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Internal Ecosystems and Modularity: Evidence from Multinational Corporations

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1 Introduction

"For ecosystems to be useful, there must also exist a significant need for coordination that cannot be dealt with in markets, but which also *does not require*[1] fiat and authority structure of a central actor", posit Jacobides et al. (2018). To complement this position, the authors use the tension between the necessity for cooperation and existence of transaction costs. Literature clearly acknowledges that transaction cost economics plays an important part in explaining the existence of hierarchies, even going as far as specifying the level of hierarchy necessary to minimize such costs. Taking the perspective directed in the opposite way, markets clearly exist due to the necessity of cooperation, division of labor, to achieve the unachievable to the individual. Ecosystems, according to Jacobides et al., emerge when the outcome of the tension lies rather on the cooperation side, where transaction costs are low enough to allow the preference for market-based transactions.

Using these perspectives, the authors provide Figure 1, where we can clearly see that ecosystems are perceived as systems between hierarchy-based and market-based structures. While this picture is a significant expansion of our vision, I suggest that it is not utilized to its fullest potential: The presented ecosystem is an external ecosystem, where complementors and suppliers lie outside of the firm. An internal counterpart, on the other hand, is not mentioned; the assumption that any internal structure is strictly hierarchic and well-integrated should be questioned. An example for this would be Intel Corporation with 28 subsidiaries across the world and having completed at least 24 acquisitions since 2009 in 19 different business segments in 9 different countries. How can we assume that Intel can impose coordination among its subsidiaries and other acquired business all around the world? The answer to this question lies in the extension of ecosystems theory to intrafirm setting and the underlying chronic state of internal heterogeneity is the key factor to be investigated. As such, as an extension to Jacobides et al.'s reference above, I suggest that ecosystems are useful, when there exists a significant need for coordination that cannot be dealt with in markets and fiat and authority structure of a central actor is present, but which cannot effectively resolve the heterogeneity across subunits.

Subsequently, I focus on the co-occurring notion of modularity. Theory of modularity has covered many lines of research, from existence of a firm to competition and cooperation. First, Jacobides et al. (2018) pin down an important connection between modularity and ecosystems: "More modularization has been associated with a greater prevalence of ecosystems in a number of sectors, from telecommunications to financial services to mobility. Many of the sectors that have been studied in the context of ecosystems - IT, telecommunications, video games, and so on - tend to be more modular, suggesting that ecosystems may well be a distinct solution to the problem of inter-firm coordination, distinct from the use of alliances, supply chains, or market-based interactions." In this statement, we see that modularization concerns the product. Since modularization allows firms to develop their own innovation strategies independently, yet coordinate to create the most value and capture it separately. While product modularity might facilitate cooperation in an ecosystem, we see that modularization has competitive implications when we focus on the focal industry that is surrounded by buyers and suppliers. Schilling (2000) offers a general systems theory framework to explain the factors that could lead to the decreasing or increasing of inter-firm product modularity. Once again, we encounter the key factor of heterogeneity in this framework: Heterogeneity of inputs and of demands lead to higher levels of product modularity. On the other hand, gains to specificity balances the force of heterogeneity: If a) greater functionality is achieved through component specificity, b) it is difficult for customers to assess component quality and interaction, and c) it is difficult for customers to assemble the product, we will observe less product modularity.

The competitive dimension plays an important role in having a holistic understanding of firms' behaviors embedded in ecosystems. In Figure 1, the competitive ties of suppliers are presented, however

[1] Italics added here.

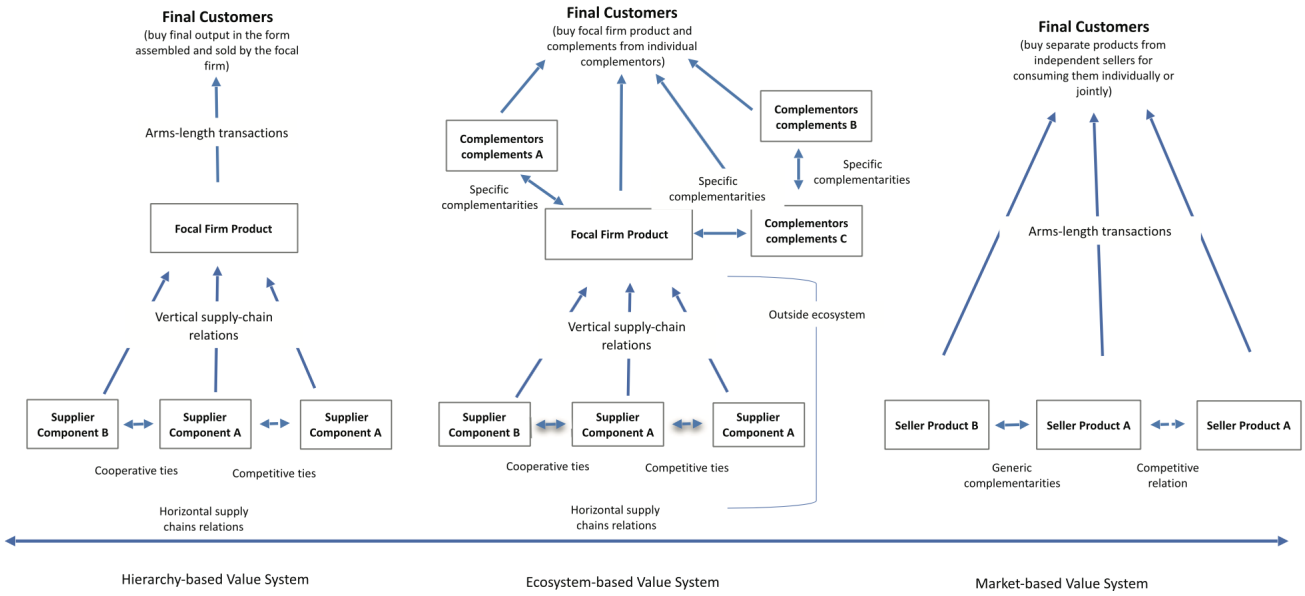

Figure 1: Taken from Jacobides et al. (2018). Hierarchy-, Ecosystem- and Market-based Value Systems are compared.

the competitive pressure on complementors and customers are omitted. External competitive pressures on suppliers, complementors and customers might force these members to comply with modularization or specification movements in their corresponding industries and lead to a disruption in the ecosystem. As such, we observe a web of ecosystems intersecting each other leading to external interdependencies. The necessary management of the balance between cooperation and competition is also discussed by Hannah and Eisenhardt (2017) and separately brought to our attention in Adner (2017). Carrying this picture to internal ecosystems perspective, I suggest that firms with many subunits committed to different external ecosystems but as well as to the internal ecosystem will face the pressure of managing these interdependencies. Going back to the example of Intel Corporation, we have to understand that management of the subsidiaries as well as acquired businesses means alignment of their value propositions imported from their geographical and industrial proximity; a potentially successful way of achieving this would be through embracing the internal ecosystems perspective. This is further discussed in later sections.

When it comes to internal ecosystems, we have to look for modularity somewhere else than product level. While internal ecosystems might include suppliers for the product of the firm as well as complementary products to achieve the value proposition of the ecosystem, hence an ecosystem built around a value chain, firms might have several value chains which may even interact with each other (see for example Pil and Holweg, 2006, for the value grid model). Moreover, focusing on product modularity may block our understanding regarding internal ecosystems and its organizational implications. Modularity scholars have proposed much earlier that the modularity (more generally the complexity structure) of a product should reflect itself in the organizational level; this proposition is deemed as "mirroring hypothesis" (Henderson and Clark, 1990; Sanchez and Mahoney, 1996). However, a broad look into the literature (Hoetker, 2006; MacCormack et al., 2012; Sosa et al. 2014; Colfer and Baldwin, 2016) shows that a consensus supporting or rejecting this hypothesis does not exist yet. Colfer and Baldwin's (2016) analysis of the literature focusing on mirroring hypothesis shows that "over two-thirds (70%) of the descriptive studies provide strong evidence of mirroring, 22% provide partial support, while only 8% do not support the hypothesis. [...]The evidence from open collaborative projects (a relatively new form of organiza-

tion) paints a very different picture. Here the majority of descriptive studies (56%) do not support the mirroring hypothesis..." On a different level, Langlois (2002) proposes a modularity theory of the firm, where transaction cost economics, incomplete contracts and agency theory are taken as different facets of modular rights to control and firms "arise as islands of nonmodularity in a sea of modularity"; in this work, he also points out that the notion of modularity is not inconsistent with the knowledge-based-view of the firm; a view of the firm which emphasizes the "supermodular" complementarities of its subunits (term intentionally adopted from Jacobides et al. 2018).

Following the analogy of non-modular islands in a sea of modularity as well as the findings that not all firms fulfill (or normatively should not fulfill, Chesbrough and Kusunoki 2001, Colfer and Baldwin 2016) complete modularization, I propose that firms that inhibit high levels of sustained heterogeneity have to commit to high levels of modularity. The source of heterogeneity, clearly, determines the kind of modularization that the firms have to consider. I focus on knowledge-based sources of heterogeneity, which is fundamental to coordination. As such, instead of looking at product modules and the modular architecture which combines them, I look at knowledge-based modules, and suggest that knowledge-based modules also impact the modularity of the firm. Internal ecosystems, in this case, is not about complementary, supplied or consumed products, but about complementary, supplied, or consumed knowledge. It should be, however, acknowledged that internal ecosystems theory as well as modularity theory cannot be demonstrated for all firms. To explore the insights gained from both of these theories, I propose to look into multinational corporations (MNC)[2]. As many modularity scholars suggest, the modern business entreprise of Chandler (1977) and the M-form are themselves a form of (non-)modularization. However, this modularization concerns business-based functional modularization and still allows specialization in terms of organizational identity, culture and shared knowledge. Multinational corporations, on the other hand, derive their advantage from sustained heterogeneous source of knowledge and their superior knowledge management capabilities. This not only requires modularity but also an internal ecosystems perspective to extend our understanding of the firm. In the following sections, I highlight the transition from external ecosystems to internal ecosystems by shortly comparing the theories of the firm and contrasting them with the market mechanism. As next, I look at some previous works that look at organizational modularity and partially reveal the internal ecosystems perspective. Following this, I focus on knowledge-based view of the firm and especially the works in multinational entreprise setting. As such, I will limit the scope of the internal ecosystems perspective on knowledge and point out some connections to the modularity theory, one of the theoretical primers of ecosystems. For the hypotheses, I utilize Schilling's (2000) framework and insights from ecosystems theory. Having formulated the hypotheses, I suggest an empirical strategy to test them, and, finally, I conclude with limitations and outlook.

2 Theory

First, I highlight some of the existing theories developed for hierarchies and markets, a dichotomy that has attracted the interest of many scholars since the beginning of 20th century. To understand how ecosystems in markets can be translated into the firm, I use the mechanisms theorized on both sides of the firm boundary and argue that they cannot be separated in a clear way. Interestingly, this discussion can be found in many references presented here, even though each is written in different contexts, such as modularity, multinationals and ecology/culture.

[2]Multinational corporation (MNC) and multinational entreprise (MNE) are interchangeably used from here on.

2.1 Theory of the firm, Market Mechanism and Ecosystems

Looking at the literature, we can see that the necessity of division of labor, cooperation and coordination is an almost universally accepted notion, when it comes to understanding how people can achieve more and more. Cities can not be built by one person, nor can be maintained by one person. Every object we use in our everyday lives requires high levels of coordinated effort before it reaches us. However, when it comes to explaining how to achieve this, we see a different, rather segmented, picture; there are many theories of the firm and they do not necessarily agree in their assumptions nor mechanisms. In economics and finance, some of the well-known theories are transaction cost economics (TCE) attributed mostly to Coase (1937) and Williamson (1975), incomplete contracts to Grossman and Hart (1986) and agency theory to Jensen and Meckling (1976). On the other hand, in organizational theory and strategy, we come across behavioral theory of the firm attributed to the Carnegie School of Simon, Cyert and March (1974), knowledge-based theory of the firm to Kogut and Zander (1996). While an extensive review of these theories cannot be offered here, I would like to focus on the fact that explaining the emergence of an organization as a reaction against any kind of misalignment or conflict is common to all; organizations are arenas where Williamson tackles opportunism, Grossman and Hart and Jensen and Meckling incentive problems, Carnegie School coalitional disagreements and Kogut and Zander discrepancies between people. So, underlying the theory of the firm is the chronic dialectic of divide and conquer but don't divide yourself meanwhile.

Let's step out of the firm and look outside now. Market mechanism is another way of getting organized. It is the most loosely coupled form of organization which also achieves more than what an individual can alone and some scholars might even suggest that it is the best way of organizing. Going back to Adam Smith's invisible hand and, later, Hayek's spontaneous order, we see strong support for the argument that markets not only organize fairly but also in the most efficient way, aggregating information from all sides of the markets, even from local obscure corners of it. "The most significant fact about this system is the economy of knowledge with which it operate, or how little the individual participants need to know in order to be able to take the right action... It is more than a metaphor to describe the price system as a kind of machinery for registering change, or a system of telecommunications which enables individual producers to watch merely the movement of a few pointers, as an engineer might watch the hands of a few dials, in order to adjust their activities" (Hayek, 1945). Taking markets as a mechanism of efficient coordination, we are two steps away from encountering competitive ecosystems theory adopted by strategic management community.

Lamey (2015) extends the spontaneous order of Hayek (1945), the mechanism that supports the argument that markets are more efficient than any organization (including governments) can be, to the biological ecosystems. While price mechanism efficiently transmits information through actors in the market, the author argues that the biological coding (whether behavioral or genetic) of different species transmits information through the actors in the ecosystem. The equilibrium in this biological ecosystem bearing many species is sustained through the complex and intricate interdependency between the species, each reflecting some component of its environment. An important leap achieved by this author is the mapping of the price mechanism and the interdependencies due to its transactional nature to the biological coding mechanism, which also evolves due to biological exchanges of any form.

Before moving on to the discussion of ecosystems, I would like to point out, that in multinationals context Rangan and Sengul (2009) have pinpointed an important consequence of the dichotomy between hierarchies and markets, between transaction cost economics and agency theory; with this perspective, they explain the change in multinational entreprises' boundaries due to development of information communication technologies (ICT). At this point, there are two important connections to be drawn from Rangan and Sengul (2009): 1) An important remark by the authors is that "ICT makes coordination easier and cheaper. This can be expected to shift the balance away from hierarchy more toward markets,

because when bandwidth is limited and communication is costly, centralization is optimal. In a setting of multiple entities (three or more), a single message sent to a central agent (headquarters) from on entity (a subsidiary) can be efficient received and retransmitted to the other entity (another subsidiary) to whom that information is most pertinent." As such, through ICT (knowledge processing and transfer capabilities), modularity theory has direct impact on firm boundaries. 2) The MNEs are described as being in an "open economy" setting and "ICT influences might be expected to be particularly salient". Not only the "open economy" can be paralleled with ecosystems, but also the three factors identified by authors for the high salience of the ICT effects, i) MNEs high reliance on information transfer, ii) control and coordination being a "prime challenge", and iii) "opportunities for value creation via governance shifts [being] higher", supports the earlier argument that multinationals offer a unique setting to study knowledge-based ecosystems and modularity; shrinking firm boundaries due to development in ICT (facilitation of knowledge transfer) merely exposes the underlying ecosystem structure found in multinationals, just as low tides reveal marine ecosystems.

2.2 From External to Internal Ecosystems

Moore (1993) writes in his article "A business ecosystem, like its biological counterpart, gradually moves from a random collection of elements to a more structured community. Think of a prairie grassland that is succeeded by stands of conifers, which in turn evolve into a more complex forest dominated by hardwoods. Business ecosystems condense out of the original swirl of capital, customer interest, and talent generated by a new innovation, just as successful species spring from the natural resources of sunlight, water, and soil nutrients." What we observe in this statement is the importance of emergence of structure and how it depends on others. As such, Hayek's price mechanism is transferred from simple currency exchange and the information contained in the amount changed to the interdependent evolution of organizations that aim at surviving; the transfer demonstrated by Lamey (2015). I would like to point out that Moore (1993) refers to "Apple, IBM, Ford, Wal-Mart, and Merck", which are all multinationals that are managing ecosystems; this supports our theoretically derived choice for MNEs as empirical settings. Since 1993, research on ecosystems grew exponentially (Adner 2017, Jacobides et al. 2018). We see that the scholars focused mostly on innovation, however their conclusions are generalized to product market based competition. The literature expanded even further and considers different aspects of ecosystems from different perspectives such as platforms (Gawer and Cusumano, 2014), multi-sided markets (Hagiu and Wright, 2015), value networks (Nalebuff and Brandenburger, 1996) and such. As such, there is also rather a non-unified perspective on ecosystems and attempts to unify it (Thomas and Autio, 2014).

In this paper, I refer to Jacobides et al. (2018) to make use of ecosystems perspective. They define an ecosystem as "a set of actors with varying degrees of multilateral, nongeneric complementarities that are not fully hierarchically controlled." Complementarities are generic when they are "generic (i.e. standardized) enough for firms to draw on it with little concern for governance structure or risks of misappropriation." The other two kind of complementarity defined by authors are unique complementarity, which posits one component cannot exist without the other, and supermodular complementarity, the system is more than the sum of its parts, as defined in Milgrom and Roberts (1990). Another important dimension brought to the table by Jacobides et al. (2018) is the fungibility of the components. They state that "this is, in our view, a fundamental structural feature that makes within- and across-ecosystem interactions strategically distinct. The degree to which a participant's effort is tied to one ecosystem, and cannot be recoupled in any other setting, determines the economic basis of their attachment to that ecosystem (see e.g., Cennamo, Ozalp, & Kretschmer, 2018)." It can be argued based on resource-dependence theory that both complementarity and fungibility allow us to realize a stable external ecosystem, but their meaning has to be re-interpreted, when it comes to intra-firm setting. Internal ecosystems are built rather around a knowledge-based value proposition than product-based. In the next section, I discuss

through knowledge-based view of the firm how even the presence of ownership and control does not lead to participation in knowledge ecosystem and knowledge-based heterogeneities still require an ecosystem perspective.

Internal ecosystems have been already described by some scholars in different settings. An important example is Galunic and Eisenhardt (2001), where the authors' focus was rather on modularity than on ecosystems perspective. They offer a case study of a multinational corporation (pseudo-name Omni) with more than 100 subsidiaries spread to around 69 countries [3]. Their research on different divisions of the company, 8 of them local and 2 foreign, includes different business group level strategies as well as different business segments. The corporation was not only sustaining this heterogeneity and making the most out of it, but also present an ecosystems mindset: "Another example was Voyageur [4]. [...] Corporate managers recognized that if Voyageur's technological stream were combined with another technology emerging within Omni (a networking technology, a new business could be developed. Although there was no existing charter for this business opportunity, managers saw market potential for a new business." What is important to acknowledge here is that the corporation acted as a facilitator of knowledge flow, but not as a hierarchic authority, and fostered collaboration among its divisions. In addition to this example, Galunic and Eisenhardt's work reveals many components of ecosystems rather than modular systems, and the reader should refer to this work to uncover this internal ecosystem management.

Dissecting the word "ecosystem" should support our analysis of internal ecosystems: A system consists of a set of components and specified relations among them. However, what makes it an ecosystem is that these components stand in cooperative and competitive relations, or more generally they have positive and negative externalities for each other, and the survival of the system is endogenously achieved rather than exogenously sustained. In Omni corporation of Galunic and Eisenhardt (2001), we observe competition among divisions, as well as cooperation. Moreover, we observe a rather endogenous self-sustaining system than the strong support of a hierarchy or such an omni-potent control and coordination: "In contrast to the role of executives in the new charter opportunities, executives influence in the charter wars was limited. They clearly could have intervened to stop the wars, but they did not [...]they let a Darwinian process cull the herd."

2.3 Knowledge-based View of the Firm and Multinationals

Studying knowledge ecosystems in firms requires understanding of the role of knowledge flows and management accordingly. Kogut and Zander (1996) state that "identity improves coordination, communication and learning" and they suggest that this becomes even more important in a firm, where division of labor accompanied with specialization is necessary to achieve more than what an individual could alone. In their work, the authors acknowledge an important dimension of heterogeneity in organizations and make the case that organizations exist, because they naturally align its members' perceptions and mental views of the world and, in a sense, reduce heterogeneity. However, the question arises "what happens when this cannot be achieved?" Kogut (1985) offers a model for multinational expansion, explaining which part of the value chain should be located in which country. As an example, he suggests that R&D, advanced electronics manufacturing and industrial machinery manufacturing should be allocated to developed countries, basic manufacturing, assembly and simple consumer goods to newly industrialized countries and food processing to less-developed countries.

While for external ecosystems the discussion of geographic distribution of the components of the value chain is avoidable, such a distribution in a firm due to economic considerations enhances the necessity of an internal ecosystems perspective accompanied with modularity. Porter's (1986) analysis of configuration and accordingly associated coordination problems reflects this very well: "A firm faces an array of options

[3] https://www.sec.gov/Archives/edgar/data/1645590/000162828016022051/ex-21x10312016.htm

[4] A division of the company

in both configuration and coordination for each activity. Configuration options range from concentrated (performing an activity in one location and serving the world from it - e.g. one R&D lab, one large plant) to dispersed (performing every activity in each country). [...]Coordination options range from none to very high. For example, if a firm produces its product in three plants, it could, at one extreme, allow each plant to operate with full autonomy - e.g., different product standards and features, different steps in the production process, different raw materials, different part numbers." If we look at low coordination dispersed configuration, we can end up revealing geographically dispersed lone-standing ecosystems. On the other hand, if we look at moderate level of coordination for geographically concentrated strategies, we find an ecosystem spread out to world.

Coordination strategies of multinationals have been investigated by the scholars of KBV extensively, especially in terms of managing knowledge flows. Hansen (1999) looks at how complexity of knowledge in product innovation affects the subunits ability to transfer it to the other subunits. Here, the author touches on modularity and its interaction with complexity: "(Another) important dimension of knowledge complexity, especially in product development tasks, is the extent to which the knowledge to be transferred is independent or is an element of a set of interdependent components. A stand-alone component, a distinct software *module*[5], for instance, can be uprooted from its existing use fairly easily, and transfer can take place with the focal team having little or no knowledge of a larger system." He finds that weaker social ties between subunits leads to shorter project completion time when the knowledge to be transferred is highly codified and independent. The opposite hypothesis, longer completion time when knowledge is non-codified and dependent, finds support as well. As such, we see an example for the influence of knowledge modularity interacting with the bandwidth of the knowledge transfer channel on performance. While the author does not reveal the exact structure of the communication network nor the role of headquarters, he mentions that three corporate R&D managers "coordinate the product development efforts undertaken by the 41 divisions". Out of 41 divisions, "four divisions were located in Asia and Australia, sever were located in Europe, and the remaining divisions were located in various places in the U.S." Finally, he states that "the company is structured into [...] fairly autonomous operating divisions that are responsible for product development, manufacturing, and sales." This points at geographically dispersed rather loosely-connected model of Porter (1986). The role of corporate headquarters is yet to be explored in this setting.

While Hansen considers the complexity of knowledge and the channels of transferring it, Gupta and Govindarajan (2000) and Monteiro et al. (2008) look at several other factors involved in knowledge transfer between headquarters and subsidiaries, such as richness of transmission channels or knowledge stock and perceived capability of subsidiaries. Both of the works combined, we see that the structure of the knowledge network as well as the perceived capability of the subsidiaries play an important role. Gupta and Govindarajan's (2000) findings regarding the relationship with headquarters are 1) Existence of formal vertical integrative mechanisms leads to higher out-/inflow between subsidiaries and headquarter, 1) subsidiaries with higher incentive focus and that are subject to more HQ-Subsidiary decentralization have less knowledge transfer with the headquarters. The interaction effect is not studied and it would be interested to see whether formal integrative mechanisms are used complementarily with more incentive focus and decentralization. The zero order correlation between incentive focus and formal vertical integration mechanisms indeed have positive correlation, and both negative with decentralization.

Monteiro et al. (2008) finds that 1) Higher rating of the subsidiary's capabilities by HQ is positively associated with a high frequency of vertical knowledge outflows, and 2) Higher self-rating of its own capabilities by the unit is positively associated with a high frequency of vertical knowledge flows. As such, we see that headquarters and subsidiaries both make use of their knowledge flows actively, and they do so when they perceive the knowledge as most valuable. Agency is inevitable in knowledge-based

[5]Italics added here.

systems. An interesting finding is that those subsidiaries which participate less in knowledge flows have significantly lower performance. These two works highlight the interaction between the knowledge flow structures (regarding modularization) and the consequences on degree of coordination (decentralization towards ecosystems) and on performance (lower performance due to isolation from ecosystem).

In three different works, we see that knowledge transfer and integration has positive effects on the system as a whole (given that the subsidiaries cooperate) and the economic and social design of the company plays an important role in regulating the participation. As such, there are two pressures following from the discussion so far, that concern corporation headquarters:

1. Knowledge is specialized to the functionality and geography of the subsidiaries. This is a pressure towards a hierarchy-like structure to mitigate transaction costs.

2. The subsidiaries' high level of effort can be sustained through more autonomy. This will further foster participation in the knowledge-based ecosystem. This is a pressure towards a market-like structure.

Clearly, the pressure towards a market-like structure foster the notion of ecosystems and, following, I offer some hypotheses regarding the existence of internal ecosystems. It is important to note that, as already discussed, achievement of ecosystems inhibiting heterogeneous components is enabled by modular systems. As such, the second pressure is necessarily countered with modular structures of knowledge flow to foster coordination and cooperation in the ecosystem, and are expected to be present in MNEs, as argued below.

3 Hypotheses

Baldwin (2007) brings together transaction cost economics, knowledge-based view of the firm and modularity theory to locate the transaction intense points in a market and answer the question "Where to transactions come from?". Her unit of analysis constitutes decisions, components, tasks and their dependencies, and she shows how the nature of components and their dependencies influences transaction costs as well as the efficiency in making use of knowledge. However, her discussion is, as in Langlois (2002), to some extent limited and how her analysis would reflect itself in the firm is not clear. She considers transfer pricing in corporations as the transactional unit, as well as the corporations as transaction-free zones encapsulated by transactions, and connects her consideration of corporations to the rest of her theory by this. This description of the corporation resembles a rather an unrelatedly diversified corporation exercising simple financial control than a corporation that aims at nourishing its subunits. This is the point where ecosystems perspective has to be taken seriously: Managers in the headquarters are the natural designers of ecosystems. While the designers in external ecosystems can neither directly monitor nor directly control the components (Jacobides et al. 2018), it is a different situation for internal ecosystems. Although headquarters have more control over the design as the survival of subunits depends strongly on the corporation's survival, as previous discussion indicates, they have to balance the gains from control with loss from decreasing incentives. As such, headquarters' resort to monitoring and knowledge flow controlling practices is what allows the emergence of internal ecosystems.

Following, I discuss the implications of the theoretical framework proposed regarding internal ecosystems and then modularity. While monitoring and knowledge flow controlling practices has been researched by multinationals scholars to some extent, a modularity perspective to it seems to be currently underdeveloped. [6]

[6] Mingjie (2007), Qiu-Zhi (2012), Madiedo and Salvador (2015) were not accessible at this stage of the term paper. They would be included, if access is established.

3.1 Internal Ecosystems

While there has been many works focusing on internal management of multinationals as well as regarding modularity, to my knowledge, revealing knowledge-based ecosystems has not been hypothesized or empirically achieved yet. A difficulty in establishing measurement of ecosystem structures comes from the multi-causality problem; many components of ecosystems theory can be attributed to agency theory, resource-dependence theory and many others. As such, the differentiating propositions of ecosystems become elusive. To tackle this problem, I first refer to some methods developed by organizational theorists utilizing ecological models (Weeks and Galunic, 2003; Pontikes and Hannan, 2014). For example, Weeks and Galunic (2003) go through a very similar path of discussion as proposed here and take a culture based perspective to the tension between markets and hierarchies, transaction cost economics and knowledge-based view of the firm. They define "memes" as collective cultural modes of thought including "values, beliefs, assumptions, know-how, and so on." The important insight here is that "the meaning and effect of any element of culture depends less on its essence than on the context of the rest of the culture around it. We cannot look at memes in isolation. When conceptualizing how culture evolves through a process of the variation, selection, and retention of memes, we must explicitly take into account the fact that memes only make sense when we look at their patterns of combination." This statement highlights an important aspect of ecosystems theory, even for the external ones as it for example parallels the findings of Adner and Kapoor (2010): Whatever is the unit of analysis, its evolution depends on the state of the surrounding units. In Adner and Kapoor (2010), we observe that the performance (in this case retention) of a technological innovation depends on the complementary technologies as well as suppliers. Hence, achievement through collective development is a signature mechanism of ecosystems.

Following this mechanism unique to ecosystems perspective, the first method to reveal the internal knowledge-based ecosystem in a multinational would require an analysis of evolution of memes, or to focus our discussion, of know-hows and routines. To analyze this, we not only have to look at the knowledge flows as Gupta and Govindarajan (2000) or Monteiro et al. (2008), but also for example the diffusion of the know-how or the routine specified by its type. It must be pointed out that we are not only looking for sequential evolution/adoption of know-how, but more importantly at co-evolution of them. For example, we can look at two different subsidiaries separated by their functionality and geography, manufacturing subsidiary 1 in country A and R&D subsidiary 2 in country B. If the successful adoption or development of a know-how in subsidiary 1, depends on a complementary know-how development in subsidiary 2, then we can speak of knowledge-based ecosystems. We can then argue in a similar tone with Adner and Kapoor (2010):

Hypothesis 1a: *An increase in challenges in obtaining novel know-how in one subsidiary will decrease the know-how adoption and development of other subsidiaries as well.*
Hypothesis 1b: *The effect will be stronger, when the subsidiaries are closer in terms of either functionality or geography.*

An important remark is that the ecosystems mechanism is applicable only when the adoption of such know-how and their development are not prescribed by the headquarters. The autonomy of the subsidiaries are crucial and headquarters' role should rather concern knowledge transfer than imposing the implementation of the transferred knowledge. This is in accordance with the existence of pressure towards a market-like internal system and also supported by preliminary empirical evidence in Belanger et al. (2000) on ABB highlighted by Noorderhaven and Harzing (2009): "This study illustrates how in some cases peripheral units try to catch up by learning from the MNE center, while in other cases lateral learning relationships form, ?no imposed and not even organized by corporate headquarters' (p 253)." While the authors deem it as learning, here, I do not specify the micro-mechanisms and leave it

for future work to study the extent to which learning is present in ecosystems. Focusing on identification of ecosystems, a necessary condition can be suggested as following:

Hypothesis 2: *In presence of the previously hypothesized finding, the rate of adoption of know-how due to knowledge inflows from headquarters is (at least) not significantly higher than that due to knowledge inflows from other subsidiaries.*

As next, I look at the implications of the theory for modularity in knowledge flow structures that enable these ecosystems, if they exist.

3.2 Modularity

The discussion so far has pointed out that the subsidiaries will be specialized to their locations and their autonomy should be preserved. Allowing the sustained autonomy of subsidiaries limits the ability of headquarters to impose lateral knowledge communication structures, as well as the ability to impose lateral interdependencies. So, although the corporation has a modular structure as each subsidiary constitutes one, including headquarters, their coordination and cooperation around a single value proposition can be sustained only if a component is compatible with all the others and act as the designer as well as the facilitator of the underlying structure. As discussed earlier, headquarters being directly separated from operations is the natural candidate to act as the designer of the ecosystem.

Baldwin and Clark (2009) suggest that modularity is achieved successfully if the information is partitioned into visible design rules and hidden design parameters. The visible design rules regarding modularity are categorized into three: 1) An architecture, which specifies what modules will be part of the system and what their functions will be. 2) Interfaces that describe in detail how the modules will interact, including how they will fit together, connect, and communicate. 3) Standards for testing a module's conformity to the design rules (can module X function in the system?) and for measuring one module's performance relative to another (how good is module X versus module Y?) While this notion is complementary to the ecosystems perspective, it assumes away the dynamism of the system as well as the designer of the system. I propose in addition to these three categories that the designer has to be more complex to be able to actually design the modules as well as maintain their interdependencies. This notion acknowledged by Baldwin and Clark (1997): "The designers of modular systems must know a great deal about the inner workings of the overall product or process in order to develop the visible design rules necessary to make the modules function as a whole." Shipilov (2009) argues similarly ("firms with a wide scope of experience have superior absorptive capacity for dealing with heterogeneous information") in his analysis of collaborative ties among investment banks.

Having the power of designing the system, how can headquarters then connect to heterogeneous modules in the company? One way is clearly attempting to standardize the modules in such a way that headquarters can be compatible with each in a less costly way. However, this is not compatible with agency theory nor ecosystems. The alternative way is that headquarters becomes more modular given the heterogeneity of knowledge flows. Schilling's (2000) systems model demonstrates this (see Figure 2). Her model concerns product modularity, identifies successfully the influence of external heterogeneity. Here, we take product as the know-how/knowledge and consider that inputs as well as demands are placed by subsidiaries to the headquarters. The headquarters has to develop modular knowledge acquisition, processing and transferring structures to meet the heterogeneous knowledge inputs and demands of the subsidiaries. Santos and Williamson (2015) point at several dimensions, where the modular headquarter structure could be realized: "Headquarters needs to share control over the corporate future and abandon the idea that local subsidiaries must march in lockstep and adapt standard product designs and processes. [...]headquarters executives also need to seek out the new global opportunities that local integration

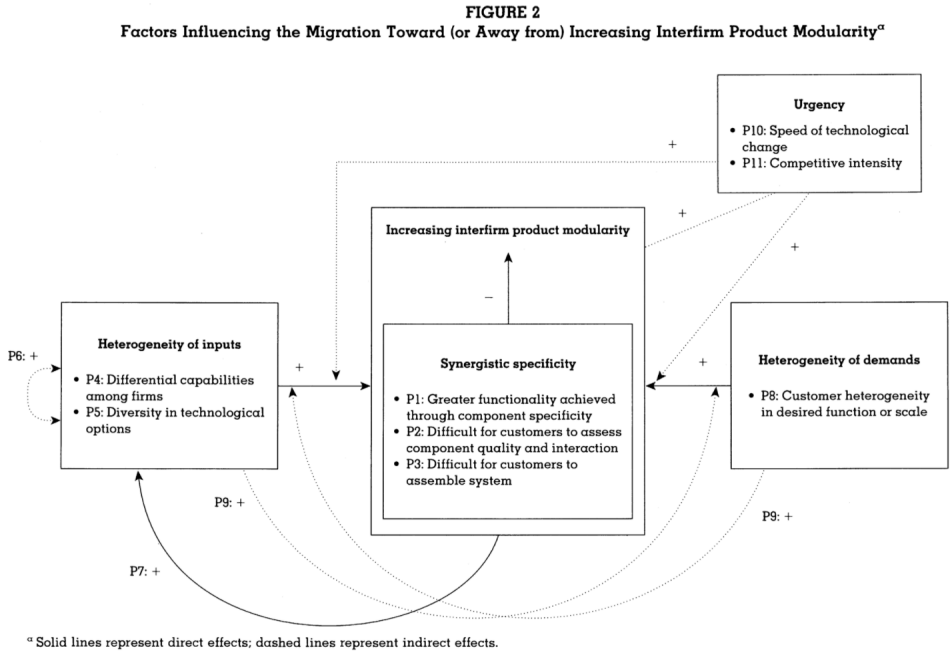

Figure 2: Schilling's (2000) general systems model

spawns. Interactions with local partners will generate new knowledge and unexpected opportunities for global innovation." Hence, we see that the preservation of local heterogeneity requires compatibility of headquarters. The "differentiated fit" of Nohria and Ghoshal (1994) already demonstrated the positive outcomes of this. Similarly, O'Donnell (2000) looks at how headquarters should manage their subsidiaries and finds that the subsidiary characteristics as well as their environments influences monitoring and incentive schemes.

In this paper, I take two different approaches. First, looking at the knowledge flows as a dyadic relationship between headquarters and subsidiaries, I look how unique is the knowledge transfer from headquarters to the subsidiary. This encompasses uniqueness of all of the components of the communication channel (Krone et al. 1987): the sender, the coding scheme, the channel, the decoding scheme and the receiver. This would also be an extension to Gupta and Govindarajan (2000).

Hypothesis 3: *Sustained heterogeneity on subsidiary level will lead to more unique communication channels between the headquarters and the subsidiaries.*

Furthermore, the diversity in the communication channels has to be complemented with rather complex internal structure in the headquarters. The acquisition of diverse information requires highly complex internal mechanisms, which can translate the knowledge coming from one source, analyze it and translate it to the form that another subsidiary can make sense out of (Shipilov 2009). This can reflect itself in different ways. One example would be the number of independent foreign directors on the directory board would be an indicator for the support for the analysis of incoming knowledge or for the translation for the outgoing knowledge. It has been shown by Masulis et al. (2012) that independent foreign directors lead to better acquisition decisions undertaken in their own country. Another example would be the number of corporate managers per functional division. The three corporate R&D managers in Hansen's analysis is an indicator that the incoming R&D related knowledge will be analyzed thoroughly. Finally, in addition

to the presence of numerous actors being involved in decodifying, analyzing and translating, we would expect formal or informal ties connecting different actors in the headquarters to each other. In absence of such ties, the internal processes will not see any benefits.

Hypothesis 4a: *The higher the subsidiary level heterogeneity, higher will be the number of actors in headquarters responsible per subsidiary.*
Hypothesis 4b: *The higher the subsidiary level heterogeneity, stronger will be the lateral and vertical integrating channels internal to the headquarters.*

Finally, we have to address the interaction of ecosystems with modularity. For this, we import the notions of fungibility and complementarity from ecosystems (Jacobides et al. 2018) to understand the subsidiaries influence on modularity. As we already established, each subsidiary is a dissimilar component in the system. However, first of all, the degree of interdependence as well as dissimilarity still have to be included in the analysis; multinationals are not necessarily perfectly modularized. Moreover, in addition to the chronic heterogeneity problem due to culture, functionality and such, we also have changing attributes of the subsidiary, especially due to its environment (or local ecosystem). For this, I follow Rugman et al.s (2011) extended typology resulting from the criticism directed at Ghoshal and Bartlett's (1986). There are two important criticisms, 1) Ghoshal and Bartlett did not take into account the different positions the subsidiaries have in the value chain, and 2) The effects of semi-globalization lead to changes in comparative advantage of subsidiaries and their importance changes accordingly. The new framework offered by Rugman et al. (2011) combined with Schilling's (2000) framework for modularity allows us to draw some hypotheses regarding the structure of knowledge ecosystems. As both Gupta and Govindarajan (2000) and O'Donnell (2000) show, the strategic importance of a subsidiary influences the monitoring activities of the headquarters of that subsidiary; more specifically, more valuable the knowledge is (or perceived to be, in case of Monteiro et al. 2008) the more knowledge flows exists between headquarters and subsidiaries. These findings show that headquarters prioritize their communication based on the performance of the subsidiaries. Whether this is actually effective or not, its influence on Schilling's (2000) model would be a decrease in heterogeneity of inputs as well as "competitive intensity", which can be seen as one communication channel becoming rather the monopoly among others.

Hypothesis 5a: *The more concentrated is the strategic importance of subsidiaries in one subsidiary, less modularization will be observed in headquarters.*

Moreover, if we see that one subsidiary is becoming more autonomous and profitable, hence strategically more important, the concentration of headquarters efforts to this subsidiary will lead to an asymmetry in the evolution of ecosystems. The challenges for adopting and developing relevant knowledge and know-how in other subsidiaries will be undermined by the lack of support of the headquarters or lack of participation of the profitable subsidiary in the ecosystem. As such, we can say that:

Hypothesis 5b: *i) The more concentrated is the strategic importance of subsidiaries in one subsidiary, the more impacted will be other subsidiaries in terms of knowledge and know-how adoption and development, ii) This will be exacerbated by the decreasing modular compatibility of the headquarters.*

Finally, as Rugman et al. (2011) points out, influences from local ecosystems, or simply from local environments, will lead to changes in strategic importance of the subsidiaries. This will make longitudinal observation of these mechanisms possible. While I do not hypothesize separately, I will use longitudinal aspect of this analysis to test hypotheses 5a and 5b.

4 Empirical Strategy

The empirical strategy can be divided into several groups. First, I discuss the hypotheses regarding only ecosystems, namely hypotheses 1 and 2. Then, I discuss hypotheses 3 and 4 regarding modularity. Finally, for the interaction of both I focus on hypothesis 5.

While identifying indicators of an external ecosystem structure in innovation intense industries is possible (for example Adner and Kapoor 2011), this is more challenging when the ecosystem is inside a firm and it is knowledge-based. So far, I referred to Galunic and Eisenhardt (2001) to describe an ecosystem like structure. However, even in their case, we do not see knowledge ecosystems, rather ecosystem management if there is any. An important take-away from this work, on the other hand, is that case studies are the most appropriate way of uncovering such structures. For example, Sharpe et al. (2011) makes an ethnographic case study focusing on the evolution of the intra-organizational ecology of a medical UK subsidiary. Referring to Scott-Morgan (1994), the authors identify the following five categorization of interview statements: 1) Perceived rules, 2) Side effects, 3) What is important to individual employees within the organization; in other words, what are the personal agendas (Motivators) of various people with the organization? 4) Who (Enablers) is important to the individual given these "motivators"? 5) How (Triggers) does the individual impress those who are important? While these categorizations are constructed for intra-organizational studies, they can be still expanded to multinational firms. Although multinational firm-wide case-studies are not feasible, there could be two ways of collecting data. The scholars of multinational firms (such those already cited in this work) as well as intra-organizational researchers (for example Gargiulo et al. 2009), who study knowledge channels, extensively used surveys. In a work studying the embeddedness of multinationals in local environments, Saliola and Zanfei (2009) ask managers "whether the buyer sent employees to (or organized personnel exchanges with) suppliers as a means to disseminate and diffuse new technologies into the local firms' production facilities" and code the answers as "knowledge dissemination and process and product R&D". Building on the surveys used by Monteiro et al. (2008), surveys can include not only the ratings of other subsidiaries but also the type of know-how that is transferred from and to other subsidiaries and headquarter can be asked. A well-known problem with surveys is that the information gathered depends on the memory as well as perception of the person surveyed. Directly asking how frequently know-how develops and what the major developments in the subsidiaries were could give more focused information, which could lead to a temporal map of know-how evolution in different subsidiaries.

A second technique which is not yet widely applied in management research is utilizes content analysis. Goldberg et al. (2016) use company-wide email exchanges and "propose that e-mail archives can provide a window into both network structure and an important facet of culture - the extent to which the language of people use within their organizations conforms to the linguistic style of their colleagues." Having access to such a communication data and application of content analysis, not necessarily style analysis, would enable us to map the evolution of know-how as well as subsidiary-level routines. For routines, I consider practices that require periodic and repetitive interactions between people; this could be periodic increase and decrease in email exchange frequency as well as periodic initiation of chain of email exchanges. Clearly, combined with survey data, we can have a complete understanding of the evolution of know-how and routines. As a result of these analysis, we can employ a model which investigates the co-evolution of know-hows or routines. A crucial factor to measure would be an increased amount of "know-how turnover" in a subsidiary, defined as high number of know-how development but low number of successful retention, when the amount of know-how production is low in other subsidiaries. To test hypothesis 1b and 2, we can further include questions regarding functionality, geography and amount of knowledge in- and outflows among the subsidiaries and with the headquarters as already done by other scholars.

Similarly, the empirical strategy for modularity related hypotheses also relies on survey data. In general, organizational charts or employment data of the firms are not disclosed. However, if the managers

of the firms participate enough in surveys, which is the case for previous works, information regarding the functional structure of the subsidiaries and geographic locations can be easily collected, which would be combined to measure subsidiary heterogeneity, the main independent variable. For hypothesis 3, in addition to Gupta and Govindarajan's (2000) questions, we would include questions regarding the point of contacts, means of communication and subsidiary specialized vertical integration mechanisms. An example for the vertical integration mechanisms would be visits by headquarter officials to subsidiaries (Nohria and Ghoshal, 1994) and uniqueness would be established by who visited and how often. The other dependent variables such as number of actors in headquarters per subsidiary as well as integrative mechanisms can be constructed in a similar fashion.

Finally, hypotheses 5a and 5b moderate the above given relationships, and the independent variable of moderation is the strategic importance. At this point Rugman's (2011) remarks regarding the change in environment leading to change in strategic importance can guide our empirical strategy. He states that "the main source of substantive shifts in subsidiary roles because of regional integration is changes in national location advantages vis--vis other nations in the region. [...]This approach is consistent with McCann and Mudambi's (2004, p. 502) observation that ?much of the geographical relocation of activities within MNEs consists of the reallocation of activities and resources within an existing spatial configuration of establishments, with little or no discernable external changes..."' As such, we can use Rugman's (2011) typology of changes in strategic importance and use the six patterns proposed by him to build our independent variables: 1) Subsidiary shutdown or full activity swap, 2) Status quo, 3) Full regional charter, 4) Partial regional charter, 5) Single activity specialization, and 6) Added, single-activity regional charter. These patterns describe changes along value chain and importance. Hence, for example when a subsidiary swiched from status quo to full regional charter, we would expect higher concentration and weakening of the observed effects in all other hypotheses. An advantage of this method is also that environmental changes can be taken as exogenous shocks to the system and the impact on ecosystems and modularity can be observed clearly.

5 Conclusion and Outlook

More than 20 years ago, Gupta and Govindarajan (1991) note that "although past research provides some clues regarding how the global structure of an IBM might differ from that of a Siemens or a Fujitsu, it sheds little light on how, within an IBM, corporate control over one specific subsidiary might differ from that over another." Their work addresses the internal heterogeneity found in multinationals, but it is formalized specific to multinationals. In this work, based on ecosystems and modularity, I proposed a more fundamental theory of why the heterogeneity exists and its main drivers. As such, I aimed at contributing to ecosystems and modularity research by approaching multinationals as market-like hierarchies rather than control exerting closed systems.

First of all, the important distinction proposed in this paper is the internality or externality of the ecosystem setting. While transiting from markets to hierarchies leads to an abrupt change in ownership and control, the emergent unified organizational identity is an important moderating factor in achieving the efficiencies offered by hierarchies. Knowledge-based-view of the firm has offered a substantial contribution to the research on multinational entreprises and identified the source of their relative advantage as the efficient processing and sharing abilities of the heterogeneous knowledge acquired across countries. As such, the literature fundamentally assumes the heterogeneity of the actors and investigates their coordination mechanisms. The tension between the sustained heterogeneity and pressure to cooperate, however, cannot be fully captured on by coordination; modularity as a complementary factor needs to be included in the analysis. Hence, this well-established striking contrast to domestic or international companies allows us to investigate the role of modularity in a hierarchical setting. Ecosystems perspective provided

a natural fit to investigate this system. In summary, the chronic heterogeneity found in multinationals are expected to have impact on knowledge structures and knowledge-based ecosystems.

Moreover, modularity literature has focused mainly on product modularity and investigated its consequences on organizational structure and on organizational performance. While product modularity can be clearly discussed in the presence of consumers of this product, organizational structure does not necessarily have to align with product modularity as the structure is not a direct reflection of the technological heterogeneity, but a social heterogeneity. As such the performance due to organizational modularity will also not be optimally measured in product markets but in organizational social dynamics. Further research could extend the ecosystems and modularity perspective to turnover rate, decrease in stickiness of knowledge and intra-firm conflict. The main limitation of this work arises from empirical difficulties. As already mentioned, multi-causality of the findings can make it difficult to pinpoint ecosystems theory. Hence, we need higher temporal resolution as well as social structure granularity. Overcoming such difficulties with the developing techniques such as big data analysis as well as thanks to evolving trends of management such as open-source activities could shed light on the hypothesized ecosystems structure found in market-like hierarchies.

I conclude with some excerpts from Sam Palmisano's speech "The Globally Integrated Enterprise" (Palmisano, 2006), CEO of IBM, one of the oldest MNEs, which reflects the ecosystems-based modular management style: "Let me tell you about what we're doing at my own company. At IBM, we've set off down the path of empowering and enabling our people to make decisions and to act. We call this ?lowering the center of gravity' of the company - that is, trusting IBMers and pushing decision-making authority out and down. [...] Management has to provide the tools, the mechanisms, the funding... and the individual has to make use of them. It has changed everything from how we manage our client relationships and R&D, to our benefits programs. More choice, more control, more responsibility in the hands of the people who are in the best position to call the shots - not headquarters, but the individual IBMer. [...]We're planning to create a global training ground in emerging markets of the developing world. [...] IBM will benefit from leaders with new perspectives and enhanced skills, and the community will benefit from our technology and talent. We hope it will help broaden our people's thinking and understanding not only of different cultures, but of the global context in which business today operates."

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