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The changing roles of foreign-owned subsidiaries in India in organizationally decomposed innovation processes

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Abstract

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State of the Art: The emergence of a new geography of innovation?
The globalization of R&D has been witnessed for decades. However, the dispersion of innovative activities of MNCs has long remained limited to developed countries. Yet in the last decade the extent of knowledge creation of MNCs in emerging economies such as China or India has surged dramatically. After all, they offer MNCs a highly skilled labour force and novel knowledge sources at low costs. Consequently, some argue that these developments may lead to the emergence of a ?new geography of innovation? which may shake the foundations of today?s economies of OECD countries.
Nevertheless, the literature on the organization of international business offers only meagre evidence on spatially and/or organizationally decomposed creation of knowledge and the role of subsidiaries therein. Even literature which takes the intra-firm creation of knowledge in account often treats knowledge as yet another good to be sourced and transferred, ignoring its exceptional characteristics. The ways in which knowledge is shared and created in collaboration networks remains underexplored.
Research gap: How is the structure of knowledge interactions shaped?
The actual knowledge interactions within MNCs leading to innovation elude the analysis of aggregated data such as R&D expenditures and patents. In return, qualitative studies, which describe single innovation events in-depth, lack the possibility to generalize findings and find determinants of the observed practices. In the ?black box? of intra-firm knowledge creation, the subsidiary role and its development over time and relation to possible determinants remain hidden.
This paper focuses on the creation of knowledge within MNCs and the roles Indian subsidiaries play therein, hereby providing answers to the following research guiding questions: What are the structures of interactions Indian subsidiaries participate in? How do these structures develop over time and how do they relate to the innovativity of the subsidiaries?

Last but not least the question as to whether or not these structures are affected by the knowledge base the innovators are located in is tackled.

Theoretical arguments: Determinants and effects of subsidiary roles

From the vast literature on MNC organization, three generic subsidiary roles in knowledge production will be derived: Autonomy, dependency and interdependency. These roles represent constellations in which employees of a subsidiary participate in knowledge creation. They can either create knowledge on their own, together with actors from the home country or in multi-site projects, involving actors from peer subsidiaries. It is suggested that the subsidiary role in the creation of knowledge constitutes its value for the subsidiary. Furthermore it is proposed that the roles of a subsidiary in knowledge production changes over time, on the one hand because of paradigm shifts in international business organization, on the other hand because of learning processes with increasing subsidiary experience. Furthermore, the author proposes that the innovativity of a foreign-owned subsidiary is associated with its role. Finally, possible relations between the knowledge base a foreign firm draws upon and its subsidiary?s role are elaborated on.

Method: Using relational patent data

The above-mentioned research gap is addressed by the use of patent data. Even though it is primarily used as an input or output indicator for innovation on an aggregated level, patent data holds a potential to provide relational data on the creation, sharing, transfer and diffusion of knowledge which led to an innovation. This potential is exploited by the analysis of data on the structures of (co-) inventorship data to identify subsidiary roles of Indian subsidiaries.. Together with the explanatory analysis of this data by logistic regressions, this paper sheds light on the extent, characteristics, dynamics and determinants of the participation of Indian subsidiaries in the intra-firm innovation networks of MNCs.

Results

First of all, the paper shows that interdependent knowledge creation with Indian participation is still rarely conducted. However, the subsidiary roles indeed evolved due to organizational paradigm shifts and to subsidiary experience towards autonomy and interdependency. Subsidiary innovativity and subsidiary roles are however not as tightly connected as expected. Furthermore, analytical knowledge, which is suggested to be rather codified and transferable, is more likely to be created in interdependent constellations.

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1. Introduction

Political and scientific observers in OECD countries may be resigned to the shift of a significant share of production activities to developing countries (ALTENBURG et al. 2007). Until the late 1990s, they took comfort from the remaining concentration of innovative, knowledge-intensive activities in the high cost countries of the 'triad' (BRUCHE 2009; CANTWELL 1995). This seemed to be grounded in a fundamental impossibility to relocate these activities to developing countries.
Yet during the last decade, both aggregate data and case study evidence indicate that the extent of knowledge creation of MNCs (multinational corporations) has surged dramatically in emerging economies such as China or India (UNCTAD 2005). Apparently, the organizational decomposition of production processes is followed by an organizational decomposition of innovation processes (ODIP) (STRAMBACH & SCHMITZ 2009) Consequently, some argue that these developments may lead to the emergence of a "new geography of innovation" which may shake the foundations of today's economies of OECD countries (BRUCHE 2009: 267).
Yet to announce such a dramatic inversion in the organization of the world economy may be somewhat premature, given that so little is known about the way the exploitation and tapping of innovation capabilities by MNCs happens in these countries. For instance, little is known about the roles of subsidiaries in emerging economies, for instance their degree of autonomy (ASAKAWA & SOM 2008), even though a high autonomy is thought to be necessary for a subsidiary to develop linkages with actors in the innovation system of the host country/region which in turn could trigger knowledge-spillovers to the host country (ZANFEI 2000)

The actual knowledge interactions within MNCs which would shed lights on these subsidiary roles have been eluding the analysis of aggregated data such as R&D expenditures and patents. At the same time, qualitative case studies lack the possibility to generalize findings and find determinants of the observed practices (KELLE 2007). The subsidiary role, its development over time and its relation to possible determinants remain hidden in the 'black box' of intra-firm knowledge creation. Consequently, the 'nature and organisation of R&D tasks in the newly developing regions of China and India' (ATHREYE & PREVEZER 2008) has remained a largely underexplored research area.

Hence, this study intends to contribute to this research area by focussing on the creation of knowledge and the roles Indian subsidiaries play therein, hereby providing answers to the following guiding research guiding questions: What are the 'structures of interactions' (ALTENBURG et al. 2007: 328) in the knowledge creating systems these subsidiaries participate in? How do these structures develop over time, how are they determined and how do they relate to the innovativity of the subsidiaries in question?

This study focuses on India because it has emerged as the most attractive destination for R&D investments (see JARUZELSKI & DEHOFF 2008, HERSTATT et al. 2008, UNCTAD 2005). Furthermore 83% of all patents featuring at least one Indian inventor are assigned to foreign applicants, illustrating the big role foreign-owned subsidiaries play in its innovation system (GUELLEC & VAN POTTELSBERGHE DE POTTERIE 2004).

In order to do so, an initial overview of the characteristics of cross-border knowledge creation within MNCs will be provided. In the subsequent section, three generic subsidiary roles in knowledge production are derived from the literature on MNC organization. Four hypotheses are postulated regarding the subsidiary role development, the relation of subsidiary roles to innovativity and the type of the created knowledge. The methods by which these hypotheses are tested are elaborated upon in section 3. The empirical findings will be presented and discussed in section 4. Furthermore, some limitations of this study are presented to encourage further research in this field, followed by concluding remarks on the 'new geography of innovation'.

2. Theoretical framework

To develop the theoretical framework guiding this study, it is necessary to emphasize on the characteristics of knowledge that influence the decomposability of its production. From that follow several implications for the labour division in knowledge production that is central to this analysis. In the next step, three distinct subsidiary roles are derived from a review of the international business literature. The combination of this literature strand with the characteristics of labour division in knowledge production provides the basis for the formulation of four hypotheses regarding the dynamics, determinants and impacts of subsidiary roles.

2.1 Characteristics of knowledge

As Gerybadze (2003) acknowledged, an understanding of the definition and characteristics of knowledge and its influence on the decomposability of tasks in innovation processes is required to analyze the international configuration of innovative activities. Due to the particular characteristics of knowledge its production, especially the labour division thereof, differs significantly from the production of tangible goods.

Following Stehr (2001), knowledge provides the 'ability to act'. Its value depends on the actor's capability to 'set something in motion'. To make use of knowledge, actors have to have the cognitive capabilities to interpret it and command the context the knowledge is related to. This so-called context-dependency of knowledge limits its transferability between contexts, distinguishing it not only from tangible goods, but also from information.

Since the importance of knowledge as a driving force of the modern society has been acknowledged throughout many scientific disciplines, many views on knowledge have been developed. For the purpose of this paper, two qualities of knowledge will be further elaborated on: Its tacitness and its path-dependency.

Tacitness

The term tacitness relates to knowledge which cannot, or is difficult to be articulated in form of symbolic representations such as writings, formulas or even natural speech. It is embodied in actors which 'know more that they can tell' (POLANYI 1966). Thus it cannot be transmitted or communicated to third parties without considerable efforts. The degree of tacitness decreases the extent of knowledge exchange between actors which are spatially separated, acting in different local contexts (DICKEN & MALMBERG 2001), are associated with different organizations (KOGUT & ZANDER 2003), do not share the same codes and languages (NOOTEBOOM 2010) or do not possess sufficient amounts of prior related knowledge (COHEN & LEVINTHAL 1990). Hence, its transfer or creation in transnational innovation networks over great spatial distances poses many challenges, even if it takes part within the same company. Even knowledge which is highly codified comprises tacit parts which prevent third parties from fully appropriating the knowledge and putting it to use. In fact, as all knowledge is bound to specific contexts, all knowledge has a certain tacit dimension. Fully codified knowledge that can be easily transmitted at low or even no costs does not exist (ANTONELLI 2006). At the same time, there are hardly any pieces of knowledge which are not codified at all (JOHNSON et al. 2002).

Especially important for this analysis is that actors who participated in the creation of novel knowledge (e.g. by taking part in an innovation process) possess high amounts of tacit knowledge about the innovation. Without possessing tacit knowledge, novel knowledge cannot be fully understood, even when it is codified, e.g. in a patent description. For instance, a discovery of new molecular structures can only be made because of the valuable results of many failed scientific experiments, which remain unpublished (ASHEIM et al. 2005). Hence, even though the results of this research are patented or otherwise codified, the scientists or engineers who participated in its discovery always know more than they *can or want* to tell about several problems that have occurred or may occur when applying the new technology.

Path-dependency

From the perspective of evolutionary economics, the accumulation of knowledge is characterized by path-dependency. Regarding knowledge, pre-existing knowledge influences the direction of learning trajectories of knowledge creating actors, as knowledge accumulation is subject to dynamic increasing returns, sunk costs, learning effects and self-reinforcing expectations. Employees and organizations require a certain degree of 'absorptive capacity' to make use of external knowledge resources and develop new knowledge in a particular technological field (ARTHUR 1989, COHEN & LEVINTHAL 1990). The path dependency of knowledge accumulation is considered to ultimately lead to technological specialization of organizations or regional economies (MARTIN & SUNLEY 2006).

In relation to processes of knowledge creation, this implies that actors being engaged in knowledge creation in a particular field have acquired the 'ability to act' in such a way that they can (and tend to) produce further novel knowledge along a technological trajectory (COHEN & LEVINTHAL 1990). It can be safely assumed that in subsidiary role development, the path-dependency of knowledge plays a role in the build-up of competencies and innovativity.

2.2 Labour division in knowledge production

In international business research, these characteristics appear mostly as influence factors on the intensity and directionality of exchange of knowledge between organizational units of the MNC. Yet there is a lack of research on the actual social processes leading to and occurring in the creation, production or generation of knowledge itself[1] (GERYBADZE 2003, MCFADYEN & CANNELLA 2004). In the following work, knowledge creation is both a localized practice which is physically performed at certain locations, and a collective process undertaken by a myriad of interacting and complementary actors, in which learning processes - not directed knowledge flows - connect interrelated places (IBERT 2007). These places are characterized by heterogeneous social, historical and structural contexts that shape how individuals learn and

[1] In this work, these terms are treated as synonyms for the same action.

generate knowledge. Accordingly, in a multinational corporation (MNC), each place is linked to locally rooted knowledge resources, e.g. local alliances, partnerships and supply relationships. In a process of knowledge creation, the MNC uses several methods to align, convert or transmit the diverse local knowledge resources in order to augment its knowledge base (AMIN & COHENDET 2005, SOLE & EDMUNDSON 2002).

These learning processes apparently gain importance in MNCs. Originally, innovations in MNCs have been regarded as originating primarily in the home-country, created in a single R&D centre which was geographically close to the corporation's headquarters (HQ). The resulting new products or knowledge were then diffused to subsidiaries in other countries. The primary role that subsidiaries outside the home country have been assigned to was the sale of these innovations to their local markets. The headquarters solely decided over R&D investments and strategies (ALMEIDA & PHENE 2004).

But in the last decades, theoretical and empirical research has changed the view on the creation of knowledge in MNCs. MNCs appear as primary actors of the generation of innovation on a global scale through the operation of in-house, globally dispersed R&D facilities. At first, the internationalization of R&D appeared to be accompanied by a continuing dominance of the home-country R&D centre. While the home-base remained dominant, subsidiaries have hardly been assigned to more than exploiting the knowledge of the headquarters and adapt it to the demands of the local market (GERYBADZE & REGER 1999, KUEMMERLE 1997, REDDY 1997).

Yet the innovation architecture of MNCs did not remain static. It supposedly evolves towards a transnational, distributed and open architecture of knowledge production. R&D subsidiaries are not just exploiting the home-base knowledge, but also augmenting it, as they are increasingly involved in the generation, use and transmission of knowledge by tapping knowledge from actors in the local business environment (KUEMMERLE 1997, ZANFEI 2000). This is indicated by a steady growth of the share of cross-border-patents since the 1960s (CANTWELL 1995), and the share of R&D spending abroad. While 91% of the 1000 most innovative corporations conduct innovation activities outside their home country, they spend an average of 55% of their R&D spending outside their home country (JARUZELSKI & DEHOFF 2008).

Increasingly, subsidiaries act as organizational units which are able to create knowledge on their own, as the knowledge creating MNC searches for options to gain access to tap into knowledge pools from around the globe in order to optimize location advantages and economies of scale of their R&D efforts (BIRKINSHAW & HOOD 2001, GASSMANN & VON ZEDTWITZ 1999). The MNC emerges as an organization, whose ownership ties allow access to globally dispersed units possessing distinct competencies and knowledge. The recombination and integration of these geographically dispersed knowledge resources may lead to an improved quality of innovation (ZANDER 2002).

Some even argue that MNCs only exist because of their ability to create, exploit and transfer (especially tacit) knowledge across borders more efficiently in intra-corporate mechanisms than external market relations (KOGUT & ZANDER 2003). One central challenge of the MNC is hence the transfer and creation of knowledge within organizational networks 'characterized by separation through time, space, culture and language' (AMBOS & AMBOS 2009). Knowledge is not only transferred from headquarters to subsidiaries, but also vice versa (YAMIN 1999). Furthermore it is also created in the interaction of several subsidiaries without the participation of the home-country R&D centre in cross-border innovation processes. Even though the transaction costs of management of these multi-site innovation processes are higher than the merely local operation of R&D activities, these costs appear to be outweighed by decreased time-to-market, improved effectiveness and enhanced learning capabilities (GASSMANN & VON ZEDTWITZ 1999).

2.3 Subsidiary roles

In the International Business literature, several approaches have been postulated that capture and simplify the variety of organizational architectures of MNCs and accordingly, the roles of subsidiaries therein. In the literature on subsidiary roles, the subject of knowledge creation is rarely touched, as it developed from the investigation of the role of subsidiaries in the production of tangible goods (e.g. WHITE & POYNTER 1984)

For the purpose of this study, three approaches on subsidiary roles were chosen which treat the subject of knowledge and its creation at least to a small extent. These taxonomies comprise the magnitude and direction of resources, which are exchanged between MNC entities in particular constellations, by the use of different management mechanisms of headquarters. They regard knowledge as one resource among many that are subject to exchange, transfer and labour division. Thereby knowledge is somewhat treated like information, which can easily be stored and transferred within the organization. They have been formulated by the three author duos of Bartlett & Ghoshal (1990), Gassmann & von Zedtwitz (1999) and Gupta & Govindarajan (1991). Even though the dimensions the authors use to distinguish their ideal types differ, the typologies show common constellations in which a subsidiary creates, diffuses and receives knowledge from other subsidiaries or the headquarters. From these approaches, three generic subsidiary roles are derived that distinguish different ways in which a subsidiary takes part in knowledge creation processes (see Figure 1): The *autonomous, dependent* and the *interdependent* role.

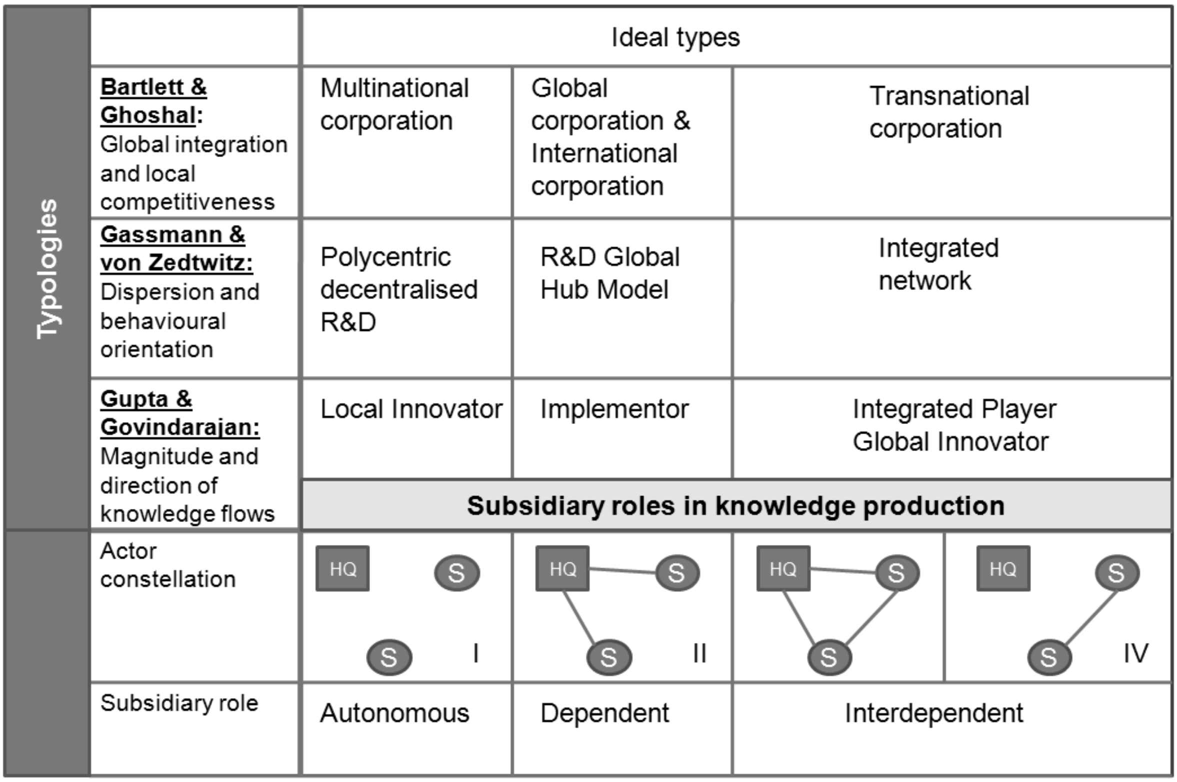

Figure 1: Subsidiary roles in ODIP (HQ=headquarters, S=subsidiary)
Source: Author's draft, based on BARTLETT & GHOSHAL 1990, GASSMANN & VON ZEDTWITZ 1999 and GUPTA & GOVINDARAJAN 1991

Autonomous subsidiary role

In the ideal types of the multinational corporation, the polycentric decentralized R&D or the local innovator the subsidiary is not tightly controlled to or linked with the headquarters or other subsidiaries. The MNC strategically aims at being sensitive for local markets and demands. New ideas and products are developed directly in the host countries. There are hardly any exchange ties between subsidiaries, as the central management regards its subsidiaries as a portfolio of independent companies. The R&D directors report to local management, not to a central R&D centre and the locus of strategic and operational decision-making over the knowledge creation process does lie within the observed subsidiary (O'DONNELL 2000, HARZING 2000).

It has been widely stated that autonomy of subsidiaries is required to establish tight linkages to the local context of the host country, enabling MNCs to tap into cluster knowledge of a variety of local contexts, learn from local innovation systems and make efficient use of local competencies (ZANFEI 2000, FOSS & PEDERSEN 2002, ALMEIDA & PHENE 2004, RUGMAN & VERBEKE 2001).

Knowledge which is created autonomously is primarily available to employees of the subsidiary, as they possess the tacit knowledge relevant to fully understand the novel knowledge. The subsidiary is enabled to develop its own unique resource profile to function without the rest of the firm (HARZING & NOORDERHAVEN 2006, BIRKINSHAW & HOOD 1998). By autonomous knowledge creation, subsidiaries can build a stock of knowledge which is only shared amongst its employees through frequent, casual interactions. Outsiders, who do not interact with the subsidiary and are not familiar with its norms of sharing knowledge, do not have access to this knowledge (SOLE & EDMUNDSON 2002). Subsidiaries that autonomously create knowledge resources have strong bargaining power in comparison to other subsidiaries or headquarters. Context-specific, tacit knowledge can constitute a subsidiary-specific advantage, when the knowledge gained is dispersed across several individuals in the subsidiary and superior to other affiliates. Furthermore, the created knowledge has to enable the MNC to make use of synergies (MUDAMBI & NAVARRA 2004, RUGMAN & VERBEKE 2001).

Dependent subsidiary role

Each of the above-mentioned typologies possesses an ideal type, in which each subsidiary is strongly dependent on knowledge inputs from the headquarters, while there are hardly any flows of resources between peer subsidiaries. Their scope of responsibilities is limited to predefined areas to reduce the risk of suboptimal resource allocation or duplication of R&D efforts. Subsidiary R&D is focused on the adaption of existing products to the local market. In some cases, instead of developing own knowledge resources, the subsidiary kind of supports the parent with certain knowledge bits. The control over R&D investments and projects is centralized in the strong R&D centre (BARTLETT & GHOSHAL 1990, GASSMANN & VON ZEDTWITZ 1999). Hence, constellation II is associated to this subsidiary role.

Most importantly, dependent knowledge creation does only to a limited extent involve the build-up of unique knowledge resources by the subsidiary, in contrast to autonomous knowledge creation. However, dependent knowledge creation can lead to an accumulation of knowledge in a distinct field of research on sides of the subsidiary, in which it may further its efforts to generate novel knowledge, maybe in autonomous ways (STRAMBACH & KLEMENT 2012).

Interdependent subsidiary role

This role is most common in Integrated R&D networks and the transnational corporation, in which the subsidiary role can be entitled as an Integrated player or an Innovator, being a provider and receiver of resourceful knowledge flows (BARTLETT & GHOSHAL 1990, GASSMANN & VON ZEDTWITZ 1999, GUPTA & GOVINDARAJAN 1991). The extent of lateral knowledge flows and linkages is significantly higher than in the other subsidiary roles. In an interdependent network, some subsidiaries assume strategic roles in the production of knowledge, which affect the entire company. The interdependent role can be considered to be associated with the business function of a Centre of Excellence. These centres possess sophisticated knowledge in a certain field of strategic importance to the firm. In the technological field assigned to this centre, it is responsible for creating, leveraging and sharing

knowledge with peer subsidiaries (MOORE & BIRKINSHAW 1998). Interdependent subsidiaries are taking part in R&D projects which are spread over multiple sites in the company. Knowledge is jointly created and diffused within the MNC (BARTLETT & GHOSHAL 1990, GASSMANN & VON ZEDTWITZ 1999). Accordingly, constellation III and IV of knowledge production correspond to the interdependent subsidiary role. Note that both constellations have been summed up under this role, because both constellations comprise multi-site R&D projects. Thus, a subsidiary plays an interdependent role in ODIP when it takes part in multi-site R&D projects, which may or may not involve the R&D centre but in any case peer subsidiaries.
Innovation processes, whose participants are spread over multiple sites, are at the same time very valuable and challenging for the MNC. On the one hand, the diversity of knowledge sources enables the MNC to make effective use of locally situated knowledge and unique expertise from a multitude of sites (GASSMANN & VON ZEDTWITZ 1999). On the other hand, the coordination problems occurring with the exchange of tacit knowledge over a distance certainly do not diminish with an increasing number of involved actors, as spontaneous interaction or mutual understanding is constrained and actors do not possess a common identity, knowledge and repertoire (SOLE & EDMUNDSON 2002).

2.4 Determinants of subsidiary roles

Based on this theoretical framework comprising three distinct subsidiary roles, four hypotheses are postulated. It is proposed that the roles of a subsidiary in knowledge production changes over time, on the one hand because of paradigm shifts in international business organization, on the other hand because of increasing subsidiary experience. Furthermore, it is proposed that the innovativity of a foreign-owned subsidiary is associated with its role in ODIP. Finally, possible relations between the knowledge base a foreign firm draws upon and its subsidiary's role are elaborated on.

Subsidiary role development over time

Subsidiary roles may differ between different time periods, implying that different organizational paradigms are followed by a majority of firms. Mostly through case studies and small sample quantitative studies, international business management literature played a role in discovering and labelling new organizational paradigms, which then spread throughout the firm population. There is reason to believe that also in this study's sample, that different time periods are characterized by different dominant subsidiary roles. Counter-intuitively, a high degree of subsidiary autonomy is considered to characterize the early stages of R&D internationalization, when high tariffs, high differentiation of local markets and the lack of effective communication technologies prevented the global integration of R&D subsidiaries, leading to rather polycentric networks of MNC units (BARTLETT & GHOSHAL 1990, GASSMAN & VON ZEDTWITZ 1999).

In the 1980s and early 1990s however, the global integration of R&D was apparently accomplished by following an organizational architecture with a dominant global R&D centre in the MNC's home country and highly dependent subsidiaries. Thereby economies of scale were achieved through realization of synergy effects and the avoidance of duplicate R&D (GASSMANN & VON ZEDTWITZ 1999).

Yet the global hub model is assumed to be suboptimal for the full exploitation of modern ICT for the organization of knowledge production and the achievement of economies of scope. Bartlett & Ghoshal (1990) and Gassmann & von Zedtwitz (1999) predicted that the organizational model which requires a high level of interdependency in the MNC is the upcoming model of MNC organization which can cope best with the challenges of globalization by combining global integration and local responsiveness. Here, the headquarters is not the only location of control and coordination. Instead, subsidiaries can even emerge as centres of excellence in specialized fields of technology, which may gain some competencies and control responsibilities usually reserved to headquarters (MOORE & BIRKINSHAW 1998). Yet this organizational model comes at the costs of having to establish sophisticated control institutions in the corporation. As central control seems to be inadequate, headquarters grant subsidiaries more autonomy, while connecting them more to other MNC entities than in the multinational model of business organization (GASSMANN & VON ZEDTWITZ 1999). Hence, it is postulated as the first hypothesis:

H_1: A graph of the occurrence of autonomous and dependent subsidiary roles over time follows a parabola, respectively an inverted parabola, while the significance of interdependent knowledge creation is supposed to have increased in a linear way.

Subsidiary role development with subsidiary experience

Changes in the role of subsidiaries in knowledge production may also occur because of the effects of subsidiary experience based on the path-dependent nature of knowledge. Central to this thought is the argument that the accumulation of knowledge enables subsidiaries to take part in knowledge production in roles different to its initial ones.

There is no clear picture though about the sequentiality of subsidiary roles and even less is known about subsidiaries in non-OECD countries. Some argue that autonomy is linked to the upgrading of competencies in a subsidiary, so that an increase in subsidiary experience over time should lead to higher autonomy and lower dependency (HOLM et al. 2003, CANTWELL & MUDAMBI 2005, HERSTATT et al. 2008). Yet there is also evidence that autonomy may be granted primarily in the starting phase of a subsidiary, to foster creativity and make it attractive for potential employees (ASAKAWA 2001).

Regarding the interdependent role, the complexity of knowledge production involving peer subsidiaries requires high organizational capabilities (GERYBADZE 2003) and the build-up of social relationships between employees (FOSS & PEDERSEN 2002). Hence, an increase of interdependency with subsidiary experience should be expected.

H_2: The more experience a foreign-owned subsidiary in India has accumulated in knowledge production, the more likely it is to create knowledge autonomously and interdependently.

Subsidiary innovativity

Whether autonomy is primarily the precondition or the result of innovative activity is not entirely clear. On the one hand, the higher the competencies of a subsidiary are, the less controllable are its (intangible) assets to headquarters (HOLM et al. 2003). Furthermore, the innovativity of a subsidiary may signal its competencies to headquarters and cause the granting of higher autonomy. This would speak for autonomy as a result of innovation. On the other hand, the employees of autonomous, self-determined subsidiaries apparently are more creative and highly motivated to create self-initiated innovations (ASAKAWA 2001, JOHNSON & MEDCOF 2007) and have a higher propensity to further develop their competencies (CANTWELL & MUDAMBI 2005). From this perspective, autonomy represents a precondition for innovativity. Nevertheless, both lines of thoughts point to the positive association of innovativity with the autonomous subsidiary role in ODIP.

Interdependency has overall been associated with a high degree of innovativity in a specialized technological field. Reddy (1997) shows in a survey of managers of 32 R&D units of MNCs in India that even though all the R&D centres maintain linkages to the parent's R&D in the home country, only the most advanced R&D units have established tight linkages to peer subsidiaries. This is also underpinned by empirical findings that those subsidiaries which possess the highest amount of knowledge also participate the most in knowledge exchange (FOSS & PEDERSEN 2002, MUDAMBI & NAVARRA 2004, GUPTA & GOVINDARAJAN 1991). Hence, it is proposed:

H_3: The innovativity of foreign-owned subsidiaries in India is supposed to be associated with higher subsidiary autonomy and interdependency and subsequently, lower degrees of dependency of the subsidiary.

Knowledge base and subsidiary roles

Since Pavitt's seminal article on the 'sectoral patterns of technical change' (1984), it is acknowledged that the organization of innovation processes differs across industries. To explore sectoral differences in subsidiary roles in organizationally decomposed innovation processes, the knowledge base approach (also called SAS typology, MANNICHE 2010) developed by the CIRCLE research group, was used. The term *knowledge base* refers not only to the area of knowledge itself, but to its embodiment in techniques and organizations as well (ASHEIM et al. 2005). It enables to show the broader organizational and geographical implications of different types of knowledge in terms of the organization of innovation processes, patterns of cooperation, spatial aspects and importance of various forms of proximity (ASHEIM et al 2012). Yet instead of distinguishing industries according to their knowledge-intensity (low tech vs. high-tech) or content (e.g. physics, biology, marketing, etc.), the SAS typology puts the epistemological characteristics of knowledge centre stage. The different knowledge types are defined by the learning processes prevailing in the development of knowledge and the evaluation criteria for the assessment of its usefulness (COENEN et al. 2005, MANNICHE 2010).

The taxonomy distinguishes between the analytical, synthetic and symbolic knowledge base. These three knowledge bases differ in relation to the importance of tacit and codified knowledge, possibilities and limits in the codification of knowledge, qualifications and skills required by organizations and institutions involved as well as specific innovation challenges and pressures (ASHEIM et al. 2005, COENEN et al. 2005). This distinction has to be regarded as referring to ideal types. In practice, industries may comprise all three types of knowledge bases. However in most industries, a particular knowledge base dominates its knowledge-creating activities (see ASHEIM 2007).

From a knowledge base perspective, industries drawing on a synthetic knowledge base (engineering, specialized machinery, automotive, shipbuilding) cannot use communication technologies as effectively as analytical industries in knowledge creation processes. As in synthetic industries knowledge creation is geared towards the creation and transformation of human-made systems to solve specific problems, e.g. to increase the efficiency, reliability or user-friendliness of existing or new solutions (ASHEIM et al. 2005, ASHEIM 2007), a higher amount of geographical/social/organizational proximity to exchange tacit knowledge is far more relevant in these industries than in analytical industries (e.g. biotechnology, pharmaceuticals, chemicals). In analytical industries however, knowledge exchange between actors appears to be less sensitive to separation by geographical, social or organizational distance. Co-location is less a driver of collaboration in knowledge production than the belonging to global epistemic communities, which understand and share the thoroughly codified knowledge (ASHEIM et al. 2012).

In fact, some empirical studies hint at the wider geographical scope and higher division of labour in science-based industries dominated by an analytical knowledge base (FRIETSCH & JUNG 2009). As analytical knowledge appears to be more decomposable across geographical distance, H_4 is proposed as follows:

H_4: Innovations which are based on analytical knowledge are more likely to be produced by subsidiaries in dependent or interdependent roles.

3. Methodology

From a methodological perspective, one of the central challenges of this study is to conduct a quantitative analysis of these processes which is able to identify both the roles played by particular actors in the knowledge creation process and the factors associated with these roles. Also, to investigate subsidiary role development, longitudinal data is necessary. In this study, this challenge is addressed by the use of patent data. Even though it is primarily used as an input or output indicator for innovation on an aggregated level, patent data holds a potential to provide relational data on the creation, sharing, transfer and diffusion of knowledge which led to an innovation.

Patents do not merely contain information on the knowledge content of an innovation, but also on the innovation process by providing data on names and addresses of inventor(s) and assignee(s) and references to other patents or scientific literature (TER WAL & BOSCHMA 2009). Hence, they can be considered as revealing the sources and relations between 'bits of knowledge' (ANTONELLI 2006) and their respective carriers of knowledge. This use of patents as relational data has evolved since the early 1990s and has recently gained popularity especially at the interface of social network analysis and innovation studies. For these purposes, especially the use of citation data and co-inventorship data has proven to be insightful (for citation data see ALMEIDA & PHENE 2004, for co-inventorship data see BRESCHI & LISSONI 2004, TER WAL & BOSCHMA 2009).

To gain insights on knowledge creation processes and the role of different entities of a firm therein, this study will employ co-inventorship data. Data on the inventor(s) of a patent can be regarded as the paper trail of the knowledge creation process which involves active communication and knowledge sharing (YAMIN & OTTO 2004).

It is common practice in patenting that the assignee of a patent refers to the holder of the intellectual property rights and thus lists the location of its headquarters (or the R&D headquarters) as assignee address, whereas the location of the technological or inventive activity resulting in the patent is given by the address of the inventors, which are assumed to work in their country of residence (BERGEK & BRUZELIUS 2010, ALMEIDA & PHENE 2004).

Table 1: Definitions and measurements of variables

Variable	Definition	Measurement
Dependent Variables: Subsidiary role		
AUTONOM	Autonomous subsidiary role	0/1; 1= only inventors with Indian residence listed
DEPEND	Dependent subsidiary role	0/1; 1= inventors from India and home country of assignee listed
INTERDEP	Interdependent subsidiary role	0/1; 1= patent file includes inventors from India, the assignees home country and at least 1 other country
Independent: Change of subsidiary roles over time		
TIME	Year of the patent application	Year of application - 1991
TIMESQ	TIME squared	(Year of application - 1991)[2]
Independent: Subsidiary experience		
TFIRM	Lifetime of subsidiary at point of patent application	(Year of application - application year of first patent applied by assignee involving Indian inventors)+1
PREVPAT	Number of previous patents at point of patent application	Rank in an order of patents of an assignee by application year - 1
Independent: Subsidiary innovativity		
PATCOUNT	Number of patents granted to an assignee involving Indian inventors	Count of patents granted to an assignee, which involve at least one inventor with residence in India
PATPERYEAR	Patents per year of an assignee involving Indian inventors	Count of patents granted to an assignee, / Maximum of TFIRM for the assignee
Independent: Knowledge base		
KB_ANA	Patent draws on an analytical knowledge base	0/1; 1= Patent is attributed with an IPC class assigned to the technological fields 10-15 (Schmoch et al. 2003)
Control variable		
INV	Number of inventors	Number of persons listed as inventor(s) in the patent file

Hence, the database underlying this study has been generated by acquiring granted USPTO patents which fulfilled the condition of listing at least one inventor with India as country of residence while being assigned to a patentee residing outside India. In summary, 4687 patents granted by the USPTO in the available time period 01.01.1972 and May 21, 2010 matched this condition. After excluding patents with unknown assignee or private person(s), research organizations, Indian-led corporations and governmental organizations as assignee(s), 3733 patents remained in the database.

For the purpose of conducting an explanatory analysis, the data was used to create several independent variables which reflect the change of subsidiary roles over time, subsidiary experience, extent of innovative activity in India and knowledge base on which the patent is drawn. These variables have been defined and measured according to Table 1 above and then attributed to each patent. The aim of the analysis is to find associations between the subsidiary role in which a patent is created (dependent variable) and the various independent variables by a logistic regression. A control variable INV based on the count of inventors listed in a patent was introduced to control for differing policies of crediting inventors on a patent.

In the following empirical analysis, logistic regressions were calculated for each dependent variable. They analyze the relations of the independent variables on the likeliness of each individual patent to be produced in a specific subsidiary role (cf. BACKHAUS et al. 2008).

In the folllowing empirical analysis, five logistic regressions have been computed for each subsidiary role: Two on the full dataset and two on a reduced dataset (comprising 3033 patents)[2], respectively including and omitting the control variable INV. In addition to that, the best-fitting model (indicated by a high pseudo r^2) is again computed with the exclusion of multicollinear variables. Validity and fit of the logit models are tested by likelihood-ratio tests, respectively McFaddens-R^2.

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[2] To exclude patents that only fulfilled the initial data acquisition criteria because of inventor mobility (cf. BERGEK & BRUZELIUS 2010), patents which matched any of the criteria below were excluded from the data base:

a. maximum of TFIRM < 3 years
b. PATCOUNT < 4
c. PATPERYEAR ≤ 0.2
d. only one Indian inventor in a group of more than 30 inventors
e. There is a time span of more than 10 years to the next patent of the same firm.

4. Empirical analysis

As shown in Table 2Table below, the most patents (49.9%) with Indian participation have been generated a dependent role, followed by the autonomous subsidiary role, which accrues to 40%. Only about 10% of all patents with at least one Indian inventor list inventors from a third country, indicating the marginal role of interdependent knowledge creation. Obviously, Indian subsidiaries rarely participate in truly global teams spanning several countries. The most Indian inventors still collaborate with inventors from the MNC home country, indicating a high dependency to headquarters.

Table 2: Significance of subsidiary roles in knowledge production

Subsidiary Role	Constellation	Count	Share (%)	First-named inventor		Share (%)
Autonomous	I	1509	*40.4*			
Dependent	II	1863	*49.9*	Foreign	1233	*66.2*
				Indian	630	*33.8*
Inter-dependent	III	141	*3.8*	Foreign	121	*85.8*
				Indian	20	*14.2*
	IV	220	*5.9*	Foreign	119	*54.1*
				Indian	101	*45.9*

Source: Author's calculations

Additionally, regarding the 'leadership' in innovation processes, Indian inventors are rarely listed as first-named inventors. The locations of first-named inventors are often used to assign patents to a single location, the location of the assumed 'leader' of the innovation process (see ATHREYE & PREVEZER 2008). As can be seen, following such an approach would underestimate the number of patents with Indian participation.

Another interesting picture is provided by the change of subsidiary roles over time. Seven time periods have been created, each comprising five years, starting with 1972-1976. Figure 2 shows the share of patents produced in the three subsidiary roles on all patents in the data base- The assumptions on the subsidiary role development over empirical time seem to be true for the autonomous and dependent subsidiary role. The curve of the interdependent subsidiary role however, reaches its peak in the years 1982-1986, after which it stagnates with little increases.

Regarding the total number of patents, a surging increase in the significance of Indian subsidiaries in knowledge creation processes can be observed, especially since the late 1990s.

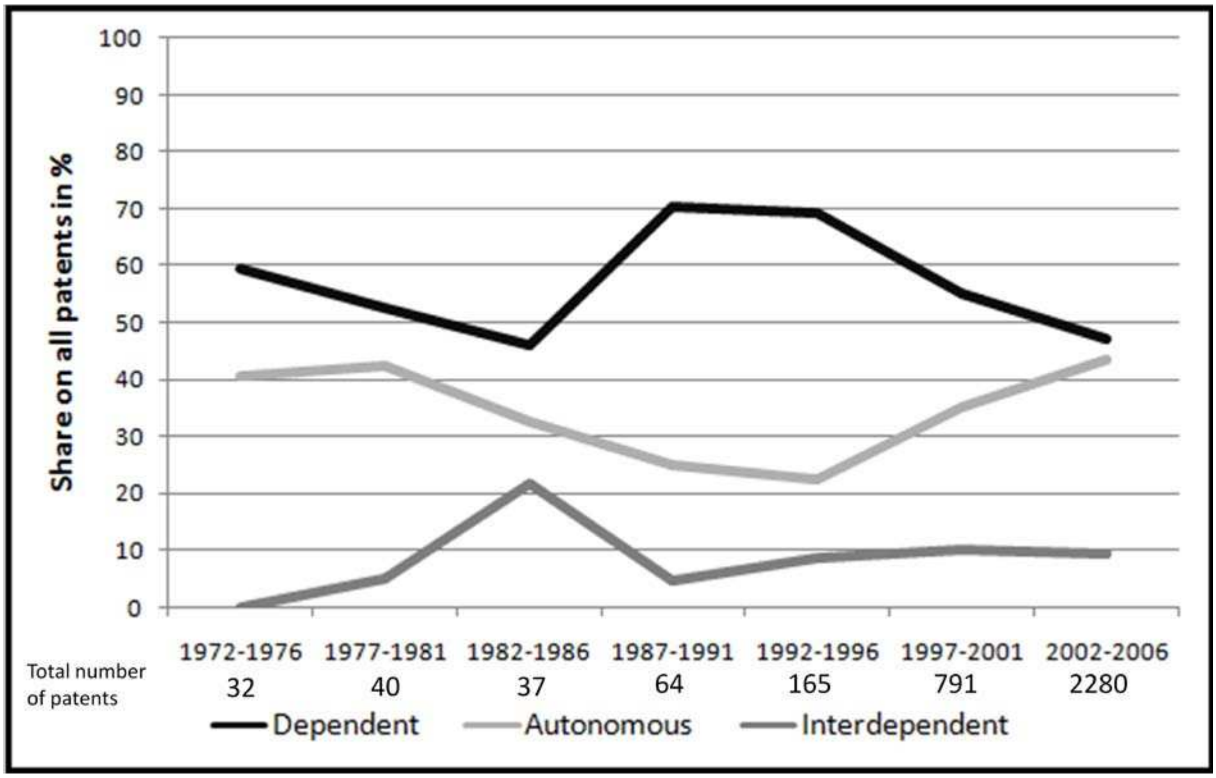

Figure 2: Significance of subsidiary roles in knowledge creation over time
Source: Author's calculations

To test the hypotheses as postulated in 2.4, for each subsidiary role five logit models have been calculated and named (a) - (e), thus resulting in 15 logistic regressions in total. The models differ in the used dataset and the inclusion of variables:

Model (a): Complete data base, control variable
Model (b): Complete data base, no control variable
Model (c): Reduced data base, control variable
Model (d): Reduced data base, no control variable
Model (e): The best-fitting model of the above without multicollinear variables (PATCOUNT)

In the following, these five models are presented for each subsidiary role. To keep the hypotheses in mind, the estimated signs are noted under the variable names.

Table 3: Regression results for the autonomous subsidiary role

Independent variables		Dependent variable: Autonomous subsidiary role				
		Full dataset		Reduced dataset		Model (a) mod.
		(a)	(b)	(c)	(d)	(e)
Time	TIME 0	0.006293	**-0.017318**	-0.025888	**-0.0385185**	0.0165158
		(0.52021)	(0.04143) *	(0.107157)	(0.002529) **	(0.085564)
	TIMESQ +	**0.001893**	**0.002213**	**0.002547**	**0.0029230**	**0.0032441**
		(0.02366) *	(0.00182) **	(0.022856) *	(0.001246) **	(4.89e-05) ***
Experience	TFIRM +	**0.080178**	**0.059735**	**0.046209**	0.0168065	**0.0443390**
		(< 2e-16) ***	(9.41e-16) ***	(0.000116) ***	(0.080388)	(3.36e-11) ***
	PREVPAT +	-0.001371	-0.000643	0.000302	0.0008019	**-0.0029128**
		(0.10927)	(0.35350)	(0.748543)	(0.289590)	(0.000309) ***
Innovativity	PATCOUNT +	**-0.004659**	**-0.003818**	**-0.004086**	**-0.0029522**	
		(1.94e-08) ***	(1.35e-08) ***	(5.51e-06) ***	(5.68e-05) ***	
	PATPERYEAR +	**0.098808**	**0.078930**	**0.081323**	**0.0599214**	**0.0446834**
		(6.51e-15) ***	(4.74e-14) ***	(5.42e-09) ***	(2.34e-07) ***	(2.86e-08) ***
K. base	KB_ANA -	**0.388402**	**-0.472035**	**0.587343**	**-0.4030315**	**0.4441749**
		(0.00504) **	(2.86e-05) ***	(0.000791) ***	(0.003641) **	(0.001161) **
Contr.	INV -	**-0.969093**		**-0.955634**		**-0.9620997**
		(< 2e-16) ***		(< 2e-16) ***		(< 2e-16) ***
	Intercept	**1.2713507**	**-1.1310657**	**1.916378**	**-0.5100513**	**1.1694428**
		(2.11e-14) ***	(< 2e-16) ***	(< 2e-16) ***	(0.000837) ***	(1.18e-12) ***
Likelihood Ratio		1485.975 ***	170.9700 ***	1194.133 ***	76.40672 ***	1453.849 ***
McFaddens R^2		0.2949978	0.0339412	0.2826372	0.01808457	0.2886202

Source: Author's calculations

Note: Regression coefficients, with corresponding p-values in paraphrases. Significant estimates are printed in bold.
Significance levels indicated by * (p-value<0.05), ** (<0.01), * (<0.001)**

Table 4: Regression results for the dependent subsidiary role

Independent variables			Dependent variable: Dependent subsidiary role				
			All data		Reduced dataset		Model (c) mod.
			(a)	(b)	(c)	(d)	(e)
Time	TIME	0	**-0.023942**	-0.0059167	-0.019690	-0.0005653	-0.0263489
			(0.00590) **	(0.47059)	(0.148356)	(0.96362)	(0.0510)
	TIMESQ	-	**-0.001630**	**-0.0020766**	-0.001600	**-0.0025097**	**-0.0024259**
			(0.02448) *	(0.00228) **	(0.098818)	(0.00464) **	(0.0093) **
Experience	TFIRM	-	**-0.056906**	**-0.0508648**	**-0.036640**	**-0.0198300**	**-0.0164795**
			(2.05e-12) ***	(9.28e-12) ***	(0.000668) ***	(0.03748) *	(0.0468) *
	PREVPAT	-	0.000922	0.0005370	0.000047	-0.0002684	0.0007955
			(0.20884)	(0.42984)	(0.954925)	(0.71961)	(0.3091)
Innovativity	PATCOUNT	-	**0.003073**	**0.0030473**	**0.002382**	**0.0020892**	
			(1.83e-05) ***	(4.90e-06) ***	(0.002630) **	(0.00377) **	
	PATPERYEAR	-	**-0.044858**	**-0.0466264**	**-0.034010**	**-0.0331242**	-0.0043614
			(4.40e-05) ***	(6.24e-06) ***	(0.006071) **	(0.00391) **	(0.5570)
K. base	KB_ANA	+	**-0.583915**	-0.0602242	**-0.874200**	-0.1779817	**-0.9283938**
			(3.74e-07) ***	(0.56054)	(9.70e-09) ***	(0.17964)	(9.99e-10) ***
Contr.	INV	+	**0.425652**		**0.474100**		**0.4723867**
			(< 2e-16) ***		(< 2e-16) ***		(< 2e-16) ***
	Intercept		**-0.420339**	**0.8010367**	**-0.855700**	**0.4701500**	**-0.8059850**
			(0.00202) **	(6.85e-12) ***	(1.00e-06) ***	(0.00167) **	(3.55e-06) ***
Likelihood Ratio			641.638 ***	106.9311 ***	561.7545 ***	46.34406 ***	552.6328 ***
McFaddens R^2			0.1239875	0.0206629	0.132506	0.01093159	0.1303544

Source: Author's calculations

Note: Regression coefficients, with corresponding p-values in paraphrases. Significant estimates are printed in bold.
Significance levels indicated by * (p-value<0.05), ** (<0.01), * (<0.001)**

Table 5: Regression results for the interdependent subsidiary role

Independent variables		Dependent variable: Interdependent subsidiary role				
		All data		Reduced dataset		Model (c) mod.
		(a)	(b)	(c)	(d)	(e)
Time	TIME +	**0.056114** (0.00113) **	**0.0645620** (0.000225) ***	0.169005 (0.00534)	**0.1975458** (0.00174) **	**0.0979450** (2.00e-06) ***
	TIMESQ 0	0.000307 (0.80143)	-0.0001484 (0.903817)	-0.003380 (0.29988)	-0.0056024 (0.09436)	
Experience	TFIRM +	-0.020237 (0.07848)	-0.0194245 (0.088742)	0.004783 (0.73454)	-0.0031853 (0.81810)	**0.0294759** (0.00875) **
	PREVPAT +	0.000432 (0.72664)	0.0002846 (0.818036)	-0.000560 (0.68613)	0.0001233 (0.92849)	-0.0002156 (0.86056)
Innovativity	PATCOUNT +	**0.003377** (0.01380) *	**0.0034110** (0.012608) *	**0.003966** (0.00962) **	**0.0049817** (0.00153) **	
	PATPERYEAR +	**-0.131380** (8.67e-07) ***	**-0.1336671** (4.67e-07) ***	**-0.137509** (4.96e-06) ***	**-0.1638152** (1.63e-07) ***	**-0.0673905** (7.91e-06) ***
K. base	KB_ANA +	**0.872552** (8.71e-10) ***	**0.9936898** (1.12e-12) ***	**0.859845** (2.29e-06) ***	**1.1652567** (2.68e-11) ***	**0.8068690** (1.26e-05) ***
Contr.	INV +	**0.110117** (1.82e-09) ***		**0.201701** (< 2e-16) ***		**0.2107861** (< 2e-16) ***
	Intercept	**-2.903495** (< 2e-16) ***	**-2.5009946** (< 2e-16) ***	**-4.224640** (< 2e-16) ***	**-3.3559369** (< 2e-16) ***	**-4.2142642** (< 2e-16) ***
Likelihood Ratio		172.9735 ***	126.0696 ***	217.8682 ***	143.6084 ***	210.8449 ***
McFaddens R^2		0.0729058	0.0531365	0.1229943	0.08107203	0.1190294

Source: Author's calculations

Note: Regression coefficients, with corresponding p-values in paraphrases. Significant estimates are printed in bold.
Significance levels indicated by * (p-value<0.05), ** (<0.01), * (<0.001)**

A more comprehensible overview of the findings in relation to the postulated hypotheses is given with Table 6. Here, above regression tables are summed up. It shows only the results which were consistent over all models. In parentheses the signs of the regression estimates as postulated by the hypotheses are given. Empirical results which matched the hypotheses are shaded grey.

Table 6: Overview of the empirical findings

Independent variables		Dependent Variables (Subsidiary roles) Autonomy	Dependency	Interdependency
Time	TIME	**0** (0)	**0** (0)	**0** (+)
	TIMESQ	**+** (+)	**0** (-)	**0** (0)
Subsidiary Experience	TFIRM	**0** (+)	**-** (-)	**0** (+)
	PREVPAT	**0** (+)	**0** (-)	**0** (+)
Innovativity	PATCOUNT	**-** (+)	**+** (-)	**+** (+)
	PATPERYEAR	**+** (+)	**0** (-)	**-** (+)
Knowledge Base	KB_ANA	**0** (-)	**0** (+)	**+** (+)

Source: Own draft: 0= no consistent results, +=positive relation, -=negative relation

The change of subsidiary roles over time

As stated in H_1, the autonomy of subsidiaries did not just increase in a linear way over the last decades. Apparently there was a phase in the 1980s/early 1990s, in which the dependent subsidiary role was more common than today. As shown in Figure 2 and underlined by the results of TSQUARE, the graph for autonomy is U-shaped. The results that can be regarded as robust also emphasize that today the autonomy of Indian foreign-owned subsidiary does not appear to be higher than in the starting phase (indicated by TIME). Interdependency did also not increase as much as was expected, hinting at the still low integration of Indian subsidiaries in global knowledge creation processes. This may underline the sequentiality of organizational paradigms proposed in the international business literature (see GASSMANN & VON ZEDTWITZ 1999), in which the starting phase of R&D organization can be characterized by highly autonomous, yet only locally active R&D. A good example in this sample is a patent (US3937810) by Unilever, which had been applied as early as 1974. It refers to the invention of a `Skin-lightening composition' that has been autonomously invented by the Indian subsidiary, most probably catering to the specific customer preferences in the Indian cosmetics market.

The change of subsidiary roles with subsidiary experience

The only robust results show that with increasing subsidiary experience (measured by subsidiary age), dependency appears to decrease. The results imply that knowledge resources of Indian subsidiaries have rather evolved initially in close connection with their headquarters. From an evolutionary perspective on knowledge, the findings show that Indian subsidiaries seem to have accumulated knowledge by high participation in labour division of knowledge led by the headquarters, which further enabled them to engage in autonomous knowledge production. Obviously the inclusion of Indian inventors in innovation projects led by the home base precedes the granting of further autonomy in knowledge production.

These results are in line with the exploratory survey of Herstatt et al. (2008) of managers of Indian subsidiaries. He found that the role of Indian subsidiaries has evolved from being adaptors or in-house contractors to local, respectively global developers, thereby increasing their autonomy. Similarly, Strambach & Klement (2012) showed how quickly Indian subsidiaries of German software firms move from knowledge-using roles such as bodyshopper and subcontractor, in which there is a high dependency on the parent firm to knowledge-creating ones associated with higher autonomy.

Subsidiary roles and subsidiary innovativity

Here the results are rather unclear. While a high innovation intensity (measured by PATPERYEAR) is associated with high subsidiary autonomy, subsidiaries with high number of total patents (PATCOUNT) are more likely to create knowledge and interdependently. A closer look at the most innovative subsidiaries revealed that indeed some of them only show shares of autonomous knowledge production below average. For instance, the Indian subsidiary of General Electric which was the most innovative foreign-owned subsidiary (407 patents) created only 24% of its patents autonomously. Even in recent years dependency has been the usual subsidiary role. The positive relation between PATCOUNT and interdependency matches the hypothesis insofar that innovative subsidiaries (most probably subsidiaries of large MNCs) are more able to take part in global multi-site R&D projects.

Subsidiary roles and Knowledge Bases:

As proposed in H_4, subsidiaries are indeed more likely to engage in interdependent roles when the knowledge to be produced stems from an analytical knowledge base. In these cases, more lateral networks between peer subsidiaries could be found. This finding indicates that there is a higher degree of labour division in knowledge production possible in industries based on analytical knowledge, due to the higher decomposability of knowledge. It enables effective knowledge exchange mechanisms over spatial distance. Similar to Asheim et al. (2012), industries based on analytical knowledge are associated with a wider geographical scope of collaborations in knowledge production. However the argument of higher decomposability of analytical knowledge is contradicted by the results that dependency and analytical knowledge base are not positively associated with each other. It may be supposed that the relationship to headquarters is substituted by interdependent relationships.

A closer look at the data revealed that in the industries Chemicals & Pharmaceuticals (defined by SCHMOCH et al. 2003) 19.1% of patents (524 in total) have been created interdependently, while in the synthetic industry machinery (76 patents) only 6.6% stem from interdependent subsidiaries in India. Even in the highly developed ICT/electrical industry only 6.9% of 2532 patents are created interdependently by Indian subsidiaries.

4.1 Limitations and further research

Despite providing several insights into the inclusion of Indian subsidiaries in ODIP, this study also has some shortcomings. Yet these can well be considered as starting points for further research on intra-firm R&D networks, in-depth analysis of cross-border collaboration in ODIP and external relations in host countries.

The identification of subsidiary roles by the examination of inventorship networks could be extended to cover the complete R&D networks of MNCs. The corresponding patent data exists, yet requires plentiful resources. Analyzing complete intra-firm network structure(s) in ODIP may permit a comparison between Indian subsidiaries and those in other countries. Furthermore, evidence could be gathered on the degree of technological specialization of subsidiaries in emerging economies. Eventually the analysis of intra-firm inventorship networks of MNC allows for quantitative examination of the existence of several organizational architectures proposed by international business literature. Thereby the low degree of interdependent subsidiary roles in ODIP could be put into a wider perspective.

This study focuses on intra-firm innovation networks. Yet deeper quantitative insights on inventor and assignee data of patents may also reveal to what extent subsidiary roles in intra-firm knowledge production are associated with the establishment of linkages with other innovating actors in the local business environment of the (developing) host country. For instance, one may test whether or not the autonomy of subsidiaries in a country enhanced the likeliness of the occurrence of co-patenting with external actors from this country.

5. Conclusions

In this study, relational patent data was used to identify three distinct roles of foreign-owned Indian subsidiaries in knowledge creation: Autonomy, dependency and interdependency. Together with the explanatory analysis of this data by logistic regressions, this study shed some light on the characteristics, dynamics and determinants of the participation of Indian subsidiaries in the intra-firm innovation networks of MNCs. Thereby this study can contribute to the debate on a 'new geography of innovation' and on the properties of subsidiary roles.

The proclamation of a 'new geography of innovation' with severe consequences for developed economies may not only be alarming, but also alarmist. Even though the upgrading of innovative capabilities in India has taken up pace in the 2000s, Indian inventors still contribute to the generation of a marginal number of patents. The empirical findings show that autonomous knowledge creation is still rare. Yet autonomous knowledge creation is necessary for subsidiaries to develop own technological specializations and gain tacit knowledge which is not freely mobile within the MNC. The build-up of tacit knowledge constitutes capability gaps between MNC affiliates and leads to the gain of specific advantages on behalf of the Indian subsidiary (RUGMAN & VERBEKE 2001). Yet considering the low degree of autonomy of Indian subsidiaries, these advantages are unlikely to accrue.

Furthermore, an important part of the argument for a new geography of innovation refers to the establishment of linkages between innovative MNC subsidiaries and actors in the host country's innovation system, fostering the upgrading of capabilities of actors in the host country (SCHMITZ & STRAMBACH 2009). Yet as pointed out before, the establishment of these linkages requires a certain degree of subsidiary autonomy. Given the low share of autonomous knowledge creation by Indian subsidiaries, MNCs may have not yet been able to tap the full potential of local competencies in India, for instance from research institutes, universities or domestic firms. In turn, Indian actors may not have been able to profit from knowledge spillovers from MNCs. Instead, negative impacts of foreign MNCs may ensue. For instance, domestic firms may be in an inferior position in the competition for the recruitment of highly skilled personnel (REDDY 1997).

Structures of interactions in ODIP

First of all the study showed that over time the autonomy of Indian subsidiaries has evolved in a U-shaped form. Yet similar to Gerybadze (2003), this study showed that MNCs are far from practicing the 'transnational solution' proposed by Bartlett & Ghoshal (1990). Only 10% of analyzed patents are interdependently created. Only rarely Indian employees take part in multi-site R&D projects. Obviously, the coordination costs for carrying out multi-site projects in R&D involving Indian subsidiaries are still quite high.

Furthermore, subsidiary roles also changed with increasing subsidiary experience. This study showed that subsidiary age is a better predictor of subsidiary roles than the number of previous patents. The empirical results suggest that subsidiaries start to create knowledge dependently. With increasing age, subsidiaries apparently loosen these ties to headquarters and begin to create knowledge independently. The findings imply that a parent-driven accumulation of knowledge is required for an Indian subsidiary to engage in autonomous knowledge creation. Obviously it is rather unlikely that a subsidiary initially accumulates knowledge autonomously, thereby signaling its competencies to the headquarters, which in turn integrates the subsidiary in its innovation network.

Interestingly, the interdependency of subsidiaries in ODIP is not influenced by subsidiary experience at all, but by the characteristics of the created knowledge. In this study, the knowledge base approach was applied to test for the decomposability of different types of knowledge. Indeed, analytical knowledge, which is suggested to be rather codified and transferable, is more likely to be created in interdependent constellations. These findings underpin sectoral differences in the organization of innovation processes, which apparently also apply for their decomposition onto spatially separated actors.

Last but not least the relation between innovativity and subsidiary roles is not as strong as suggested. Unexpectedly, the total number of patents assigned to a foreign subsidiary is unrelated or even negatively related to subsidiary autonomy. Together with the finding that the number of previous patents does not affect the role in which a patent is produced, one may draw the conclusion that subsidiary autonomy is not compulsory for a higher innovativity of a subsidiary.

In summary, this study was able to illuminate ODIPO within firms, with a particular focus on foreign-owned subsidiaries in India. Most importantly, it augmented the debate on the globalization of R&D with a detailed account of the inclusion of subsidiaries in an emerging economy in the innovation networks of foreign MNCs.

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