.02	0.01	0.01	0.02	0.49	0.65	0.71	1.00	0.24	0.13	0.08	0.00	0.13	0.03	0.22	0.18	0.12	0.02	0.14	0.01
NoPat	0.01	0.02	0.07	0.00	0.01	0.04	0.02	0.34	0.34	0.31	0.24	1.00	0.56	0.09	-0.02	0.06	0.01	0.87	0.67	0.05	0.04	0.04	0.01
App	0.00	-0.03	0.01	0.07	-0.04	-0.01	-0.05	0.32	0.32	0.30	0.13	0.56	1.00	0.02	-0.03	0.05	0.01	0.66	0.65	0.02	0.04	0.02	0.01
Age	0.04	0.13	0.07	-0.30	0.20	0.23	0.32	0.10	0.08	0.08	0.08	0.09	0.02	1.00	-0.05	0.02	0.03	0.07	0.05	0.06	0.12	0.03	0.05
NACE	0.05	0.05	0.09	-0.23	0.16	0.16	0.23	-0.01	-0.01	-0.01	0.00	-0.02	-0.03	-0.05	1.00	0.08	0.02	-0.02	-0.03	-0.02	-0.02	0.05	0.00
FA_MNE	0.22	0.01	0.46	-0.03	0.03	0.02	0.02	0.10	0.18	0.19	0.13	0.06	0.05	0.02	0.08	1.00	0.20	0.06	0.07	0.02	-0.19	0.05	-0.11
TA_MNE	0.83	0.05	0.39	-0.03	0.01	0.00	0.03	0.02	0.04	0.04	0.03	0.01	0.01	0.03	0.02	0.20	1.00	0.01	0.02	0.04	-0.11	0.05	-0.16
SPEC	0.00	0.00	0.05	0.03	-0.01	0.01	-0.01	0.40	0.39	0.36	0.22	0.87	0.66	0.07	-0.02	0.06	0.01	1.00	0.74	0.04	0.05	0.03	0.03
DIV	0.02	0.00	0.05	0.05	-0.02	0.01	-0.02	0.39	0.41	0.38	0.18	0.67	0.65	0.05	-0.03	0.07	0.02	0.74	1.00	0.03	0.03	0.02	-0.05
COML2	0.02	-0.03	-0.05	-0.04	-0.01	-0.05	0.00	0.09	0.12	0.16	0.12	0.05	0.02	0.06	-0.02	0.02	0.04	0.04	0.03	1.00	0.08	0.95	0.06
RESL	-0.18	0.02	-0.41	-0.05	-0.01	0.00	0.02	0.08	0.06	0.06	0.02	0.04	0.04	0.12	-0.02	-0.19	-0.11	0.05	0.03	0.08	1.00	0.04	0.27
COML_SQ	0.04	-0.03	-0.01	-0.06	0.01	-0.03	0.03	0.08	0.13	0.17	0.14	0.04	0.02	0.03	0.05	0.05	0.05	0.03	0.02	0.95	0.04	1.00	0.04
SPEC2	-0.21	0.06	-0.27	-0.05	0.01	0.00	0.03	0.01	0.00	0.01	0.01	0.01	0.01	0.05	0.00	-0.11	-0.16	0.03	-0.05	0.06	0.27	0.04	1.00

Abbreviations: NoSub = Number of MNE subsidiaries , MultiSub = Share of foreign MNE subsidiaries to all MNE subsidiaries, Countries = Number of countries the MNE is operating in, TP = Total Patents (MNE), TR = Technological Readiness (MNE), Inno = Innovativeness based on the Global Competitiveness of the MNE home country, EMP = Employees (Sub), TA_Sub = Tangible Assets, FA_Sub = Fixed assets, INT = Intangibles (subsidiary), NoPat = sum of patents, App = Number of priority patent applications, Age = Age of subsidiary, NACE = Industry Classification, FA_MNE = Fixed assets (MNE), TA_MNE = Tangible assets (MNE), SPEC =Specialisation, DIV = Diversification, COML = Commitment level, RESL = Resource level, COML_SQ = Commitment level squared, SPEC2 = relative specialisation.

Annex 5: Results logistic regression model – Share of priority patent applications in MNE specialization area in total priority patent application by subsidiary (SPEC2)

	Estimate	Std.	Error	z	Pr(>|z|)
(Intercept)	0.891	0.024	36.480	< 2e-16	***
RESL	1.358	0.022	61.316	< 2e-16	***
COML	-0.080	0.022	-3.701	0.000	***
NACE	0.000	0.000	-3.269	0.001	**
Age	0.000	0.000	0.690	0.499	
EMP	-0.001	0.000	-2.708	0.007	**
Countries	-0.003	0.000	-15.181	< 2e-16	***
NoSub	0.000	0.000	-30.859	< 2e-16	***
MultiSub	0.000	0.000	21.524	< 2e-16	***
TP	0.000	0.000	-3.649	0.000	***
TR	0.000	0.000	-0.494	0.621	
Inno	0.000	0.000	-0.800	0.424	
IPR	0.000	0.000	-0.206	0.837	
Residual deviance	171,216				
Degrees of freedom	242,587				

*Significant codes: *** p < 0.001, ** p < 0.01, * p < 0.05*

Abbreviations: RESL = Resource level, COML = Commitment level, NACE = Industry Classification, Age = Age of subsidiary, EMP = Employees (Sub), Countries = Number of countries the MNE is operating in, NoSub = Number of MNE subsidiaries, MultiSub = Share of foreign MNE subsidiaries to all MNE subsidiaries, TP = Total Patents (MNE), TR = Technological Readiness, Inno = Innovativeness based on the Global Competitiveness of the host country, IPR = Intellectual Property Rights Index in the host country.

Annex 6: Results logistic regression model – Share of priority patent applications in MNE specialization area in total priority patent application by subsidiary (SPEC2 with COML_SQ)

<table>
<tr><th></th><th>Estimate</th><th>Std.</th><th>Error</th><th>z</th><th>Pr(>|z|)</th></tr>
<tr><td>(Intercept)</td><td>9.31E-01</td><td>2.49E-02</td><td>37.401</td><td>< 2e-16</td><td>***</td></tr>
<tr><td>RESL</td><td>1.39E+00</td><td>2.25E-02</td><td>61.907</td><td>< 2e-16</td><td>***</td></tr>
<tr><td>COML</td><td>-6.17E-01</td><td>6.56E-02</td><td>-9.409</td><td>< 2e-16</td><td>***</td></tr>
<tr><td>COML_SQ</td><td>7.03E-01</td><td>8.14E-02</td><td>8.632</td><td>< 2e-16</td><td>***</td></tr>
<tr><td>NACE</td><td>-4.84E-06</td><td>3.00E-06</td><td>-1.614</td><td>0.10645</td><td></td></tr>
<tr><td>Age</td><td>6.73E-04</td><td>3.30E-04</td><td>2.039</td><td>0.04148</td><td>*</td></tr>
<tr><td>EMP</td><td>-9.24E-07</td><td>3.28E-07</td><td>-2.813</td><td>0.00491</td><td>**</td></tr>
<tr><td>Countries</td><td>-2.69E-03</td><td>1.78E-04</td><td>-15.097</td><td>< 2e-16</td><td>***</td></tr>
<tr><td>NoSub</td><td>-1.68E-04</td><td>5.42E-06</td><td>-31.036</td><td>< 2e-16</td><td>***</td></tr>
<tr><td>MultiSub</td><td>5.04E-05</td><td>2.32E-06</td><td>21.737</td><td>< 2e-16</td><td>***</td></tr>
<tr><td>TP</td><td>-8.00E-08</td><td>1.88E-08</td><td>-4.258</td><td>2.06E-05</td><td>***</td></tr>
<tr><td>TR</td><td>-4.72E-05</td><td>8.11E-05</td><td>-0.583</td><td>0.5601</td><td></td></tr>
<tr><td>Inno</td><td>-1.64E-04</td><td>1.45E-04</td><td>-1.137</td><td>0.25537</td><td></td></tr>
<tr><td>IPR</td><td>-1.37E-04</td><td>2.29E-04</td><td>-0.6</td><td>0.54837</td><td></td></tr>
</table>

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Abbreviations: RESL = Resource level, COML = Commitment level, COML_SQ = Commitment level squared, NACE = Industry Classification, Age = Age of subsidiary, EMP = Employees (Sub), Countries = Number of countries the MNE is operating in, NoSub = Number of MNE subsidiaries, MultiSub = Share of foreign MNE subsidiaries to all MNE subsidiaries, TP = Total Patents (MNE), TR = Technological Readiness, Inno = Innovativeness based on the Global Competitiveness of the host country, IPR = Intellectual Property Rights Index in the host country.

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