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Knowledge decomposability and external knowledge sourcing

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Abstract

Knowledge decomposability and external knowledge sourcing Danica Bauer; University of Antwerp, Department of Management, ACED; 2015-2018; danicachristin.bauer@uantwerpen.be As firms learn over time, various knowledge elements are accumulated and retained in a firm's knowledge base. The literature states that the size of a knowledge base seems to be important. A larger knowledge base indicates a larger amount of knowledge elements and hence a larger amount of possibilities to recombine knowledge elements to arrive at new innovations. Yet, while the size of a knowledge base is important, the structure of a knowledge base has not received the same attention. Yayavaram and Ahuja (2008) claim that the decomposability, and hence the structure, of a knowledge base can influence a firm's innovation performance. The decomposability of a firm's knowledge base can range from non-decomposable over nearly-decomposable to fully decomposable. The classification of decomposability is determined by the coupling between various knowledge elements and hence determined by the degree of integration and differentiation of the various knowledge elements within the knowledge base. In their paper, Yayavaram and Ahuja (2008) showed that a knowledge base (and hence the decomposability of that knowledge base) can change over a rather short period of time. While they refer to changes within the knowledge base in their paper, the exact roots of these changes in the knowledge base are yet unknown. One factor that could potentially affect a firm's decomposability of its knowledge base is the sourcing of externally developed knowledge elements – referring to those knowledge elements that have been developed by other firms, hence outside a firm's own boundaries, and which are ultimately acquired by the focal firm. By sourcing knowledge externally, a firm makes a strategic choice between integrating or differentiating knowledge elements and so changes the decomposability of its knowledge base. This leads to the following research question: To what extent do different forms of external knowledge acquisition, and in particular, joint ventures and acquisitions, have a differential effect on changes in knowledge base decomposability? In the case of a joint venture, two firms are "linking" their main capabilities to create one common capability and thus an invention. The knowledge that is being created by the joint venture is achieved through close collaboration and hence assumed to be tacit. It follows that the new knowledge is firm-specific to the partners and hence increases the couplings between the knowledge elements. An increase in couplings between the various knowledge elements increases the integration of knowledge elements within the knowledge base and thus leads to a decrease in decomposability. Hence, our first hypothesis states that joint ventures lead to a less decomposable knowledge base of the focal firm. In case of an acquisition, the reverse effect might be achieved. Especially in the beginning, an acquisition may simply "add" new knowledge elements

to the knowledge base. As no new couplings are established, the differentiation of the knowledge elements increases which ultimately leads to an increase in decomposability. Our second hypothesis thus states that acquisitions lead to a more decomposable knowledge base of the focal firm. We test our model on a unique sample of the 95 largest (based on # full-time employees) U.S. public pharmaceutical biotechnology firms over a 16-year period. Following Yayavaram and Ahuja (2008), we measured our dependent variable, knowledge decomposability, by USPTO assigned patent classes which are a proxy for knowledge elements. We strictly followed the measurements proposed by Yayavaram and Ahuja (2008). The independent variable, external knowledge sourcing, is a count variable of the number of joint ventures and acquisitions. We control for firm size, R&D intensity, firm performance, and size of the knowledge base. Preliminary results provide support for our predictions that joint ventures lead to a decrease in knowledge base decomposability, while acquisitions lead to an increase in knowledge base decomposability. References Yayavaram, S., & Ahuja, G. (2008). Decomposability in knowledge structures and its impact on the usefulness of inventions and knowledge-base malleability. Administrative Science Quarterly, 53, 333-362.

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Knowledge base decomposability and external knowledge acquisition

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Abstract

Building on Yayavaram and Ahuja (2008), this paper explores the relationship between external knowledge acquisition and the decomposability of a focal firm's knowledge base. The decomposability of a knowledge base can range from a non-decomposable to a decomposable knowledge base. We argue that knowledge acquisition, which is achieved through joint ventures will lead to a more integrated and hence less decomposable knowledge base. On the other hand, knowledge acquisition that is achieved through acquisitions will lead to a more differentiated and hence more decomposable knowledge base.

1. Introduction

In a competitive and technological change-driven environment, innovation is an important anchor for many firms (Porter, 1990; Tushman & O'Reilly, 1996). It is thus important for a firm to stay ahead of competition and to be able to renew themselves. Strategy scholars have often stressed the importance of organizational knowledge, arguing that organizational knowledge provide firms with a competitive advantage over other firms (Grant, 1996; Eisenhardt and Martin, 2000). Organizational learning and innovation are often used in conjoint (Levitt & March, 1988; Conner & Prahalad, 1996; Grant, 1996).

The theory on absorptive capacity has received much attention in the literature (e.g., Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Van Den Bosch, Volberda, and De Boer, 1999; Lane, Salk, Lyles, 2001; Zahra and George, 2002), which is "the ability to recognize the value of new information, assimilate it and apply it to commercial ends" (Cohen and Levinthal, 1990, p. 128). The underlying idea of absorptive capacity is that a firm needs prior knowledge in a related field in order to make use of newly acquired knowledge (Cohen and Levinthal, 1990). Conclusively, the size of a knowledge base matters: It is generally argued that a larger knowledge base may lead to a larger variation in knowledge elements and that this could potentially lead to a better ability in recombining these knowledge elements.

While size forms an important aspect for a firm's knowledge base, Yayavaram and Ahuja (2008) have argued that also the decomposability of a knowledge base may be of crucial importance. With the decomposability of a knowledge base, they refer to the integration and differentiation (Lawrence and Lorsch, 1967) of knowledge elements within a knowledge base. Hence, when knowledge elements are linked (knowledge elements are recombined), its knowledge

base exhibits a larger degree of integration and hence is less decomposable. On the other hand, knowledge elements with a larger degree of differentiation may lead to a more decomposable knowledge base. A middle way between the two, is a nearly-decomposable knowledge base, which Yayavaram and Ahuja (2008) identify as the knowledge base to achieve better innovation performance.

Previous studies have argued that firms must change adapt their knowledge bases over time to keep pace with a changing technological environment, and to avoid exhausting or exhaustion of combinations of knowledge elements (e.g., Kogut and Zander, 1992; Henderson and Cockburn, 1994; Rosenkopf and Nerkar, 2001; Yayavaram and Ahuja, 2008). As Yayavaram and Ahuja (2008) point out: "As organizations learn and become aware of the true interdependencies between knowledge elements, their coupling patterns should change to reflect this new knowledge" (Yayavaram and Ahuja, 2008, p. 335). They furthermore state that the decomposability of a knowledge base can change over time, as they demonstrate with an example of Intel's knowledge base. Within a relatively short period of time of six years, Intel's knowledge base changed from a non-decomposable to a nearly-decomposable knowledge base. While it seems plausible (or intuitive) that a knowledge base can change as a firm engages in in the process of recombining knowledge, the antecedents of these changes in the knowledge base are yet unknown.

Studies have shown that a firm's ability to learn increases if they are exposed to technological knowledge that differs from a focal firm's own capabilities in an acquisition process (see for example, Ghoshal, 1987; Hitt, Hoskisson, Johnson, and Moesel, 1996). It follows that one factor that could potentially affect a firm's decomposability of its knowledge base is the acquisition of externally developed knowledge elements – referring to those knowledge elements that have been developed by other firms, hence outside a firm's own boundaries, and which are ultimately

acquired by the focal firm. Linked to this acquisition of external knowledge is the option of co-creation of knowledge, which happens if, for example, a joint venture is being set up to facilitate knowledge creation.

All in all, this leads to the following research question: To what extent do different forms of external knowledge acquisition, and in particular, joint ventures and acquisitions, have a differential effect on changes in knowledge base decomposability? Here, the aim is to explain whether the decomposability increases or decreases if the firm, for example, uses joint ventures or acquisitions as an external knowledge acquisition source.

By answering the aforementioned research question, we aim to provide a link between the general argument that external knowledge sourcing can lead to innovation. We look at the change in knowledge structures (knowledge base decomposability) of firms in order to better understand the underlying mechanisms of co-operating (through joint ventures) and the acquisition of knowledge bases (acquisitions). In this vein, we aim to bring together two different literature streams, namely external governance modes literature and the literature on knowledge structures.

The paper continues with an overview of the relevant literature on knowledge base decomposability. We continue with a hypothesis development, a methods section in which we elaborate on the secondary data that we have used to test our hypothesis, a results section, followed and concluded by the discussion of our findings.

2. Theoretical framework and hypotheses

The following part further defines the concepts related to the theory of knowledge base decomposability, and furthermore elaborates on the proposed relationship between external knowledge acquisition and the degree of knowledge base decomposability of a focal firm's current knowledge base.

A knowledge base is defined as the "set of knowledge elements that a firm possesses and the relations that it has forged between the knowledge clusters to which these elements belong" (Yayavaram and Chen, 2015, p. 377). Knowledge bases differ in size (Cohen and Levinthal, 1990), which previous studies have shown to have potentially important consequences for innovation: size matters, as it determines the absolute number of how many possible connections between knowledge elements a firm could potentially make. The larger the knowledge base, the greater the opportunity for firms to recombine knowledge elements but also the greater the chance of stumbling upon something radically new, that other firms with perhaps smaller knowledge bases might have not come across at. Other studies have argued that the larger a firms knowledge base, the more able they to assimilate knowledge and learn from it that might reside outside their firm capabilities and boundaries. In this sense, knowledge elements created externally to a firm's boundaries and being acquired by a focal firm may add to a current knowledge base of a firm. In order for the focal firm to actually use these knowledge elements, it is an advantage if a firm has related knowledge. In the literature, this much discussed concept is referred to as a firm's absorptive capacity (Cohen and Levinthal, 1990).

However, as previously mentioned, not only the size, but also the structure of the firm's knowledge base matters, a subject that until very recently has received surprisingly little attention.

Hence, this paper focuses on the 'decomposability' of the firm's knowledge base (Yayavaram and Ahuja, 2008), its different forms, and how changes in a firm's knowledge base decomposability may occur.

2.1 Knowledge elements and different forms of knowledge base decomposability

A focal firm's knowledge base can be viewed as a network of various knowledge elements. Knowledge networks can be thought of as linkages between scientific and technological knowledge elements (Yayavaram and Ahuja, 2008; Carnabuci and Bruggeman, 2009). These individual elements contain field-specific scientific or technological facts, theories, methods, or procedures (Kuhn, 1996). The knowledge elements of a firm's knowledge base can be experimentally recombined, paving the way to innovation (Schumpeter, 1934; Weitzman, 1998). Yet, generally speaking, the creation of a new product demands the combination of multiple fields of expertise. A biotech firm, for example, may need knowledge in fields like chemistry, pharmacology, microbiology, and biochemistry in order to combine or recombine these knowledge elements in a way which may ultimately lead to innovation (Drews, 2000).

A firm's knowledge base decomposability, then, reflects the firm's ability for innovation through the potential for forming new connections between knowledge elements. Some firms possess a non-decomposable knowledge base, which means that most of a focal firms' knowledge elements indicate a high degree of integration. High integration, in this context, means that knowledge elements are linked to one another and exhibit a high degree of relatedness. Other firms exhibit a more decomposable knowledge base with a more diverse set of knowledge elements. In the case of a decomposable knowledge base, knowledge elements that are related, are usually

clustered. A firm that exhibits a larger degree of integration amongst its knowledge elements within a knowledge base is more specialized in one particular field and hence achieves more depth in its knowledge base. On the other hand, a firm with a differentiated, hence more clustered and decomposable knowledge base achieves more breadth within its knowledge base.

A nearly-decomposable knowledge base is a combination of a non-decomposable and decomposable knowledge base. Here, various knowledge elements are clustered, while single knowledge elements outside these knowledge clusters function as boundary spanning or as an integration mechanism between the knowledge elements. Yayavaram and Ahuja (2008) show that a nearly-decomposable knowledge base could potentially make the firm better able to innovate, since this sort of knowledge base could bridge the gap between depth (advantage of a non-decomposable knowledge base) and breadth (advantage of a decomposable knowledge base), and such a balance has previously been associated with successful inventions (March, 1991; Katila and Ahuja, 2002).

2.2 The knowledge base as a knowledge network and the importance of couplings

As a metaphor to rely on, we refer to a knowledge base as a knowledge network, we can view this network as defined by its nodes and ties. The nodes, in this case, are knowledge elements, while the ties represent a combination of two knowledge elements in a prior invention (Fleming, 2001; Fleming and Sorenson, 2004; Carnabuci and Bruggeman, 2009). Knowledge elements that have previously been coupled to one another form different knowledge clusters, which can in turn be coupled to other knowledge elements or other clusters. For example, knowledge elements X1, X2, X3a/b/c, etc. belong to knowledge cluster X and knowledge elements Y1, Y2, Y3a/b/c, etc.

belong to knowledge cluster Y. A coupling between two or more knowledge elements or knowledge clusters is represented by a tie, and different tie strengths also apply. Both the presence or absence of a tie or coupling and the strength of that tie are an important indication of how well knowledge is understood by the focal firm. For example, a very strong tie (indicating high levels of coupling) between two knowledge clusters X and Y implies that this particular domain knowledge is understood very well by the firm, thus increasing the likelihood that the firm will search along a combination of these knowledge clusters (X and Y). A weak tie (low levels of coupling), on the other hand, indicates that a focal firm is not likely to consider both X and Y in conjoint, but rather separately (X or Y) (Yayavaram and Ahuja, 2008; Yayavaram and Chen, 2015).

In general, couplings are embodied in routines (Nelson and Winter, 1982), in beliefs about underlying interdependencies between clusters, in communication networks, and in organizational structure. Hence, couplings truly represent knowledge that is part of a firm's "made world", indicating full understanding of the knowledge elements or knowledge clusters. Interactions, on the other hand, refer to all potential ties of various knowledge elements or knowledge clusters. Interactions, thus, refer to the "natural world" (Yayavaram and Chen, 2015), in which each combination is still possible regardless of a firm's decision on which knowledge to couple.

Although the concept of knowledge decomposability is of relatively recent origin in innovation studies, it builds on previous work, as for example on Simon's theory of complex systems (Simon, 1962). Simon (1962) outlines that complex systems could be described as a hierarchic system. In this sense, a hierarchic system is defined as "a system that is composed of interrelated subsystems, each of the latter being, in turn, hierarchic in the structure until we reach some lowest level of elementary subsystem" (Simon, 1962, p. 457). In the figurative sense, an invention can be seen as a complex system, with many interrelated subsystems that contribute to

one another. Essentially, an invention is an accumulation of various knowledge elements. However, the mere stock of knowledge elements does not make up an invention. It is the coupling between these knowledge elements and hence the combination of knowledge elements that provide an invention with the newness, described by Yayavaram and Ahuja (2008) as the network of nodes and ties between knowledge elements.

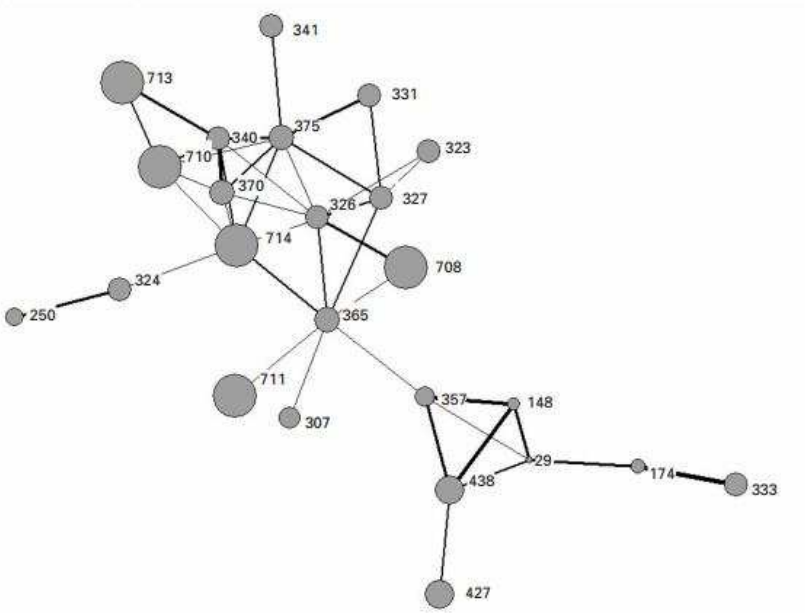
2.3 The link between knowledge base decomposability and external knowledge acquisition

To move beyond internal search, a firm may engage in more exploratory search and hence choose for boundary spanning activities that enable the firm to source knowledge externally that spans both, organizational and technological boundaries. Though search within the internal knowledge base can be complex, in order to stay ahead of competition and reach sustainable competitive advantage, it may be important for firms to source technology externally.

In the past years, firms became more aware of the necessity of being able to generate, acquire and integrate both internal and external sources of knowledge (Nonaka and Takeuchi, 1995; Simonin, 1997).

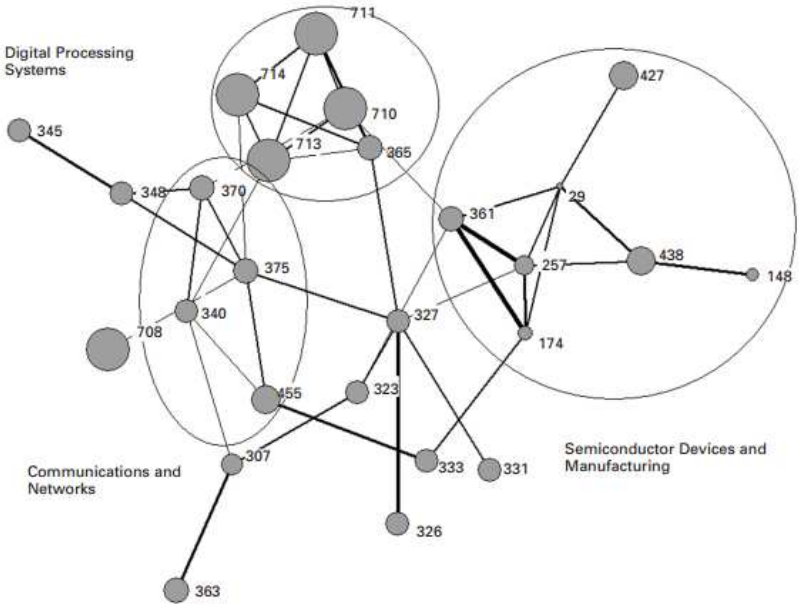
Yayavaram and Ahuja (2008) study the decomposability of knowledge bases solely at the level of the focal firm without an inclusion of external knowledge acquisitions, as for example, joint ventures or acquisitions. In addition, knowledge elements are not easily diffused across the boundaries of a firm. In this study, it is being studied whether a knowledge base remains unaltered or changes after a focal firm engaged in external knowledge acquisition. That a knowledge base can change, is further clarified by an example: Consider Intel's knowledge couplings in 1996 (see

Figure 1b). The increased coupling between class 257 (Active solid-state devices), class 174 (Electricity: conductors and insulators), and class 361 (Electricity: electrical systems and devices) from 1990 to 1996 is an example of coupling changes between existing knowledge domains (Yayavaram and Ahuja, 2008; Yayavaram and Chen, 2015). The example that is provided here, will later be exchanged by an example of a biotech firm from our own data.



* Nodes represent technology classes, ties between nodes represent coupling between technology classes, and the strength of a tie represents the level of coupling; darker lines indicate stronger ties; the size of node is a measure of the number of patents that belong to that technology class. Isolates and very weak ties have been removed for illustration purposes.

Figure 1a. Non-decomposable knowledge base of Intel in 1990 (Yayavaram and Ahuja, 2008).



* Nodes represent technology classes, ties between nodes represent coupling between technology classes, and the strength of a tie represents the level of coupling; darker lines indicate stronger ties; the size of node is a measure of the number of patents that belong to that technology class. Isolates and very weak ties have been removed for illustration purposes.

Figure 1b. Decomposable knowledge base of Intel in 1996 (Yayavaram and Ahuja, 2008)

2.4 External knowledge acquisition

Through external knowledge acquisition a focal firm is able to source knowledge elements externally and establish ties between existent and externally sourced knowledge elements.

Many forms of external knowledge sourcing exist, as for example in-licensing, research contracts, corporate venture capital (CVC), minority stake investments, joint ventures, as well as mergers and acquisitions. External knowledge sourcing has been studied by Dushnitsky and Lenox (2005), for example, who looked at a firm's likelihood of sourcing knowledge externally through corporate venture capital investments. Another example includes Ahuja (2000) who examined technology sourcing via cooperative relationships.

Firms engage in external knowledge sourcing because developing technologies in-house is a costly and lengthy process. Additionally, external knowledge acquisitions bear the advantage of "cherry picking" and a better fit with a firm's knowledge base (internal capabilities). Especially innovation in the biopharmaceutical industry is associated with long lead times of commercializing an innovation. Furthermore, it is associated with many trial and error processes. This makes research in this area particularly expensive. Hence, it seems to be important for a firm to engage in external knowledge acquisition.

In tracking the changes to the decomposability of a knowledge base, we use joint ventures and acquisitions as examples of external knowledge acquisition modes. These two modes of external knowledge acquisition have been chosen due to the fact that they may lead to opposite changes in a focal firm's knowledge bases. While joint ventures usually imply a close relationship with a partner, this may result in more tacit knowledge in which the focal firm has an understanding of some knowledge elements and hence taps into more related fields (Yayavaram and Chen, 2015). This in turn may facilitate faster integration into the focal firm's knowledge base. On the other hand, acquisitions provide the focal firm with patents in fields they may not have the absorptive capacity make use of or the connection to the focal firm's knowledge base. The acquisition of a firm may provide the focal firm with knowledge domains that are unrelated to the current knowledge base and may thus be more difficult to integrate. Since the firm in this case may not yet have partial knowledge of the knowledge domains it acquires, integration of these foreign knowledge domains may prove difficult and the mere differentiation of a knowledge base is achieved. It can thus be "assumed" that the knowledge base of a focal firm becomes more differentiated and hence more decomposable.

2.5 Hypotheses

2.5.1 Integration vs. differentiation

The degree of knowledge base decomposability forms the context within which the recombination process can take place; through its structure of differentiation and integration, a focal firm sets the knowledge base conditions for recombination.

The differentiation of a knowledge base includes the addition of knowledge elements to the current knowledge base without a direct linkage or coupling to current knowledge elements. A focal firm may want to differentiate their knowledge base and thus add more knowledge elements to the current knowledge base in order to create choices for recombinant activities within the knowledge base. By adding new knowledge elements, the firm is trying to either create more depth or more breadth within the knowledge base. If a firm is deliberately adding new knowledge elements that are less integrated with current knowledge elements, a firm's knowledge base may be achieving more breadth (more differentiation). A firm at this stage did not yet understand the compatibility of the newly added knowledge element towards its current knowledge elements. Only when a firm is able to fully understand the knowledge elements that were added to the knowledge base, it will be able to create ties to other current knowledge elements. The establishment of ties (coupling) between two or more knowledge elements could be seen as an attempt of integrating these knowledge elements. Thus, when a current knowledge element X and a new knowledge element Y are now considered in conjoint in the process of knowledge recombination, it is referred to as a coupling between X and Y.

On the other hand, if a firm is adding knowledge elements that are closely related to their current knowledge elements, a firm contributes to the depth of its knowledge base. This is the case

when a firm opts for the integration of knowledge elements, which allows a firm to link or couple newly acquired knowledge elements to current knowledge elements within a focal firm's knowledge base. In this case, the newly acquired knowledge elements are complementing the current knowledge base as it has been integrated into the knowledge base, while in the former, a mere addition of knowledge elements has been achieved.

2.5.2 Joint ventures as an integrative link

In the following, a joint venture acts as an instrument in explaining organizational learning within a firm. A joint venture can facilitate a focal firm's learning process by developing new knowledge elements with the aid of a partner's knowledge base. In essence, "a joint venture is used for the transfer of organizational embedded knowledge which cannot be easily blueprinted or packaged through licensing or market transactions" (Kogut, 1988, p. 319). Hence, a joint venture could be seen as a transmitter of organizational knowledge. In general, a joint venture is defined as an entity that is established when two or more firms decide to combine organizational resources (knowledge) in order to create a new capability. Joint ventures are then a mechanism through which tacit knowledge (Polanyi, 1966) is transferred (in line with Kogut, 1988). Tacit knowledge is experiential knowledge which is not yet well understood. Tacit knowledge is not codified and hence difficult to transfer across organizational boundaries. Hence, tacit knowledge is specific to a firm as it is embedded in a firm's skills and routines (Nelson and Winter, 1982).

In a joint venture, interdependencies between knowledge elements may not be obvious to a focal firm at first (natural world). However, through the work that is achieved mutually, with each partner bringing in knowledge that is understood by them, they can learn from each other.

Additionally, when a focal firm makes a coupling between one of his own knowledge elements and a knowledge element between its partnering firm, the coupling is less uncertain as the focal firm has at least partial knowledge of the project and has thus the foundation that is needed in order to successfully integrate the knowledge element. The presence of a direct tie (Hansen and Lovas, 2004), the strength of this tie (Hansen, 1999) as well as the number of ties between knowledge elements (Hansen, 2002) improve the transfer of tacit knowledge. The knowledge that is sourced externally in this specific case, is more likely to be built around existing knowledge nodes of the focal firm and hence, integration mechanisms will be facilitated.

For example, a firm that sets up a joint venture has knowledge in X, one knowledge element located within a knowledge cluster. This knowledge element X is used to be recombined with an external knowledge element Y which is brought in by the partnering firm. Hence, the focal firm only understands X but not yet Y. Through the mutual project that recombines X and Y, and henceforth XY, the focal firm is able to better bridge the cognitive distance (Nooteboom et al., 2007) that might be the case in respect to knowledge element Y and better integrate it into the knowledge base. It follows that the new knowledge is not simply added to the knowledge base but coupled to an existent knowledge element. Once coupled, the focal firm made the strategic choice of using X in conjoint with Y.

In conclusion, while a new knowledge element is added to the current knowledge base (XY), this knowledge element in coupled to knowledge element X (provided by the focal firm at the start of the joint venture). As couplings between the knowledge elements that are added by joint ventures increases, the degree of integration amongst these knowledge elements increases as well. When the integration amongst the knowledge elements increases, the knowledge clusters become

more integrated as these are better connected and henceforth lead to a less decomposable knowledge base. Taken together, this results in the following hypothesis:

H1: Joint ventures lead to a less decomposable knowledge base of the focal firm.

It is generally argued that firm could generate new knowledge from technological acquisitions (Ahuja and Katila, 2001; Graebner, 2004). When a firm decides to acquire a target, it also acquires its patents. Naturally, patents classify as codified knowledge and hence the knowledge elements that could potentially be added to a focal firm's knowledge base are explicit. Codified and explicit knowledge is mostly written down and thus readily available to a firm. Explicit knowledge, compared to tacit knowledge, is easier to transfer across firm boundaries. A consistent finding in the literature is that codification facilitates knowledge transfer while tacit knowledge impedes this process (e.g., Cheng, 1984; Zander and Kogut, 1995; Haas and Hansen, 2007). In essence, this is what characterizes the advantages of acquisitions. Through acquisitions, a focal firm is granted rapid access, ownership and direct control of specific knowledge assets and capabilities (explicit knowledge elements and patents) and is thus overcoming some of the disadvantages of time compression diseconomies (Ranft and Marsch, 2008).

In general, these advantages could be hampered by the following three barriers referring to the knowledge transfer within a firm: knowledge ambiguity, lack of absorptive capacity on behalf of the focal firm and the arduousness of relationship between the target and the focal firm of knowledge (Szulanski, 1996).

Even though the acquirer (focal firm) may come to understand a target's knowledge in form of patents, the focal firm may not have the capability or the necessary experience to search within

the target's knowledge base for new couplings. It may the case, for example, that the acquirer does not have the technological knowledge per se to link it to their own knowledge bases. Even though the acquirer's knowledge may be codified in terms of patents, this does not imply that a focal firm can make a coupling. Additionally, the "not invented here" theory may apply in this case as researchers from a focal firm may not be willing to accept a superior research from outside a focal firm's boundaries. This again can hamper the integration process and hence lead to a more decomposable knowledge base.

The reverse of the example that was provided above to explain the mechanisms of joint ventures is the case when referring to acquisitions. An acquisition adds codified knowledge to a focal firm's knowledge base. And although the knowledge is codified, the understanding of this codified knowledge element is not yet established at the beginning of an acquisition. When acquired, the new knowledge elements are not yet connected to any of the knowledge elements within the current knowledge base. In essence, this means that acquisitions simply add knowledge elements to a knowledge base. There is thus an increase in knowledge elements while there occurs no linkage building to current knowledge elements and therefore recombination and innovation is not taking place. Apart from these facts, the decomposability of a focal firm's current knowledge base increases as it becomes more differentiated and hence achieves more breadth. All in all we propose that this will result in a knowledge base that is more decomposable. Taken together, this leads to the following hypothesis:

H2: Acquisitions lead to a more decomposable knowledge base of the focal firm.

3. Methods

The following section describes the data, sample, and measures for the concepts of knowledge base decomposability and external knowledge acquisition.

3.1 Data

The pharmaceutical biotechnological industry was chosen due to its rapidly changing technological environment which further spurs innovation. The biopharmaceutical industry is a fast-paced industry with a constant technological advancement (Gambardella, 1995). Additionally the biopharmaceutical industry was chosen since research in this area is very expensive, firms may be more likely to engage in joint ventures or acquire already developed technologies through acquisitions. The biopharmaceutical industry is an industry in which most of their intellectual property is patented (Hall, Jaffe, and Trajtenberg, 2001), which makes this industry even more worthwhile studying, given the fact that our research is based on patenting.

A patent, by definition, represents a unique and novel element of knowledge. Multiple patents are the sum of a firm's knowledge elements and comprise a firm's knowledge base. The ownership of patents is an indication of a firm's knowledge in various fields. It is codified knowledge that a firm accumulated over time (Kim and Kogut, 1996) and further represents the knowledge that the firm is acknowledged as having created (Jaffe, Trajtenberg, and Henderson, 1993). A distinction that needs to be made is the one of patents and the citation of patents. A firm's patents build on previous knowledge (hence previous patents), which was either created by the focal firm itself or which has been acquired externally. Patents that build on previous knowledge, are required to cite the knowledge source. A patent can hence receive citations on their patents as

a form of recognition of their contribution to the knowledge on which it builds on. When a firm cites one or more of their own patents it shows that the new knowledge that has been created builds on past patents and is thus an addition to a firm's knowledge base. Hence, citations to patents should be included in a firm's knowledge base.

Patents have multiple advantages for this study. Patents are usually seen as "novel" and "nonobvious" contributions to a firm's knowledge base. Hence, patents are often equated with inventiveness. Additionally, patents represent an externally validated measure of technological novelty (Griliches, 1990). Furthermore, they confer property rights upon the assignee and therefore have economic significance (Kamien and Schwartz, 1982, p. 49). In addition to these advantages of using patents, empirical studies have found that patents are closely related to measures such as new products (Comanor and Scherer, 1969), and innovation and invention counts (Achilladelis, Schwarzkopf and Cines, 1987). Apart from these positive properties of patents as a proxy for knowledge elements, we need to note at this point that patents do have limitations as well. One limitation, for example, is that some inventions may not be patentable, others are never patented and again others have no significant value to the firm once patented (Cohen and Levin, 1989; Griliches, 1990; Trajtenberg, 1990).

Patents are an established way to use as a proxy for technological inventions (e.g., Trajtenberg, 1990; Trajtenberg, Henderson, and Jaffe, 1997). Patents are being measured in the following way: patents (it) are the number of successfully granted patent applications in year (t) for the focal firm (i). This implies that once a patent is granted it uses the date on which it was applied for. Hence, we will use this date in our data of when the a patent was initially applied for. In doing so we control for any delay which may occur between application of a patent and until the patent is finally granted (Trajtenberg, 1990).

3.2 Sample

We used data based on the 100 largest (based on number of full-time employees) U.S. public pharmaceutical biotechnology firms. We chose the largest firms as these are more likely to disclose their external knowledge sourcing modes, which is in line with prior research (e.g, Ahuja, 2000; Hitt, Hoskisson, Johnson and Moesel, 1996; Keil, Maula, Schildt, and Zahra, 2008). The SIC codes from which we drew our sample are as follows: 2833 (medicinal chemicals and botanical products), 2834 (pharmaceutical preparations), 2835 (in vitro and in vivo diagnostic substances), 2836 (biological products), and 8731 (commercial physical and biological research).

The sample was drawn from the Compustat database for the years 1990-2006, which resulted in 282 unique firms. We excluded all firms from the dataset that had no patents and hence our final dataset shrunk to 95 focal firms. These were in turn matched with data from the Securities Data Corporation (SDC) platinum database, which provided us with data on joint ventures and acquisitions. Information on patents were obtained from the NBER database. The U.S. Patent and Trademark (USPTO) and NBER database provided us with patenting data. The USPTO grants patents on both the subsidiary and the parent company level. In order to make use of the USPTO database, we would have needed the "who owns whom" database to track patents that are applied for by different organizational levels back to the focal firm. As we have no access to this database, we instead used NBER data that provides us with this information. The NBER data has a starting date of 1990 and an ending date of 2006. Hence, this is the time span that we were able to use in order to construct our sample.

3.3 Dependent variable: Knowledge base decomposability

In constructing the dependent variable, knowledge base decomposability, we followed the approach of Yayavaram and Ahuja (2008) and Yayavaram and Chen (2015). The first step was to collect all patent data that firms had applied for within the past five years prior to their acquisition or joint venture. Using a 5 year window is in line with prior research in this area (Ahuja and Katila, 2001; Nooteboom, Vanhaverbeke, Duysters, Gilsing, and Van den Oord, 2007; Yayavaram and Ahuja, 2008; Sears and Hoetker, 2014; Yayavaram and Chen, 2015).

The USPTO takes care of the assignment of patents to various technology classes. Each patent is assigned to one specific patent class (3 digit code). While the USPTO decides on the patent class, the firm itself makes the decision on recombination and the coupling of knowledge elements. In line with this argumentation, we assume that patents resemble knowledge elements within a firm's knowledge base. As argued earlier, a knowledge base can be seen as a network with nodes and ties. The nodes represent the knowledge elements, and methodologically the technological classes assigned by the USPTO, while the ties represent multiple classes to which a given patent is assigned to (a decision the focal firm has made). We assumed that through a coupling of two knowledge elements, a focal firm is most likely to create an invention. By repeating the coupling process of these two knowledge element, we assumed that a focal firm is using knowledge of these two knowledge elements repeatedly, indicating that the coupling is highly used within a focal firm's knowledge base.

In line with Yayavaram and Ahuja (2008) and Yayavaram and Chen (2015), we looked at a focal firm's knowledge base in year t (comprising all patents from t-3 to t-1) to predict a firm's patent stock in year t. Hence, year t is an indicator of all patents that a focal firm has accumulated during t-3 to t-1. Using a modification of the Jaccard's coefficient from cluster analysis in order to

measure the level of decomposability, the coupling between a firm's technology classes were calculated as follows:

$L_{i,jk} = n_{jk} / (n_j + n_k - n_{jk})$ where i represents a focal firm, where n_{jk} is the number of patents assigned to both classes j and k; where n_j is the number of patents assigned to both classes j but not k and nk is the number of patents assigned to class k but not to j. The coupling matrix Li, j-k, t-3 to t-1 represents the decomposability of a firm's knowledge base. Following this calculation, we calculated the coupling matrix for firm i, which shall represent the structure of the firm. Next, we looked at the strength of an association between patent classes, which emerged from the coupling matrix. The clustering coefficient does not take into account the strength of a linkage between two knowledge elements and hence needs to be adapted accordingly. If it was above median, the coupling was classified as strong which in turn indicated whether these patent classes were clustered for a focal firm. As outlined by Yayavaram and Ahuja (2008), the degree of coupling strongly depends on the size of a focal firm's knowledge base. In order to control for this in our measurements, we follow Yayavaram and Ahuja (2008) and determine the median value of coupling as a function of patent portfolio size and time.

Following, Yayavaram and Ahuja (2008) and Yayavaram and Chen (2015), we calculate the level of integration of nodes and neighboring nodes within the knowledge base of a firm. The underlying assumption is that if the integration for a node equals to zero, it had no neighboring nodes. Hence, for each node the integration of neighboring nodes outside its clusters was calculated. We calculated the level of integration of nodes within the knowledge network as follows: Integration $j = n'_j / [k'_j * (k'_j - 1) / 2]$, where *n'* represents the neighboring nodes that are located outside a knowledge cluster and where the denominator measures the maximum number of ties between these nodes that lie outside a cluster.

Further on, the level of decomposability was calculated as: Decomposability Integration = SUM (Integration j * [the number of patents class j / the number of patents in total]

After we calculated the "current state" of a focal firm's knowledge base, we are interested in the change after a firm has acquired externally created knowledge elements. We therefore follow the approach of Yayavaram and Ahuja (2008) and Yayavaram and Chen (2015) and again calculate the coupling matrix L' j,k. Then, we compare the matrix for the t-6 to t-4 period with the matrix of the t-3 to t-1 period and only consider major changes within the knowledge base (Yayavaram and Chen, 2015). We only consider major changes in the knowledge base as a knowledge base may change due to other factors, as for example, a change in recombination of internal knowledge elements. In line with Yayavaram and Ahuja (2008), a significant change in coupling and hence in the decomposability of a knowledge base was defined as a change exceeding one quartile. The 25th, 50th and 75th percentile values were estimated as a function of size and time of a focal firm's parent stock (portfolio). Hence, a change in the decomposability of a firm's knowledge structure is visible through a change in quartiles. These changes occur due to the comparison of knowledge bases between an earlier and a later time period. The following guidelines were used in determining an increase in coupling between two knowledge elements

(1) When it changed from a zero value in an earlier time period to the second, third or fourth quartile in a later time period; or
(2) When it changed from the first quartile in an earlier time period to the third or fourth quartile in a later time period; or
(3) When it changed from the second quartile in an earlier time period to the fourth quartile in a later time period.

Decreases in couplings between two knowledge elements were determined as follows:

(4) When it changed from the fourth quartile in an earlier time period to a zero value or the first or the second quartile in a later time period; or

(5) When it changed from the third quartile in an earlier time period to a zero value or the first quartile in a later time period; or

(6) When it changed from the second quartile in an earlier period to a zero value in a later time period.

3.4 Independent variable

The independent variable, external knowledge acquisition of a firm, is defined by the engagement of a focal firm in joint ventures and acquisitions. We measure both sources of external knowledge acquisitions by means of a count variable. We thus compiled the count of acquisitions and joint ventures for a focal firm.

In general, acquisitions can be used for other purposes than the mere acquisition of patents and hence the acquisition of a target firm's technological capabilities. It is therefore of importance to identify the acquisitions in the sample that were motivated by acquiring patents by collecting information of annual reports of the firms in the sample.

We only include full acquisitions, meaning that only targets that were acquired fully (100%) are included in our sample. In doing so, we can make sure that patent transfer did occur. This is opposed to acquisitions where the target was only acquired partially. In cases in which we do not know whether patent knowledge was transferred from a target's knowledge base to an acquirer's knowledge base and in which case we could not predict a change in the focal firm's knowledge base, we excluded these firms from our sample. Hence, by excluding toehold purchases and

divestures (Graebner, 2004; Puranam, Singh, and Zollo, 2006; Sears and Hoetker, 2014), we excluded possible confounding factors to this study.

3.5 Control variables

We control for economies of scale and scope on technology search (Henderson and Cockburn, 1996) by the means of firm size. This is measured by the number of employees that a firm employs. By firm size we control for the effects of inertia that may be more inherit in a larger firm than would be the case in smaller firms. Inertia may make the knowledge base more rigid and thus inhibit a firm's ability to innovate. Additionally, we control for R&D intensity. This is a measure that divides R&D expenditure by a firm's net sales. It is believed that firms that invest more in R&D also generate more innovations and hence have a larger stock of patents. Firm performance represents another control variable. It is believed that more profitable firms have more slack resources to spend on R&D. Hence, it is more likely that a profitable firm will invest its slack resources for exploration of new innovations. On the other hand, a firm with a good firm performance may not have the incentive to spend monetary resources on innovation as its overall firm performance is good. Year dummies are being included to account for industry wide and time-varying effects as well as trends in patenting rates. We also control for the size of a firm*'s* knowledge base by controlling for the total number of patents for which a firm has applied and which it has been granted in the previous 3 years.

Results

(to be updated shortly)

Discussion

(to be updated shortly)

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