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Multistep Knowledge Transfer in Multinational Corporation Networks: When Do Subsidiaries Benefit From Unconnected Sister Alliances?

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In this paper, we explore under which conditions subsidiaries of multinational corporations can benefit from the external networks of sister subsidiaries in terms of new knowledge generation. We focus on the phenomenon of unconnected sister alliances—that is, alliances of sister subsidiaries with whom the focal subsidiary lacks a recent history of internal R&D collaboration. Whereas unconnected sister alliances provide knowledge recombination opportunities for the focal subsidiary, realizing them is challenging because of particular knowledge transfer frictions. In this paper, we theorize on how particular conditions (i.e., headquarters proximity, knowledge overlap, size of focal subsidiary's own alliance network) influence the strength of these frictions, resulting in hypotheses on how these conditions moderate the relationship between the number of unconnected sister alliances and the generation of new knowledge by focal subsidiaries. We rely on a panel data set of 2,258 R&D subsidiaries belonging to 118 firms in the pharmaceutical industry to empirically test our hypotheses. Jointly, our findings enrich our current theoretical understanding of how different types of external linkages

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and their interactions shape subsidiaries' generation of new knowledge. We also illuminate the opportunities and challenges that multistep knowledge transfer processes entail.

Keywords: *strategic alliances; cooperative strategy; knowledge transfer; social networks; multinational firm coordination*

Introduction

Multinational corporations (MNCs) reflect a network of subsidiaries, which are both internally linked and have their own external connections (e.g., Achcaoucaou, Miravittles, & León-Darder, 2014; Birkinshaw, Hood, & Young, 2005; Meyer, Mudambi, & Narula, 2011). Subsidiaries can take advantage of such internal and external linkages to generate new knowledge. Researchers (e.g., Almeida & Phene, 2004; Alnuaimi, Singh, & George, 2012; Andersson, Gaur, Mudambi, & Persson, 2015; Frost & Zhou, 2005) have extensively studied internal knowledge transfers between sister subsidiaries within the same MNC as well as knowledge transfers between a focal subsidiary and its external network.

At the same time, these research streams remained relatively silent on the knowledge generating implications of the interactions between internal and external networks (Easterby-Smith, Lyles, & Tsang, 2008; Najafi-Tavani, Giroud, & Andersson, 2014). This research gap is important as strong indications are present that via the internal network, subsidiaries can also benefit from the external networks of other subsidiaries, which belong to the same MNC (i.e., sister subsidiaries). Some scholars (e.g., Andersson, Forsgren, & Holm, 2002; Mudambi & Navarra, 2004), for instance, hint toward other subsidiaries as bridging-ties, providing focal subsidiaries the opportunity to recombine nonredundant knowledge that resides in the external network of sister subsidiaries. On the basis of knowledge network theory (Ghosh & Rosenkopf, 2015; Phelps, Heidl, & Wadhwa, 2012), however, we argue that realizing these opportunities is not straightforward, especially when the focal subsidiary and sister subsidiary are unconnected—that is, they have no recent history of internal collaboration. We expect that in the particular case of unconnected sister subsidiaries, knowledge transfer frictions (Ghosh & Rosenkopf, 2015) are likely to be present, complicating the identification, transmission, and reception of nonredundant knowledge that resides in the external network of these sister subsidiaries. In particular, we point to the lack of motivation of the sister subsidiary to act as knowledge broker, internal knowledge attenuation between sister and focal subsidiary, and information overload at the focal subsidiary as frictions that can hamper the realization of knowledge recombination opportunities from sister subsidiaries' external networks.

In sum, whereas the external network of unconnected sister subsidiaries entails important knowledge recombination opportunities for the focal subsidiary, particular frictions might jeopardize the ability to realize these benefits. The core objective of this study is therefore to examine under which conditions focal subsidiaries can benefit from the external networks of unconnected sister subsidiaries in terms of knowledge generation. Combining insights from knowledge network theory and MNC subsidiary network literature, we identify three conditions—that is, knowledge overlap between subsidiaries,

Figure 1
Conceptual Distinction Between Connected and Unconnected Sister Alliances

geographical proximity of focal subsidiary to headquarters, and size of focal subsidiary's own external network—that are likely to influence the core knowledge transfer frictions. Whereas we expect that knowledge overlap between subsidiaries and geographical proximity to the headquarters weaken particular knowledge transfer frictions, we anticipate that the size of the focal subsidiary's own external network strengthens particular frictions. Figure 1 provides a graphical representation of our research setting: a focal subsidiary within an MNC, having connected as well as unconnected sister subsidiaries, which each have their own external network.

To test our hypotheses, we have developed a unique panel data set (1995–2003) of 2,258 R&D subsidiaries belonging to 118 firms in the pharmaceutical industry. To capture the external network for each subsidiary, we focus on R&D alliances. We rely on scientific publications to measure subsidiaries' generation of new knowledge and to operationalize the presence of a recent history of R&D collaboration between subsidiaries.

Our findings generate new insights into the interplay of the different external networks in which MNC subsidiaries are embedded. Whereas our empirical findings support the notion of a “paradox of external embeddedness” (Andersson, Forsgren, & Holm, 2007; Meyer et al., 2011) for the external networks of connected subsidiaries, we identify an unexpected “synergy of external embeddedness” for the external networks of unconnected subsidiaries. We also contribute to a richer understanding of interorganizational knowledge transfer by framing the

transfer of knowledge from alliance partners of unconnected subsidiaries to the focal subsidiary as a multistep process (Ghosh & Rosenkopf, 2015). We point to particular frictions such a multistep process entails and explore under which conditions these frictions become more or less outspoken. In this way, we show how complex network structures within organizations influence the ability to successfully transfer knowledge across organizations.

Theoretical Background

In this section, we first identify R&D alliances of sister subsidiaries (i.e., sister alliances) as valuable sources of nonredundant knowledge for focal subsidiaries. Subsequently, we point to a number of frictions that can complicate the transfer of knowledge from the sister alliance partners to the focal subsidiary. Moreover, we argue that these knowledge transfer frictions are likely to be more salient when focal and sister subsidiary have no recent history of internal R&D collaboration.

Sister Alliances as Sources of Nonredundant Knowledge

Multiple scholars have theorized on how network characteristics influence the ability of individuals and entities to access, transfer, and absorb knowledge (see Phelps et al., 2012, for an extensive review). Collectively, we refer to this body of insights as knowledge network theory.

Knowledge network theorists explain that entities not only can gain access to valuable knowledge from their direct network of partners but also can benefit from their indirect network of partners (Ahuja, 2000; Hansen, 2002; Salman & Saives, 2005). Indirect ties emerge when a partner of the focal actor creates ties with other actors with whom the focal actor does not share a connection. Such indirect ties are important sources of nonredundant knowledge. In particular, the direct partner can point to specific knowledge residing in his or her network to which the focal actor has no direct ties (Hansen, 1999). Here, the direct partner acts as a “bridge” into a network of unknown actors for the focal actor, which increases the likelihood of identifying and accessing knowledge that is nonredundant (McEvily & Zaheer, 1999).

In the particular setting of MNCs, some scholars have already pointed to the opportunity for focal subsidiaries to benefit from the external network of sister subsidiaries. They argue that sister subsidiaries can play a role as “bridging-ties” (Andersson et al., 2002: 992), “listening posts” (Mudambi & Navarra, 2004: 389), or centers of excellence (Achcaoucaou et al., 2014), allowing the focal subsidiary to get access to valuable external knowledge.

Transferring Knowledge From Sister Alliance Partners to Focal Subsidiary

Extant research on knowledge transfer from external sources tends to frame this process as a dyadic one between one disclosing entity and one receiving entity (Larsson, Bengtsson, Henriksson, & Sparks, 1998). In our MNC setting, however, knowledge transfer not only entails the initial transmission of knowledge from the sister alliance partner to the sister

subsidiary¹ but also requires a subsequent knowledge transfer from the sister subsidiary to the focal subsidiary.

The organizational setting of MNCs stimulates internal knowledge transfers since subsidiaries share common organizational goals, cultures, and working practices (Gomes-Casseres, Hagedoorn, & Jaffe, 2006). Furthermore, MNCs can create an infrastructure to foster knowledge flows between subsidiaries, even when they are geographically dispersed or lack a history of intensive collaboration. MNCs can implement a wide variety of personal communication channels (i.e., liaison personnel, consultation and information meetings, and temporary task forces) to stimulate member-member exchanges across different subsidiaries, allowing for the transfer of both codified and noncodified knowledge components² (e.g., Ambos & Ambos, 2009; Gupta & Govindarajan, 2000). In addition, MNCs can adopt various human resource management practices—including financial compensations and promotions—to stimulate internal knowledge transfer (e.g., Andersson, Gaur, Mudambi, & Persson, 2015). We therefore expect that MNCs have the capacity to internally transfer knowledge of external partners between subsidiaries.

However, when knowledge flows from one network node to another, it might also encounter resistance. Ghosh and Rosenkopf (2015) refer to this phenomenon as knowledge flow friction. In our context, we point to three specific frictions that can hamper the identification, transmission, and reception of nonredundant knowledge from alliance partners of sister subsidiaries to the focal subsidiary. First, we argue that the sister subsidiary might lack the motivation to disclose nonredundant knowledge that resides in its alliance network, restricting the ability of the focal subsidiary to identify such knowledge. Second, we expect that because of information attenuation between sister and focal subsidiary, the transmission of knowledge from the alliance partner to the focal subsidiary can be hampered. Finally, we point to information overload at the focal subsidiary as a friction that can complicate the reception of knowledge from alliance partners of sister subsidiaries. Below, we discuss these three frictions in detail and explain why they are most pronounced when the sister subsidiary and focal subsidiary are unconnected, meaning that they lack a recent history of R&D collaboration.

Friction that hampers identification of knowledge. Even when the external network of sister subsidiaries provides potential access to nonredundant knowledge, such knowledge still needs to be identified by the focal subsidiary. The ability of the focal subsidiary to spot nonredundant knowledge heavily depends on the sister unit. Given its structural network position, the sister subsidiary can identify knowledge opportunities in its own external network that might be relevant for the focal subsidiary (Burt, 1992). However, actors in a knowledge brokerage position are not always willing to act accordingly. When competitive pressures are present, the willingness of the bridging actor to share knowledge opportunities might be limited (Hansen, 1999). Moreover, actors in a brokerage position not only can engage in *tertius iungens* behavior (i.e., introduce previously unacquainted network contacts to one another; Obstfeld, 2005) but also can demonstrate *tertius gaudens* behavior (i.e., intentionally maintaining separation among one's social network contacts; Rosenkopf & Schilling, 2007).

When the focal subsidiary and sister subsidiary are unconnected, we expect that the motivation of the sister subsidiary to act as knowledge broker is relatively limited. In the absence

of prior R&D collaboration, subsidiaries lack a history of extensive and frequent interaction. In this way, firsthand experiences, fostering the development of resilient trust, are lacking (Frost & Zhou, 2005; Parachuri, 2010). The absence of a trustful relationship increases the likelihood that the sister subsidiary categorizes the focal subsidiary as an entity with whom they have to compete for scarce corporate resources (Björkman, Barner-Rasmussen, & Li, 2004). Given such a framing, the disclosure of valuable information to another subsidiary is likely to be considered as an act that can reduce its own competitive position with the MNC (Birkinshaw et al., 2005). We therefore expect that when the focal subsidiary and sister subsidiary are unconnected, the motivation of the sister subsidiary to disclose nonredundant knowledge from its alliance partners is likely to be limited, hampering the focal subsidiary's ability to identify such knowledge.

Friction that hampers the transmission of knowledge. Next to identifying nonredundant knowledge, it needs to be transmitted from the initial source to the final receiver (Gupta & Govindarajan, 2000). Even when the knowledge broker is motivated to spot knowledge opportunities in its external network, there is a risk that as knowledge flows from one node to the other, information is lost or distorted because of miscommunication or misinterpretation (Szulanski, 1996). In the MNC setting, such information "attenuation" (Ghosh & Rosenkopf, 2015) not only can happen externally, when knowledge is transmitted from the external partner to the sister subsidiary, but also can take place internally, when knowledge is transmitted from the sister subsidiary to the focal subsidiary.

The risk of internal attenuation is especially high when the focal subsidiary and sister subsidiary are unconnected. In the presence of prior R&D collaboration, intensive interaction allows for building a shared language and common mental models (Kogut & Zander, 1992; Nahapiet & Ghoshal, 1998), which reduces the risk of attenuation. In the absence of a collaborative linkage, however, such shared language is likely to be limited, increasing the risk that nonredundant knowledge of the sister alliance partner is distorted when transmitting from the unconnected sister subsidiary to the focal subsidiary.

Friction that hampers the reception of knowledge. A final step in the knowledge transfer process is the reception of the nonredundant knowledge by the focal subsidiary. Reception of knowledge implies that the receiver actively processes the transmitted information (Gupta & Govindarajan, 2000). When receiving knowledge, the risk is present that the capacity of the receiver to process information is lower than the information-processing requirements (Daft & Lengel, 1986). In such a situation of information overload, additional information cannot be attended to or received accurately (Hansen & Haas, 2001).

The risk of information overload is especially present when the focal subsidiary and sister subsidiary are unconnected. Prior R&D collaborations allow entities to develop joint routines, which create a behavioral foundation for efficient and flexible communication (Kogut & Zander, 1992). However, in the absence of such collaborative history, processing information from an unconnected sister is likely to require substantial effort. In other words, the information-processing requirement associated with receiving nonredundant knowledge from alliance partners of unconnected sister subsidiaries is high, increasing the risk of information overload, which in turn complicates the reception of knowledge.

Hypotheses

When the sister subsidiary and focal subsidiary are unconnected, an interesting tension emerges. On one hand, alliances of an unconnected sister subsidiary are valuable sources of nonredundant knowledge. On the other hand, several frictions might complicate the transfer of such knowledge to the focal subsidiary, hampering the actual realization of knowledge recombination opportunities. In this section, we hypothesize on the extent to which focal subsidiaries can benefit from unconnected sister alliances. We first develop our baseline hypothesis, highlighting the knowledge recombination opportunities of an extensive network of unconnected sister alliances. Subsequently, we explain how three conditions influence the generation of new knowledge by the focal subsidiary.

Size of Unconnected Sister Alliance Network and Focal Subsidiary Knowledge Generation

In the alliance literature, it is well established that the number of direct alliances of a focal entity has a positive impact on its knowledge generation (De Man & Duysters, 2005). The underlying reasoning is that as the number of direct alliances increases, the external knowledge pool of the focal entity becomes larger, increasing the opportunity for recombining complementary knowledge of the alliance partners and the focal entity (Lahiri & Narayanan, 2013). In his seminal paper, Ahuja (2000) argued that next to the size of the direct alliance network, the size of the indirect alliance network positively influences the innovation output of the focal entity. In particular, he argued that whereas a large direct alliance network is valuable for recombining focused knowledge within a rather narrow technological scope, an extensive indirect alliance network is helpful in gathering and screening information on a broad scope of technological developments.

Whereas Ahuja (2000) considered indirect ties in terms of the partners of alliance partners, we focus in our MNC setting on a different type of indirect connection, that is, alliance partners of unconnected sister subsidiaries. As already mentioned, unconnected sister alliances are sources of nonredundant knowledge for focal subsidiaries. This means that as the number of unconnected sister alliances increases, the scope of nonredundant knowledge to which the focal subsidiary can get access expands. A larger knowledge pool implies a higher probability for the focal subsidiary of discovering options to recombine complementary knowledge and generate new knowledge (Fleming, 2001; Hargadon & Sutton, 1997). Other things being equal, focal subsidiaries with more unconnected sister alliances have more knowledge recombination options than subsidiaries with fewer unconnected sister alliances, which stimulates new knowledge generation:

Hypothesis 1: The number of unconnected sister alliances positively influences focal subsidiary's generation of new knowledge.

Conditions That Influence the Strength of Knowledge Transfer Frictions

Although external sources allow for the discovery of additional knowledge recombination options, the actual development of such options requires the transfer of knowledge to the focal actor (Ardichvilli, Cardozo, & Ray, 2003; Zahra & George, 2002). This implies that the extent to which focal subsidiaries can actually reap knowledge recombination benefits of an

extensive network of unconnected sister alliances depends on the extent to which particular knowledge transfer frictions can be addressed. Below, we point to three conditions that are likely to influence the strength of the previously identified knowledge transfer frictions.

Headquarters proximity. It is well established that MNC headquarters can stimulate subsidiaries' knowledge generation by providing headquarters' specific expertise and resources (Ciabuschi, Martin, & Stahl, 2010; Phene & Almeida, 2008). Apart from the expected positive direct effect on subsidiaries' knowledge generation, we argue that headquarters can help to counter the lack of motivation of unconnected sister subsidiaries to disclose knowledge of their alliance partners towards the focal subsidiary. Within MNCs, headquarters often function as a hub where alliance-related information from different subsidiaries is collected and stored (Vapola, Paukku, & Gabrielsson, 2010). In this way, headquarters can actively spot valuable nonredundant knowledge in the alliance networks of subsidiaries (Kale & Singh, 2007; Parise & Casher, 2003). This implies that when an unconnected sister subsidiary is less motivated to signal interesting knowledge in its alliance network to the focal subsidiary, the headquarters can "take over" this identification role. We therefore point to the headquarters and its function as alliance hub as a potential solution to circumvent the friction of limited motivation of unconnected sister subsidiaries to fully disclose nonredundant knowledge in their alliance network.

At the same time, the resources of headquarters to support the identification of nonredundant knowledge in the alliance network of sister subsidiaries are restricted (Dellestrand & Kappen, 2012). Identifying knowledge is a discretionary activity and therefore follows the path of least resistance (Reagans & McEvily, 2003). The identification of nonredundant knowledge by the headquarters for a focal subsidiary also requires deep insights into the knowledge needs of this latter entity. Information-processing literature (e.g., Daft & Lengel, 1986) indicates that as the scope of communication channels between two actors increases, it becomes easier for the sender to disclose knowledge and to have a good understanding of the knowledge needs of the receiver. This implies that the broader the scope of communication channels between the headquarters and the focal subsidiary, the more the headquarters can function as a knowledge broker for this subsidiary.

Research on knowledge flows between MNC headquarters and subsidiaries (e.g., Ambos & Ambos, 2009) has pointed to geographical distance as an important determinant of the scope of available communication channels. The lower the distance between headquarters and subsidiaries, the higher the likelihood of personal encounters and frequent action response. This implies that in the case of close proximity between the focal subsidiary and headquarters, information exchange is not only possible via impersonal channels but also can be realized via personal channels. In contrast, when geographical distance is high, direct contact becomes more difficult because of travel costs and different time zones (Baaij & Slangen, 2013; Bouquet & Birkinshaw, 2008). As a result, information exchange is more restricted to impersonal channels.

In sum, the closer the geographical location of the focal subsidiary to the headquarters, the broader the scope of communication channels between them. This increases the likelihood that the headquarters can compensate for the lack of motivation of the unconnected sister subsidiary to disclose nonredundant knowledge from alliance partners to the focal subsidiary. Therefore, we expect that the potential to reap knowledge recombination benefits of an extensive unconnected sister alliance network is higher when focal subsidiaries are geographically closer to the headquarters:

Hypothesis 2: Focal subsidiary's headquarters proximity positively moderates the relationship between the number of unconnected sister alliances and focal subsidiary's generation of new knowledge.

Knowledge overlap. Overlap in knowledge suggests that two parties have experience with solving similar types of problems and that the knowledge-processing systems of both parties function in a similar way (Lane & Lubatkin, 1998). Knowledge overlap implies the existence of a shared cognitive framework that facilitates communication and coordination between sender and receiver (Makri, Hitt, & Lane, 2010). Therefore, knowledge overlap between the focal subsidiary and its unconnected sister subsidiaries is likely to have a positive direct impact on new knowledge generation of the focal subsidiary.

Next to this direct effect, we expect that knowledge overlap can help to overcome two of the identified frictions in transferring knowledge from unconnected sister alliances to the focal subsidiary. First, we expect that knowledge overlap improves the ability of the focal subsidiary to identify nonredundant knowledge in the external network of the unconnected subsidiary. When knowledge overlap is high, it is easier for receiving subsidiaries to spot nonredundant knowledge as they can associate this with what they already know (Reagans & McEvily, 2003; Shane, 2000). As a result, focal subsidiaries become less dependent on the assistance of sister subsidiaries to identify nonredundant knowledge in their external network. In a setting of high knowledge overlap, the potential lower willingness of unconnected sister subsidiaries to support knowledge identification therefore becomes less problematic.

Second, we expect that knowledge overlap helps overcome the challenge of internal attenuation of knowledge when it is transmitted from the unconnected sister subsidiary to the focal subsidiary. When knowledge is transmitted, the risk of distortion is present (Ghosh & Rosenkopf, 2015). Knowledge overlap reduces this distortion risk as the unconnected sister and focal subsidiary have a shared cognitive framework, allowing them to better deal with equivocality (Parmigiani & Holloway, 2011). In this way, the risk of misunderstanding or misinterpretation, when transmitting alliance partner knowledge from the unconnected sister subsidiary to the focal subsidiary, is reduced.

In sum, we argue that when knowledge overlap between the focal subsidiary and unconnected sister subsidiaries is high, the ability of the focal subsidiary to identify knowledge in the external networks of sister subsidiaries is higher. Moreover, knowledge overlap facilitates knowledge transmission as it reduces the risk of internal attenuation of knowledge:

Hypothesis 3: Knowledge overlap between the focal subsidiary and unconnected sister subsidiaries positively moderates the relationship between the number of unconnected sister alliances and the focal subsidiary's generation of new knowledge.

Size of focal subsidiary's own alliance network. A core characteristic of MNCs is that their subsidiaries are embedded in their own external networks (Andersson et al., 2002). As mentioned before, extant alliance research (e.g., Ahuja, 2000) strongly suggests that the size of the direct alliance network positively influences knowledge generation as it increases the external knowledge pool to which an entity has direct access. Whereas the size of the focal subsidiary's own alliance network has an expected positive direct effect, we argue that it may hamper the ability of the focal subsidiary to receive nonredundant knowledge from the external network of unconnected sister subsidiaries. The larger the direct alliance network of the focal subsidiary, the more attention it will require to manage the knowledge pool associated

with this network (Rothaermel & Deeds, 2006). Given that the information-processing capacity of entities is constrained (Daft & Lengel, 1986), more attention to the direct alliance network automatically implies less capacity to process information from other sources. In other words, as the size of the direct alliance network increases, the capacity of a focal subsidiary to process information from the network of unconnected sister alliances is likely to be reduced.

Studying alliance networks at the firm level, Ahuja (2000) provided empirical evidence for the tension between direct and indirect alliance networks, reporting a negative moderating impact of direct ties on the relationship between indirect ties and innovation output. In the particular setting of MNC subsidiary networks, Andersson et al. (2007) also hinted toward the direct network of the focal subsidiary as a factor that restricts knowledge transfer from external networks of sister subsidiaries. Andersson et al. label this as the potential

paradoxical effect of external embeddedness: that is, on the one hand, a high degree of external embeddedness is important for the development of a subsidiary's competence, with some competence spilling over to other subsidiaries; but, on the other hand, a high degree of external embeddedness indicates that the subsidiary is largely involved in external business interactions, with the possible result that issues external to the MNC are prioritized. (803)

In sum, we expect that in the case of a large direct alliance network, the friction of information overload becomes more pronounced. In this way, knowledge transfer is more complicated, reducing the likelihood that the focal subsidiary reaps knowledge recombination benefits from its network of unconnected sister alliances:

Hypothesis 4: The number of focal subsidiary's direct alliances negatively moderates the relationship between the number of unconnected sister alliances and the focal subsidiary's generation of new knowledge.

In the above argumentation, we have focused on how particular conditions moderate the relationship between unconnected sister alliances and new knowledge generation of the focal subsidiary. Our theoretical argumentation focused on how these conditions weaken or strengthen particular frictions that hamper the ability to reap nonredundant knowledge benefits that unconnected sister alliances potentially entail. Following the guidelines of Andersson, Cuervo-Cazurra, and Nielsen (2014), we also briefly reflect on potential reverse interaction effects, referring to the possibility that the number of unconnected sister alliances moderates the direct relationship between the different conditions and the focal subsidiary's knowledge generation. First, we argued that headquarters proximity can directly influence the knowledge generation of focal subsidiaries as it increases the ability for the headquarters to provide support in terms of specific expertise. We do not see a theoretical reason why the presence of unconnected sister alliances would influence this supporting ability of the headquarters. Second, we theorized that knowledge overlap with unconnected subsidiaries has a direct positive impact on focal subsidiary's knowledge generation because it facilitates transmission of sister subsidiary specific knowledge. Also in this case, we see no theoretical arguments of why the effect of knowledge overlap would be different for different levels of unconnected sister alliances. In contrast, we do expect that the number of unconnected sister alliances moderates the relationship between the number of focal subsidiary's direct alliances and its knowledge generation. The reasoning is that unconnected sister alliances might capture the attention of the focal subsidiary, reducing the focal subsidiary's capacity to process information from its

direct alliance network. Fundamentally, the hypothesized and reverse interaction effect both capture the same substitution effect: processing information from one type of external network partner reduces the capacity to process information from another type of external network partner. In other words, the theoretical meaning of both interaction effects is similar.

Method

To test our hypotheses, we created a subsidiary-level panel data set covering 2,258 R&D subsidiaries of 118 firms in the pharmaceutical industry over the period 1995 to 2003. We rely on this industry because of its extensive R&D activities and the importance of R&D alliances (Hagedoorn & Wang, 2012). The firms are selected from the 125 highest R&D-spending European, U.S., and Japanese firms in the pharmaceutical industry on the basis of the 2004 EU Industrial R&D Investment Scoreboard. This list is complemented with the 31 largest patentees in biotechnology at the European Patent Office anno 2005. This resulted in an initial sample of 156 pharmaceutical and biotechnology firms. Subsequently, we limited the sample to those 118 firms that had at least one R&D alliance during our sample period.

To create the data set, we have collected data from different sources. First, we used information on scientific publications from Thomson Reuters' Web of Science to identify the R&D units of the sample firms, to operationalize internal linkages between subsidiaries, and to measure the level of new knowledge generation of R&D subsidiaries. Second, we used the SDC Platinum database to collect R&D-alliance information and connect them to specific subsidiaries. Because subsidiary performance is likely to be affected by firm- and country-level characteristics, we also collected information from Worldscope, World Bank, the Global Competitiveness Report, Compustat, and corporate annual reports.

Identification of R&D Units

We relied on publication data to operationalize the internal R&D structures of MNCs. First, we collected the full set of publications of the sample firms. For each firm, we searched for publications under the name of the parent firm as well as all their majority-owned subsidiaries. To do so, we relied on yearly lists of firms' subsidiaries reported in corporate annual reports, yearly 10-K filings in the United States, and for Japanese firms, information on foreign subsidiaries published by Toyo Keizai in the yearly Directories of Japanese Overseas Investments.³

We used the institution information listed on scientific publications of firms to identify all subsidiaries that engaged in R&D activities. Using names and addresses of entities listed on scientific publications, we could identify whether they represented the same subsidiary (Frenken, Hölzl, & de Vor, 2005). Our two criteria to match publications and R&D subsidiaries were (1) the city location and (2) the name of the subsidiary. We used annual reports and company websites to track possible changes of subsidiary names over time. The second author was in charge of the coding process of the R&D subsidiaries. A randomly selected 1% of the sample was used to verify the coding by another author. Following the same procedure, this author arrived at the same list of subsidiaries. Subsequently, we assigned publications to subsidiaries and calculated the number of publications for each subsidiary in the past 5 years. If a subsidiary had no publications during this time period, it was labeled as an R&D-inactive subsidiary, and it was not included in the analysis for this year. In total, our data set comprises 10,280 R&D subsidiary-year observations.

Dependent Variable: Subsidiaries' New Knowledge Generation

To measure new knowledge generation of R&D subsidiaries, we use a linear citation-weighted publication count. The variable *subsidiary new knowledge generation* is calculated as the sum of the number of subsidiary publications in year $t + 1$ and the number of forward citations to these publications.⁴ We used a fixed 4-year window to calculate the forward citations. It is important to note that we depart from the existing literature,⁵ which frequently uses patents to measure the performance of R&D activities (e.g., Almeida & Phene, 2004; Della Malva, Kelchtermans, Leten, & Veugelers, 2015). The main reason is that it is difficult to identify the origin of patents in MNCs. The patent applicant can be the subsidiary that developed the invention, but it can also be another subsidiary that is responsible for patent filings or that owns the patent for fiscal or other reasons (Griffith, Miller, & Connell, 2014). In the case of publications, the authors typically mention the name of the institution where the knowledge was generated rather than the firm's legal department or another subsidiary (Jaffe, 1986). Scientific publications can therefore be assigned in a more reliable manner to specific R&D subsidiaries, which was a crucial element of the research design for this study.

Independent Variables

Direct alliances. We collected data on R&D alliances from the Thomson SDC Platinum database by searching for all name variations of the R&D subsidiaries. We assigned all R&D alliances to specific R&D subsidiaries on the basis of the names and addresses reported in the alliance announcements. *Number of direct alliances* is measured by counting all operational R&D alliances of the focal subsidiary. Following extant research (e.g., Bos, Faems, & Noseleit, 2017; Grigoriou & Rothaermel, 2017), we assume that R&D alliances remain operational for 5 years after their formation.

Involvement in joint R&D projects: Connected and unconnected sister alliances. We make a distinction between *connected sister alliances* and *unconnected sister alliances*. Whether two R&D subsidiaries are connected is measured by the joint authorship of scientific publications. Joint authorship reflects the involvement in joint research projects and requires active knowledge exchange (Cockburn & Henderson, 1998). Research has shown that copublications are a reliable indicator for collaborative research projects in R&D settings (Frenken et al., 2005; Haustein, 2012; Hicks, Isard, & Martin, 1996; Melin & Persson, 1996).⁶

We checked whether members from two R&D subsidiaries belonging to the same MNC were listed as an author on the same scientific publication in the past 5 years. Accordingly, *connected sister alliances* is calculated as the number of R&D alliances formed by other R&D subsidiaries within the same MNC with which the focal R&D subsidiary had one or more copublications in the past 5 years. *Unconnected sister alliances* is calculated as the number of R&D alliances formed by other R&D subsidiaries within the same MNC with which the focal R&D subsidiary had no copublications in the past 5 years.

Headquarters geographical proximity. To measure the *geographical proximity* between the focal subsidiary and the headquarters, we used data on the city location for each subsidiary and the headquarters. On the basis of this information, we calculated the latitudes and longitudes of the locations. Next, we calculated the number of kilometers between the city

locations of the focal R&D subsidiary and the headquarters (d_{ij}), taking into account the surface of the earth (Bouquet & Birkinshaw, 2008). We used a negative power distance function and calculated proximity as $proximity = d_{ij}^{-0.1}$ to account for distance decay (Taylor, 1971).⁷ Proximity based on power distance functions ranges between 0 and 1 (i.e., the highest possible proximity).

Knowledge overlap. To measure the *overlap in knowledge bases* between the focal R&D subsidiary and the other R&D subsidiaries of the MNC, we relied on information of the scientific disciplines in which R&D subsidiaries published in the past 5 years. Each journal issue in the Web of Science is assigned to one or multiple discipline codes, the so-called Subject Categories (Haustein, 2012). We calculated for each R&D subsidiary the share of publications in the past 5 years that were assigned to each of the 216 Subject Categories. We used Jaffe's (1986) measure of technological proximity to calculate the extent to which the knowledge profiles of two MNC subsidiaries are similar. This measure correlates the vector of publication shares in each discipline code for each subsidiary-subsidiary combination. A value of 0 indicates that two subsidiaries have completely different knowledge bases, whereas a value of 1 shows that two subsidiaries have a perfect knowledge overlap in that particular 5-year period.

To examine the interplay between knowledge overlap on one hand and connected and unconnected sister alliances on the other hand, we created two separate knowledge overlap variables. First, the variable *knowledge overlap with connected subsidiaries* reflects the average level of knowledge overlap between the focal R&D subsidiary and sister subsidiaries engaged in alliances with whom it had joint R&D projects in the past 5 years. Second, the variable *knowledge overlap with unconnected subsidiaries* is measured as the average level of knowledge overlap between the focal R&D subsidiary and sister subsidiaries engaged in alliances with whom it did not have joint R&D projects in the past 5 years.⁸

Control Variables

The first set of control variables reflects country-level characteristics to acknowledge that subsidiaries of one firm often reside in different countries and are therefore exposed to different macrolevel influences. *Gross domestic product (GDP) per capita* in the host country accounts for heterogeneity regarding countries' economic performance and the sophistication of local markets (Belderbos, Leten, & Suzuki, 2013), which may affect the performance of subsidiaries. Moreover, we include *foreign direct investment (FDI) as a percentage share of GDP* in the host country to control for countries' openness to foreign firms. To control for heterogeneity in R&D investments across countries, we include *R&D expenditure as a percentage of GDP*, calculated as the country-level average over the years 1996 to 2004.⁹ The data for these measures were collected from the World Development Indicators from the World Bank. In addition, we control for country-level differences in the protection of intellectual property rights by including an annual *intellectual property protection regime* indicator from the World Economic Forum's global competitiveness report. This indicator ranges from 1 (*weak protection*) to 7 (*strong protection*).¹⁰

Second, subsidiary performance is likely to be influenced by firm-level characteristics. We control for the *number of sister R&D subsidiaries* and *firm sales per employee*. Firm sales per employee accounts for differences in performance at the firm level, which may also

influence knowledge generation at the subsidiary level. Next, we include the natural logarithm of *R&D expenditures* at the firm level to account for differences in R&D budgets between firms and within firms over time. We also control for the *share of firm publications in the home country* to control for a home orientation in R&D, which implies that an MNC invests relatively more R&D in its home country (Belderbos et al., 2013).

Finally, we control for characteristics of the focal R&D subsidiary. We include *relative size of the subsidiary* as larger R&D subsidiaries have more access to resources and might therefore be more efficient in their R&D activities (Minbaeva, Pedersen, Björkman, Fey, & Park, 2003). The relative size of an R&D subsidiary is measured by dividing the number of publications of the focal subsidiary by the number of publications of the firm, using a 5-year lagged window. A second measure considers the *basic research orientation* of the R&D subsidiary. We classified publications as reporting on applied or basic research on the basis of the journal in which they are published, using the CHI journal classification. This classification assigns Web of Science journals to one of four research levels in a spectrum ranging from very applied research (Level 1) to very basic research (Level 4; Della Malva et al., 2015; Hicks et al., 1996). The variable basic research orientation measures the share of publications of an R&D subsidiary classified in CHI Level 4, using a 5-year lagged window. We also control for the *average geographical distance* between the focal subsidiary and the other subsidiaries that belong to the same MNC. This variable is measured as the logarithm of the average distance between the focal R&D subsidiary and all other subsidiaries. Finally, we also control for the position of the focal R&D subsidiary in the MNC network. Occupying a more central position in a network is found to increase the number of knowledge flows that one receives (Powell, Koput, & Smith-Doerr, 1996), which is likely to increase the development of new knowledge. We construct *degree centrality* by counting the number of ties of the R&D subsidiary within the intrafirm network on the basis of the number of copublications in the past 5 years.

Estimation Method

Studying the performance implications of unconnected sister alliances at the subsidiary level implies that we deal with a multilevel structure in which R&D subsidiaries are nested in firms. Moreover, our dependent variable represents count data as observations can have only nonnegative integer values. In such a case, a multilevel count-data model is suggested. We estimate our models using multilevel mixed effects negative binominal regressions (i.e., using the *menbreg* function in Stata 15.0), which represents an extension of the regular negative binominal model by including normally distributed random effects at higher hierarchical levels. This model allows for both fixed and random effects while taking into account the count-data characteristics of the dependent variable and considering overdispersion parameters (StataCorp, 2013). To account for potential firm-specific time trends in our sample, we allow for random year slopes at the firm level. Finally, we consider a 1-year time lag between the dependent and independent variables.

Results

Table 1 shows the descriptive statistics and pairwise correlations of the dependent and independent variables. The correlation matrix shows relatively low correlations between the

Table 1
Summary Statistics and Correlations

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	<i>M</i>	<i>SD</i>
1. Knowledge generation <i>t</i> + 1	1																			200.75	1,059.57
2. GDP per capita in host country	.07 (.000)	1																		10.09	0.72
3. FDI (% of GDP in host country)	-.03 (.004)	-.06 (.000)	1																	2.75	3.16
4. R&D expenditure (% of GDP in host country)	.08 (.000)	.71 (.000)	-.18 (.000)	1																2.14	0.70
5. Intellectual property rights regime	.07 (.000)	.78 (.000)	.10 (.000)	.64 (.000)	1															5.58	0.71
6. Number of sister R&D subsidiaries	.02 (.086)	-.17 (.000)	.11 (.000)	-.18 (.000)	-.07 (.000)	1														49.04	37.96
7. Firm sales per employee	.05 (.000)	.05 (.000)	-.09 (.000)	.11 (.000)	-.07 (.000)	.00 (.738)	1													286.24	135.98
8. Firm R&D (log)	.05 (.000)	-.15 (.000)	.06 (.000)	-.15 (.000)	-.09 (.000)	.78 (.000)	.24 (.000)	1												13.49	1.60
9. Share of firm publications in home country	.05 (.000)	.12 (.000)	-.13 (.000)	.16 (.000)	.02 (.017)	-.55 (.000)	.16 (.000)	-.39 (.000)	1											0.68	0.24
10. Relative size subsidiary	.29 (.000)	.12 (.000)	-.06 (.000)	.16 (.000)	.08 (.000)	-.33 (.000)	-.08 (.000)	-.41 (.000)	.20 (.000)	1										0.06	0.17
11. Basic research orientation subsidiary	.12 (.000)	.11 (.000)	-.07 (.000)	.13 (.000)	.05 (.000)	-.10 (.000)	.02 (.109)	-.12 (.000)	.06 (.000)	.20 (.000)	1									0.20	0.30

(continued)

Table 1 (continued)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	M	SD
12. Geographical distance to other subsidiaries (log)	.01 (.240)	-.19 (.000)	.00 (.960)	-.18 (.000)	-.11 (.000)	.29 (.000)	.03 (.003)	.34 (.000)	-.24 (.000)	-.29 (.000)	-.14 (.000)	1								8.47	0.73
13. Degree centrality of subsidiary	.58 (.000)	.09 (.000)	.00 (.943)	.09 (.000)	.10 (.000)	.15 (.000)	.09 (.000)	.18 (.000)	-.05 (.000)	.19 (.000)	.13 (.000)	-.01 (.244)	1							1.06	2.40
14. Direct alliances of focal subsidiary	.41 (.000)	.09 (.000)	-.03 (.001)	.11 (.000)	.08 (.000)	-.05 (.000)	-.01 (.427)	-.04 (.000)	.04 (.000)	.38 (.000)	.09 (.000)	-.04 (.000)	.34 (.000)	1						0.54	2.45
15. Connected sister alliances	.25 (.000)	.02 (.021)	-.01 (.313)	-.00 (.721)	.04 (.000)	.19 (.000)	.01 (.514)	.20 (.000)	-.06 (.000)	-.02 (.042)	.06 (.000)	.06 (.000)	.47 (.000)	.05 (.000)	1					2.55	6.40
16. Unconnected sister alliances	-.06 (.000)	-.15 (.000)	.01 (.445)	-.15 (.000)	-.07 (.000)	.69 (.000)	-.04 (.000)	.55 (.000)	-.30 (.000)	-.29 (.000)	-.11 (.000)	.24 (.000)	-.07 (.000)	-.09 (.000)	-.06 (.000)	1				19.20	20.08
17. Geographical proximity to headquarters	.21 (.000)	.20 (.000)	-.04 (.000)	.24 (.000)	.14 (.000)	-.21 (.000)	-.01 (.353)	-.25 (.000)	.18 (.000)	.61 (.000)	.18 (.000)	-.44 (.000)	.23 (.000)	.44 (.000)	.00 (.830)	-.25 (.000)	1			0.51	0.15
18. Knowledge overlap with connected sister subsidiaries	.26 (.000)	.07 (.000)	-.02 (.100)	.06 (.000)	.05 (.000)	.09 (.000)	.07 (.000)	.13 (.000)	-.06 (.000)	.04 (.000)	.12 (.000)	.01 (.543)	.52 (.000)	.09 (.000)	.64 (.000)	-.12 (.000)	.05 (.000)	1		0.12	0.24
19. Knowledge overlap with unconnected sister subsidiaries	.06 (.000)	.02 (.055)	-.03 (.012)	-.00 (.816)	.00 (.745)	.05 (.000)	.00 (.579)	.07 (.000)	.01 (.641)	-.09 (.000)	.06 (.000)	.01 (.573)	.14 (.000)	.03 (.004)	.03 (.002)	.08 (.000)	-.07 (.000)	.08 (.000)	1	0.20	0.21

Note: Data shown in parentheses are *p* values. FDI = foreign direct investment; GDP = gross domestic product.

independent variables. The only correlations above the common threshold of .7 are firm R&D expenditures and number of sister R&D subsidiaries, which are both firm-level control variables, as well as the correlation between GDP per capita and either host country R&D expenditure or intellectual property rights regime, which are country-level control variables. We also ran models in which we removed one of the correlated variables and results remained robust.

Table 1 shows that R&D subsidiaries have, on average, a citation-weighted publication count of 201. There is substantial heterogeneity in new knowledge generation across the R&D subsidiaries as about 45% of the R&D subsidiaries do not receive any publications in a particular year. R&D subsidiaries have an average of 0.54 direct alliances, 2.55 connected sister alliances, and 19.20 unconnected sister alliances.

To test our hypotheses, we conducted stepwise multilevel negative binomial regression analyses (see Table 2, Models 1–6 for our main model specifications). Model 1 is the baseline model and includes only the control variables as well as the number of direct alliances and the number of connected sister alliances of the focal subsidiary. The results of the baseline model show that the level of GDP per capita in the host country of the focal subsidiary and the strength of the intellectual property rights regime positively influence new knowledge generation of this subsidiary. Moreover, subsidiaries of firms with larger R&D budgets and a larger share of firm publications in the home country have higher knowledge generation. Relatively large R&D subsidiaries and those that are more oriented towards basic research have, on average, higher knowledge generation. We also find that R&D subsidiaries that take a more central role within the intrafirm network (i.e., high degree centrality) have higher new knowledge generation. Finally, both the number of direct alliances and the number of connected sister alliances are positively and significantly related to new knowledge generation of the focal subsidiary.

The findings in Model 2 show that in line with our baseline hypothesis, the coefficient for the number of unconnected sister alliances is positive and significant. In a negative binomial regression model, exponentiated coefficients can be interpreted as multipliers. Hence, one additional unconnected sister alliance multiplies the new knowledge generation of a focal subsidiary by $\exp(0.02) = 1.02$, that is, an increase in new knowledge generation of around 2%.

In our conceptual part, we identified several frictions that can complicate the transfer from unconnected sister alliances to the focal subsidiary as well as conditions that influence these frictions. This resulted in a number of moderating hypotheses, which are tested in Models 3 through 6. The results of Model 3 show that the coefficient for headquarters proximity is negative and significant,¹¹ whereas the interaction between headquarters proximity and unconnected sister alliances is positive and significant. Since the coefficients cannot be interpreted in isolation, we report a graphical display of the semi-elasticities of unconnected sister alliances in the upper part of Figure 2. This semi-elasticity graph shows the percentage change of the dependent variable for one additional unconnected sister alliance (along the y-axis) for different values of headquarters proximity (along the x-axis). We observe that for average and high (mean + 2 standard deviations) levels of headquarters proximity, the number of unconnected sister alliances is positively and significantly related to focal subsidiary new knowledge generation. Unconnected sister alliances have no significant effect on the new knowledge generation of a subsidiary in the case of low headquarters proximity. At an average level of headquarters proximity (i.e., 0.50), each additional unconnected

Table 2
Unconnected Sister Alliances and New Knowledge Generation of Focal Subsidiaries

							Connected sister alliances
		Hypothesis 1	Hypothesis 2	Hypothesis 3	Hypothesis 4		
Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
GDP per capita in host country	.34 (.06) 5.41 (.000)	.34 (.06) 5.43 (.000)	.34 (.06) 5.40 (.000)	.26 (.06) 4.10 (.000)	.34 (.06) 5.40 (.000)	.26 (.06) 4.11 (.000)	.31 (.06) 4.92 (.000)
FDI (% of GDP in host country)	-.01 (.01) -1.61 (.108)	-.01 (.01) -1.54 (.124)	-.01 (.01) -1.38 (.166)	-.00 (.01) -.05 (.957)	-.01 (.01) -1.54 (.123)	.00 (.01) .01 (.990)	-.01 (.01) -1.61 (.107)
R&D expenditure (% of GDP in host country)	-.04 (.06) -.72 (.469)	-.04 (.06) -.66 (.506)	-.01 (.06) -.15 (.878)	.01 (.06) .22 (.822)	-.05 (.05) -.83 (.409)	.01 (.05) .21 (.832)	-.05 (.05) -.94 (.347)
Intellectual property rights regime	.16 (.07) 2.43 (.015)	.16 (.07) 2.36 (.018)	.12 (.07) 1.76 (.078)	.21 (.07) 3.19 (.001)	.15 (.07) 2.32 (.020)	.19 (.07) 2.85 (.004)	.21 (.07) 3.14 (.002)
Number of sister R&D subsidiaries	.00 (.00) 1.46 (.145)	-.00 (.00) -1.17 (.864)	-.00 (.00) -.08 (.939)	.00 (.00) .31 (.760)	-.00 (.00) -.25 (.800)	.00 (.00) .04 (.965)	.00 (.00) .18 (.855)
Firm sales per employee	.00 (.00) 1.45 (.147)	.00 (.00) 1.51 (.131)	.00 (.00) 1.52 (.127)	.00 (.00) 2.30 (.022)	.00 (.00) 1.59 (.113)	.00 (.00) 2.27 (.023)	.00 (.00) 1.40 (.162)
Firm R&D (log)	.44 (.05) 7.99 (.000)	.43 (.05) 7.80 (.000)	.42 (.05) 7.73 (.000)	.42 (.05) 7.74 (.000)	.44 (.06) 7.91 (.000)	.41 (.05) 7.82 (.000)	.41 (.05) 7.52 (.000)
Share of firm publications in home country	1.19 (.31) 3.85 (.000)	1.13 (.31) 3.64 (.000)	1.16 (.31) 3.77 (.000)	1.12 (.31) 3.65 (.000)	1.16 (.31) 3.68 (.000)	1.10 (.30) 3.66 (.000)	1.14 (.31) 3.67 (.000)
Relative size subsidiary	4.67 (.24) 19.62 (.000)	4.67 (.24) 19.66 (.000)	5.06 (.26) 19.40 (.000)	5.20 (.24) 22.01 (.000)	5.06 (.24) 20.75 (.000)	5.38 (.25) 21.08 (.000)	4.71 (.25) 18.89 (.000)
Basic research orientation subsidiary	1.90 (.11) 17.31 (.000)	1.90 (.11) 17.32 (.000)	1.88 (.11) 17.14 (.000)	1.62 (.10) 15.44 (.000)	1.85 (.11) 17.03 (.000)	1.59 (.10) 15.26 (.000)	1.78 (.11) 16.50 (.000)
Geographical distance to other subsidiaries (log)	.07 (.06) 1.30 (.193)	.07 (.06) 1.21 (.227)	.04 (.06) .63 (.530)	.08 (.06) 1.43 (.154)	.06 (.06) 1.11 (.266)	.09 (.06) 1.58 (.113)	.03 (.06) .44 (.660)
Degree centrality of subsidiary	.40 (.02) 19.93 (.000)	.40 (.02) 19.99 (.000)	.40 (.02) 20.03 (.000)	.34 (.02) 17.38 (.000)	.39 (.02) 19.91 (.000)	.34 (.02) 17.43 (.000)	.31 (.02) 15.88 (.000)
Direct alliances of focal subsidiary	.10 (.01) 6.69 (.000)	.11 (.01) 7.12 (.000)	.12 (.01) 7.47 (.000)	.08 (.01) 5.31 (.000)	.03 (.02) 1.85 (.065)	.04 (.02) 2.47 (.014)	.15 (.02) 8.52 (.000)
Connected sister alliances	.07 (.00) 12.94 (.000)	.08 (.01) 9.95 (.000)	.08 (.01) 9.80 (.000)	.08 (.01) 10.31 (.000)	.08 (.01) 10.04 (.000)	.08 (.01) 10.44 (.000)	.08 (.02) 3.48 (.000)
Unconnected sister alliances	.02 (.01) 2.31 (.021)	.02 (.01) 2.31 (.021)	-.01 (.01) -.77 (.441)	.00 (.01) .30 (.767)	.02 (.01) 2.23 (.026)	-.01 (.01) -.85 (.395)	.02 (.01) 2.40 (.017)

(Continued)

Table 2 (continued)

Variable	Model 1	Hypothesis 1	Hypothesis 2	Hypothesis 3	Hypothesis 4	Connected sister alliances	
		Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Geographical proximity to HQ			-.91 (.26) -3.51 (.000)			-.12 (.26) -.45 (.654)	-.05 (.24) -.21 (.830)
Geographical Proximity to HQ			.05 (.01)			.02 (.01)	
× Unconnected Sister Alliances			3.78 (.000)			1.99 (.046)	
Knowledge overlap with unconnected sister subsidiaries				1.69 (.18) 9.48 (.000)		1.67 (.18) 9.40 (.000)	
Knowledge Overlap With Unconnected Sister Subsidiaries × Unconnected Sister Alliances				.04 (.01) 5.53 (.000)		.03 (.01) 4.83 (.000)	
Direct Alliances × Unconnected Sister Alliances					.01 (.00) 5.80 (.000)	.00 (.00) 3.15 (.002)	
Geographical Proximity to HQ × Connected Sister Alliances							-.06 (.04) -1.72 (.086)
Knowledge overlap with connected sister subsidiaries							1.64 (.16) 10.10 (.000)
Knowledge Overlap With Connected Sister Subsidiaries × Connected Sister Alliances							.01 (.02) .51 (.607)
Direct Alliances × Connected Sister Alliances							-.01 (.00) -6.11 (.000)
Constant	-10.37 (.94) -11.04 (.000)	-10.17 (.94) -10.82 (.000)	-9.23 (.98) -9.37 (.000)	-10.16 (.92) -10.98 (.000)	-10.25 (.94) -10.84 (.000)	-9.92 (.96) -10.29 (.000)	-9.64 (.98) -9.79 (.000)
Lalpha (SE)	1.63 (.02)	1.63 (.02)	1.63 (.02)	1.59 (.02)	1.63 (.02)	1.59 (.02)	1.61 (.02)
Firm-level random effect (var)	1.69 (.17)	1.65 (.17)	1.61 (.17)	1.62 (.17)	1.73 (.18)	1.53 (.16)	1.65 (.17)
Wald chi-square	3,410.83	3,411.79	3,433.86	4,005.97	3,490.52	4,004.84	3,794.39
Log likelihood	-34,933.41	-34,930.79	-34,921.67	-34,770.14	-34,908.16	-34,870.31	-34,849.89
LR test vs. nbinoimial; chi-bar² (P>=chi-bar²)	813.55 (.000)	792.70 (.000)	763.25 (.000)	852.37 (.000)	821.62 (.000)	826.42 (.000)	803.80 (.000)
AIC	69,900.82	69,897.58	69,883.34	69,580.28	69,854.32	69,786.62	69,745.78

Note: Multilevel negative binomial regression. For each variable, the table reports the coefficient, standard error, *z* value, and *p* value (in this order). All regressions include random year slopes at the firm level. The total number of observations is 10,280 with 118 firms and 2,258 unique subsidiaries. In Model 7, we conduct a posthoc analysis in which we test the effect of the moderators on connected sister alliances. GDP = gross domestic product; FDI = foreign direct investment; HQ = headquarters; LR = likelihood ratio; AIC = Akaike information criterion.

Figure 2
Semi-Elasticities of Unconnected Sister Alliances for Different Values of Moderators

sister alliance increases subsidiary new knowledge generation by 1.6%. At high levels of headquarters proximity (i.e., 0.82), each additional unconnected sister alliance increases

subsidiary new knowledge generation by 3.1%. Jointly, these findings show support for Hypothesis 2 and indicate that the closer the focal subsidiary is situated to the headquarters, the more the headquarters can function as an alliance hub, facilitating the transfer of nonredundant knowledge from unconnected sister alliances to the focal subsidiary.

The findings in Model 4 show support for Hypothesis 3. The coefficient for knowledge overlap is positive and significant. In addition, the interaction term of unconnected sister alliances and knowledge overlap with unconnected sister alliances is positive and significant. The semi-elasticities of unconnected sister alliances are visualized in the middle part of Figure 2. Subsidiaries with an average knowledge overlap with their unconnected sisters do not show a significant increase in new knowledge generation for each additional unconnected sister alliance, while those subsidiaries with a high knowledge overlap with their unconnected sisters experience an increase in new knowledge generation of around 2.6% for each additional unconnected sister alliance. Jointly, these findings indicate that knowledge overlap can help to overcome knowledge identification and internal attenuation frictions that are associated with transferring knowledge from unconnected sister alliances to a focal subsidiary.

Model 5 examines the interplay between the number of direct alliances and the number of unconnected sister alliances. Whereas we hypothesized a negative interaction effect between direct alliances and unconnected sister alliances in Hypothesis 4, we find a positive and significant one (a coefficient equal to 0.01). This is also shown by the graph of the semi-elasticities of the number of unconnected sister alliances in the lower part of Figure 2. Our findings indicate that when the focal subsidiary does not have direct alliances, focal subsidiaries experience a 1.6% increase in new knowledge generation for each additional unconnected sister alliance. When the number of direct alliances is high (i.e., 5.44), focal subsidiaries experience a 4.2% increase in new knowledge generation for each additional unconnected sister alliance. We elaborate on the theoretical implications of this unexpected finding in the Discussion and Conclusion section.

Posthoc Analyses

As we expect that knowledge frictions are likely to emerge when a sister subsidiary and focal subsidiary lack an internal collaborative linkage, we focused on the phenomenon of unconnected sister alliances in our hypotheses. As we already described, we found, on average, a significant positive effect of the number of connected sister alliances on focal subsidiaries' new knowledge generation. Each additional connected sister alliance is associated with an increase in performance by 8.5%.¹² Moreover, a Wald test using the findings of Model 2 in Table 2 shows that the coefficient for unconnected sister alliances is significantly smaller ($\chi^2 = 170.30$; $P > \chi^2 = 0.00$) than the coefficient for connected sister alliances. These findings seem to confirm that connected sister alliances are a valuable knowledge recombination source as well and that realizing such opportunities is less challenging in this case.

To further delve into potential differences between connected and unconnected sister alliances, we also tested the effect of our moderators on the relationship between the number of connected sister alliances and subsidiary new knowledge generation (see Model 7 in Table 2). As Model 7 shows, we do not find significant positive moderation effects for headquarters proximity and knowledge overlap. For headquarters proximity, we even find a marginally significant negative interaction effect. These findings suggest that when the focal subsidiary is

geographically distant from the headquarters and/or knowledge overlap between focal and sister subsidiary is low, the existence of the collaborative linkage is a sufficient condition to allow for the transfer of knowledge from the connected sister alliance to the focal subsidiary.

The results in Model 7 show a significant negative interaction effect between direct alliances and the number of connected sister alliances, indicating that the number of direct alliances hampers the extent to which focal subsidiaries can benefit from connected sister alliances. This is in contrast to our finding for unconnected sister alliances, where the number of direct alliances was found to improve the extent to which focal subsidiaries benefit from unconnected sister alliances. In the Discussion and Conclusion section, we delve deeper into the implications of this interesting difference.¹³

We also conducted additional analyses to investigate a potential bias due to endogeneity regarding the relationship between the number of unconnected sister alliances and subsidiary new knowledge generation. To test for potential reversed causality, we carried out a Granger-causality test, following the procedure proposed by Dumitrescu and Hurlin (2012). We find that unconnected sister alliances Granger-cause subsidiary new knowledge generation but not the other way around. To rule out additional endogeneity concerns regarding the relationship between unconnected sister alliances and new knowledge generation of subsidiaries, we also applied an instrumental variable approach and estimated a two-stage linear panel-data regression of Model 2 in Table 2 that includes subsidiary fixed effects.¹⁴ In the first stage, we predicted the number of unconnected sister alliances. Our instruments in the first stage were the change in the number of sister R&D subsidiaries and the average intellectual property rights regime score of all other subsidiaries of the firm excluding that of the focal subsidiary. The instruments turn out to be relevant as indicated by the *F* statistics of the first stage and valid as indicated by a Sargan and Hansen-Basmann overidentification test. The results of the second stage provide robust results, showing a significantly positive effect of the number of unconnected sister alliances on focal subsidiary new knowledge generation.

Discussion and Conclusion

In this paper, we examined the phenomenon of unconnected sister alliances and their impact on new knowledge generation of focal subsidiaries within MNCs. Combining insights from MNC network literature and knowledge network theory, we identified and tested conditions that shape the ability of focal subsidiaries to benefit from unconnected sister alliances in terms of knowledge generation. In line with our expectations, we find that headquarters proximity and knowledge overlap increase the ability of the focal subsidiary to reap the knowledge recombination opportunities of unconnected sister alliances. In contrast to our expectations, we find that an extensive direct alliance network can also be helpful in this respect. Additional analyses demonstrated that these conditions play out differently when considering the impact of connected sister alliances on focal subsidiaries' knowledge generation. Below, we discuss the implications of these core findings. Subsequently, we present the main limitations of our research and identify interesting avenues for future research.

Paradox Versus Synergy of External Embeddedness

Being part of an MNC implies that subsidiaries not only can benefit from their own external partners but also have the opportunity to benefit from the external partners of sister

subsidiaries (Mudambi & Navarra, 2004). At the same time, extant research points to potential trade-offs between subsidiaries' own external network and the external network of sister subsidiaries. Andersson et al. (2002) introduced the concept of the "paradox of external embeddedness" to reflect the risk that strong embeddedness of a subsidiary in its own external network might hamper its ability to benefit from external ties of sister subsidiaries. Our findings confirm the existence of such a paradox of external embeddedness for the particular case where two subsidiaries share an internal collaborative linkage. In particular, we find a negative moderating effect of the number of focal subsidiary's direct alliances on the positive relationship between connected sister alliances and focal subsidiary's knowledge generation.

At the same time, however, we found an unexpected positive moderating effect of the number of focal subsidiary's direct alliances on the relationship between unconnected sister alliances and focal subsidiary's knowledge generation. A potential explanation for this unexpected effect might be found in the literature on alliance portfolio capabilities (e.g., Heimeriks, Duysters, & Vanhaverbeke, 2007; Schilke & Goerzen, 2010). A core argument of this literature is that as firms gain experience in simultaneously managing different alliances, they can build up alliance portfolio capabilities, reflecting an increased ability to maximize potential synergies among different alliances as well as minimize potential conflicts between them. On the basis of these insights, it can be argued that subsidiaries with an extensive number of direct alliances are more likely to have subsidiary-level alliance portfolio capabilities than those with none or a limited number of direct alliances. These capabilities might imply an increased ability to process information not only from the focal subsidiary's own portfolio of alliances but also from the portfolio of unconnected sister alliances. Such increased ability to process information is likely to be more important for unconnected sister alliances as for this type of sister alliance; the absence of an internal collaborative linkage asks for alternative ways to foster the ability of the focal subsidiary to receive knowledge from sister alliances. Our findings suggest that for unconnected sister alliances, this alliance portfolio capability effect outweighs the capacity constraints that an extensive number of direct alliances brings along, resulting in what we label as a "synergy of external embeddedness."

On the basis of these findings, it also becomes clear that an expansion of a focal subsidiary's direct alliance network implies a trade-off in terms of benefiting from the alliance network of different types of sister subsidiaries. Whereas such an expansion increases the ability of a subsidiary to benefit from unconnected sister alliances (i.e., a synergy of external embeddedness for unconnected subsidiaries), it simultaneously decreases the positive impact of connected sister alliances on focal subsidiary's knowledge generation (i.e., a paradox of external embeddedness for connected subsidiaries).

Together, our findings illuminate that both direct and indirect external linkages of subsidiaries provide opportunities to boost their knowledge generation. At the same time, these different external linkages cannot be considered in isolation. Instead, we conclude that the interplay between direct external linkages and different types of indirect external linkages (i.e., unconnected and connected sister alliances) can trigger both knowledge generating synergies and trade-offs for the focal subsidiary.

Multistep Interorganizational Knowledge Transfer

In the past two decades, an extensive literature stream has emerged that studies knowledge transfer between organizations (Easterby-Smith et al., 2008). Recently, Ghosh and

Rosenkopf (2015) criticized this research stream for conceptualizing interorganizational knowledge transfer as a two-step transmission between two unitary actors. However, firms actually represent complex internal structures, implying that effective knowledge transfer might require a “multistep transmission” (Ghosh & Rosenkopf, 2015: 626). Our research provides new insights into the particular challenges that such multistep knowledge transfer processes entail within organizations and how they can be addressed.

Focusing on the transfer of knowledge from the alliance partner of an unconnected sister subsidiary to the focal subsidiary within an MNC, we show that such a multistep knowledge transfer process is theoretically different from dyadic knowledge transfer as it brings along frictions that are not present in the latter case. Multistep interorganizational knowledge transfer does imply that both the initial source (i.e., the alliance partner) and the knowledge broker (i.e., the unconnected sister subsidiary) have to be willing to disclose knowledge, allowing the knowledge receiver (i.e., the focal subsidiary) to identify it. Therefore, such a transfer process entails the risk of not only external attenuation but also internal attenuation.

At the same time, we provide evidence that these specific frictions can be overcome under particular conditions. We identify the MNC headquarters as an actor that can be particularly helpful to compensate for the lack of motivation of unconnected sister subsidiaries to act as knowledge brokers and disclose alliance partner knowledge to the focal subsidiary. We also demonstrate the relevance of knowledge overlap in addressing internal attenuation and knowledge identification problems when transmitting alliance partner knowledge from the unconnected sister subsidiary to the focal subsidiary. Finally, our additional analyses suggest that when a focal subsidiary and sister subsidiary have a collaborative linkage, the multistep process of transferring knowledge from the alliance partner of the sister subsidiary to the focal subsidiary is more straightforward.

Limitations and Future Research

This study has several limitations, which also provide interesting avenues for future research. First, the setting of our study is limited to R&D-active firms in the pharmaceutical industry, which engage in alliance activities, implying restrictions regarding the generalizability of our findings. The focus on alliance-active firms fits our research objective as we are interested in identifying under which conditions subsidiaries can benefit from the external network of sister subsidiaries. Second, existing research (e.g., Monteiro, Arvidsson, & Birkinshaw, 2008) shows that isolated subsidiaries underperform their peers, pointing to a liability of isolation. In our data set, we similarly observe that subsidiaries, which are weakly connected to external partners, are far away from headquarters, and have limited knowledge overlap with sisters, underperform their peers. This isolation may cause potential restricted variance interaction issues (Cortina, Köhler, & Nielsen, 2015).¹⁵ Third, we use scientific publications to measure knowledge generation. Although we argue that scientific publications provide a more reliable indicator than patents to measure subsidiary-level knowledge activities, we realize that this indicator also has shortcomings. Fourth, we focus in this study on a particular mode of external linkages (i.e., R&D alliances). Although prior research (Bos et al., 2017; Hagedoorn & Wang, 2012) has consistently shown the relevance and importance of such external linkages in the pharmaceutical industry, we fully acknowledge that other types of external linkages exist that can also influence knowledge generation by subsidiaries. Fifth, given the nature of our data, we focused in this study on the quantity of internal and

external linkages. Prior MNC research (e.g., Ciabuschi, Holm, & Martin, 2014; Najafi-Tavani et al., 2014) showed that it is also important to look at the quality of internal and external ties. Therefore, we encourage future research to collect primary data on quality indicators of internal and external embeddedness. Sixth, we followed the majority of MNC subsidiary network research in considering knowledge transfer as an aggregate flow between subsidiaries. However, studies are emerging that look at knowledge transfer between subsidiaries at the project level (Andersson, Gaur, Mudambi, & Persson, 2015) or the individual level (Blomkvist, Kappen, & Zander, 2014). Examining the differences as well as interactions among these levels definitely represents a valuable avenue for future research. Seventh, given our focus on secondary data collection, we relied on a relative passive headquarters proxy, that is, focal subsidiary's geographical proximity to headquarters. Whereas this proxy allowed us to demonstrate the importance of the headquarters in influencing subsidiaries' ability to reap knowledge benefits from sister alliances, we acknowledge that our operationalization underestimates the ability of headquarters to make active managerial interventions that influence knowledge flows within the MNC network. For instance, the headquarters can implement a knowledge management system that provides information on the external partners of subsidiaries (Andersson, Buckley, & Dellestrand, 2015; Gnyawali, Singal, & Mu, 2009). Such a system might provide opportunities for subsidiaries to identify valuable knowledge in the external networks of unconnected sister subsidiaries even when they are distant from the headquarters. Future research into how MNCs can actively manage the complex interactions between different external networks therefore is an important research objective. Finally, our data collection approach did not allow measuring the knowledge frictions in a more explicit way. Future research, collecting primary data on such frictions, might help to further improve our understanding of the challenges of multistep interorganizational knowledge transfers and how internal network structures influence them.

Notes

1. We acknowledge that this transfer process can be intentional (i.e., the alliance partner voluntarily disclosing knowledge to the sister subsidiary) and unintentional (i.e., unintended knowledge spillovers from the alliance partner to the sister subsidiary).

2. Next to personal communication channels, MNCs can use impersonal channels. However, in line with prior research (Almeida & Kogut, 1999; Ambos & Ambos, 2009), we assume that given the nature of knowledge in our setting (i.e., nonredundant knowledge that is used for recombination activities in a scientific setting), impersonal channels lack the richness to effectively support transfer of such knowledge. In particular, such channels do not support the transfer of the noncodified knowledge components.

3. The consolidation was done on a yearly basis to take into account changes in the group structure due to mergers and acquisitions, green-field investments, and spin-offs. Acquired companies and their stocks of publications are considered part of a parent firm from the year of acquisition onwards.

4. A robustness check shows that results are highly similar when using only publications or only forward citations as a dependent variable. All hypothesized relationships remain robust. The only difference is that when simultaneously entering all hypothesized interaction effects, the interaction effect between geographical proximity to headquarters and unconnected sister alliances becomes nonsignificant.

5. As a robustness check, we collected all patents of the firm Abbott and linked them to the identified R&D subsidiaries. Citation-weighted publication and citation-weighted patent counts are highly correlated ($r = .85$). We therefore assume that both measures are likely to provide similar results.

6. In the study of Melin and Persson (1996), only 5% of the surveyed scientists reported instances of collaboration not resulting in coauthored papers. On the basis of a survey of firms in the electronics and pharmaceutical industries, Hicks et al. (1996) found that the large majority (84%–93%) of copublications are the result of at least

some sort of collaboration between individuals. Hence, most collaborations result in coauthored publications, and most publications do reflect actual research collaborations.

7. Using an exponential weight instead of a power function to calculate the proximity of the focal subsidiary to the headquarters provides highly robust results.

8. By definition, focal subsidiaries without unconnected sister alliances can also have no overlap in knowledge with unconnected sister units. In this case, we gave these observations a value of 0 for the *knowledge overlap with unconnected sister subsidiaries* variable. The results of a Brown-Forsythe test to evaluate the (in)equality of variance indicate no potential issue of restricted variance ($p = .175$) in this respect. A robustness test excluding focal units without unconnected sister alliances provides stable results.

9. Data on R&D expenditures are available only from 1996 onwards. To avoid missing values, we calculated country-level averages over the 1996-to-2004 period. We opted for country-level averages because of a rather high persistency of country-level R&D expenditures over time.

10. For the national intellectual property rights regime variable, missing data for earlier years were imputed by taking the first nonmissing values for the earliest available year.

11. We separately tested a model including only the main effect of geographical proximity to the headquarters, finding a positive but nonsignificant relationship.

12. As a robustness check, we further distinguished between single connected sister alliances (i.e., alliances of other subsidiaries with whom the focal subsidiary has only one copublication) and multiple connected sister alliances (i.e., alliances of other subsidiaries with whom the focal subsidiary has more than one copublication). The results show a larger positive effect of multiple connected sister alliances than single connected sister alliances.

13. Besides its alliance hub function, the headquarters could steer the attention of subsidiaries. Headquarters proximity may therefore mitigate the negative impact of a focal subsidiary's direct alliance network on its capacity to process information from sister alliances (Andersson et al., 2002). We therefore tested for the existence of a three-way interaction effect between the number of unconnected/connected sister alliances, the number of direct alliances, and headquarters proximity. We do find a positive and significant three-way interaction effect for connected sister alliances, implying that the moderating effect of the direct alliance network on the relationship between connected sister alliances and new knowledge generation becomes less negative as headquarters proximity increases. We do not find a significant three-way interaction effect for unconnected sister alliances.

14. We rely on a linear panel model for the endogeneity check as instrumental variable estimation techniques are currently not implemented for multilevel count-data models in the common statistical packages.

15. We have conducted three Brown-Forsythe tests to check the (in)equality of variance of the dependent variable for the three different moderators. All test results are significant ($p = .00$), confirming the potential restricted variance issue.

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