MNC STRUCTURE, COMPLEXITY, AND PERFORMANCE:

INSIGHTS FROM NK METHODOLOGY

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Abstract

We introduce NK-simulation models to international business research and more specifically show how this methodology provides insights into the effects of MNC structure and internal complexity on performance. The interdependence of decisions made in different MNC-units is theorized as an underlying mechanism by which structure and complexity affect performance. The performance of three organizational structures, regional, matrix, and network, discussed in the IB literature is compared at the various levels of complexity. The results of our simulations show that the relationship between internal complexity and firm performance is an inverted U for all three organizational structures. Furthermore, at high levels of complexity the network structure has the best performance, followed by the matrix, with the regional last. However, at low levels of complexity the rank order of structure performance is reversed. In addition to these conclusions, this paper contributes to the international business research by demonstrating how the methodology's power can help scholars answer fundamental questions regarding other IB phenomena.

1. Introduction

A survey of global CEOs revealed the rapid escalation of complexity as the biggest challenge and more than the half of them doubted their abilities to manage it (Berman, 2010). This finding should not be surprising to international business scholars who study MNC organizational structure. Given the definition of complex systems as those “being made up of a large number of parts that interact in a non-simple way” (Simon, 1962: 468), MNCs with their multiple product divisions, each having many interdependent and geographically dispersed subunits whose decisions are interdependent regarding operation and resource allocation, are the most complex of all organizational structures. For example, consider the complexity of Siemens with its 362,000 employees who work in 290 major production and manufacturing plants located in approximately 190 countries (Siemens, 2013).

NK-modeling is a simulation methodology that is widely used in the management literature to gain insights as to how complexity of organizations or systems affects performance (Levinthal, 1997; McKelvey, 1999). NK-methodology is prevalent in research on organization theory (Rivkin & Siggelkow, 2003), management cognition (Gavetti & Levinthal, 2000), and strategy (Ganco & Agarwal, 2009; Ganco & Hoetker, 2009). However, despite ongoing IB research on MNC organizational structure and performance (Chi et al., 2004; Ceci & Prencipe, 2013), and the fact that NK-methodology lends itself to analyzing complex MNC structures, it has yet to be used in IB literature. Instead, most IB research that has enriched our understanding of the effect of complexity on performance is in the form of case studies (e.g., Ghemawat, 2005; Ghoshal & Bartlett, 1990; Malnight, 1996).

While case studies have their place, simulation is an especially powerful tool to model theory in situations where field studies are impractical because large matched samples are unobtainable, or the number of managerial and environmental control variables required to account for alternative explanations are too numerous (Davis et al., 2007; Lazer & Friedman, 2007; Venaik et al., 2004). Hence IB-research of MNC-complexity and structure's relationship with performance lies at a point between theory creating using multiple case inductive research and theory testing using field data and multivariate statistical techniques. Davis et al. (2007) call this the "sweet spot" for which simulation methods are particularly useful.

The NK-model of MNCs that we build in this paper makes it possible to investigate the relationships of interest in a controlled environment. The MNC is modeled as a network of units connected by linkages, which reflect the underlying pattern of decision-making interdependencies. These interdependencies affect overall MNE performance in that the contribution of a decision made in one unit to performance depends on the decisions made in other units. In addition to taking into account the interacting effects of decision linkages among units, the dynamic nature of the NK model allows one to study the MNC as it searches for better performance over time.

We have injected realism into our MNC-model to the degree that is possible given the technical specifications of NK-methodology. MNCs inherit their organizational characteristics through interaction with their environment and through strategic rivalry with their competitors. More specifically, the environmental conditions of international business become part of our model by constraining the managerial choices of structure and level of complexity. To demonstrate the power and validity of our model, we conduct a series of analyses examining the effect of structure and complexity on MNC-performance by having one of the two variables largely predetermined by characteristics of the MNC's environment and the other as a strategic choice of the MNC.

The results reveal that regardless of structure, a moderate level of complexity is optimal. They also show that MNC-performance comparisons across structures are meaningful only when the level of complexity is taken into account. Regional structures seem to be the best choice at low levels, matrix structures at medium, and network structures at high levels of complexity. The results are confirmed by conducting numerous robustness tests.

Our paper contributes to the international business literature in three ways. First, we introduce NK methodology to the IB field because this approach can provide researchers with insights for a variety of IB research questions for which empirical studies are difficult or impossible. The constructs of structure and complexity are particularly important to MNC performance and NK modeling enables us to examine their relationship in a controlled environment, by setting all other non-structural parameters equal. Second, we demonstrate the advantages of NK methodology by modeling comparable matrix, regional, and network organizational structures to answer our research question: how does the complexity of these structures affect performance? The literature studying structure and performance is conflicted at worst and inconclusive at best (Wolf & Egelhoff, 2010; 2012). Because of the limitations in case studies, researchers can only estimate firm performance for the type of structure design that a firm actually implemented. The results obtained by using NK methodology give insights into the effect of structure on performance are of both theoretical and practical importance and beyond what is discussed in previous IB case studies. Third, we further develop complexity theory (Eisenhardt & Piezunka, 2011) in the context of MNCs addressing the key management challenge from a complexity point of view, namely “finding the right balance of too much and too little structure” (p. 507).

The remainder of this paper is organized into eight sections. The next section discusses the problem statement and reviews the literature relating MNC-structure and performance. The third section explains decision interdependence as a theoretical mechanism by which structure and complexity affect MNC performance. We elaborate further in the fourth section by explaining basic concepts of NK-methodology in the context of MNCs. Next we explain in detail how we apply NK-methodology to answering the research question and illustrate all the technical steps by using examples. Subsequently, we present our findings and follow with a section describing the robustness tests and some extensions of the model. Further we discuss the managerial and practical relevance of the model and then conclude.

2. Review of the MNC Structure and Complexity Literature

The study of organizational structures and how they affect performance in the field of international business began as an extension of the more general discussion of strategy – structure relationship in strategy (e.g., Egelhoff, 1982, 1988; Franko, 1976; Luo, 2002; Stopford & Wells, 1972). Stopford and Wells (1972) proposed that in the first stages of internationalization firms tend to bundle their foreign activities into a separate international division and then with increased international expansion move to a geographic or product division model, or to the more advanced matrix. Perlmutter (1969) distinguished among ethnocentric or home-country oriented, polycentric or host-country oriented, and geocentric or world-oriented designs, the latter being the starting point for an extensive discussion of network-based MNC designs (Bartlett & Ghoshal, 1989; Hedlund 1986; Prahalad & Doz 1987). Broadly speaking, the previous literature has identified formal organizational structures (regional, product, or matrix) and networks as two fundamentally different coordination alternatives found in all MNCs and has also discussed the performance implications. These types of structures that we often observe are those that have survived over time by matching successfully the variety of the challenges found in the external environment.

Among the formal structures, the geographical region structure is very common. Already in the 1980's the research (e.g., Egelhoff, 1982) described such structures that divided the world into regions, each with its own HQs responsible for all of the company's business within its geographical area. The interaction between a foreign subsidiary and domestic operations or a subsidiary in another region is low and the only mechanism for coordinating across regions is the corporate HQs (see also Egelhoff, 1988; Wolf & Egelhoff, 2002). In terms of performance, this structure is best when "operations within a region are relatively large, complex, and sufficiently different from other regions that opportunities for specialization and economies of scale are greater within a region than they are along worldwide product lines" (Egelhoff, 1982: 441). Likewise, Rugman (2005) pointed out that the pattern of differences among countries along different dimensions creates regional selection pressures on MNCs by making cross-border transfer of knowledge and capabilities easier within regions than across them. Matrix organizational structures are an overlay of two elementary organizational structures or dimensions (Davis & Lawrence 1977) such as products, functions, or regions. Indeed, many MNCs recognize the importance of reflecting in their organizational design not only the geography, but also functions, products, or customer grouping (Wolf & Egelhoff, 2012). Such an organizational structure would be required, for instance, when an MNC "wants to be global when launching new products and local when serving customers" (Galbraith, 2009: 1) or MNCs that require both global integration within a business and local responsiveness within a country and feel, in addition, pressures for high information-processing capacity due to increased uncertainty, complexity, and/or interdependency (Stopford & Wells, 1972; Wolf & Egelhoff, 2012).

Both the regional and matrix organizational forms can be characterized as formal structures. In response to the rigidities that are associated with such forms, research proposed other, less structured network organizational designs, such as heterarchy (Egelhoff, 1999; Hedlund, 1986), transnational firm (Bartlett & Ghoshal, 1989), inter-organizational network (Ghoshal & Bartlett, 1990), network-based structure (Malnight, 1996), or differentiated networks (Ghoshal & Nohria, 1997). Despite the difficulty of defining network-organizations, what all these designs have in common is an emphasis on non-hierarchical coordination within the MNCs, non-dominant vertical relationships, informal communication, and relatively loose interconnectedness of the organizational subunits (Wolf & Egelhoff, 2010). For illustration purposes, Figure 1 provides examples for each types of MNC structure.

[Insert Figure 1about here]

Despite the long tradition, this literature rarely has been able to compare these structures with regard to performance. Rather, researchers point to the advantages / disadvantages of specific structures. Network structures have been promoted as the ideal way to handle MNC's heterogeneity, while regional or matrix structures as being too simple and inflexible (Bartlett & Ghoshal 1989; Hedlund 1986). However, the value of network organizations as platforms for intensive knowledge transfer is based on the assumptions that the network's components both able and willing to share information (Miles & Snow, 1992), which do not always hold (Wolf & Egelhoff, 2010). Decentralization in a network organization can hinder a quick and efficient transfer of learning throughout the corporation, even more so when the network's knowledge nodes continuously join and depart (Jarvenpaa & Ives, 1994). Finally, the loosening of the traditional hierarchical structure makes MNCs resemble more political coalitions with significant information asymmetries, where a subsidiary's competence development does not necessarily increase the subsidiary’s ability to influence strategic decisions within the MNC (Mudambi & Navarra, 2004).

The evaluation of performance of matrix structures has been also inconclusive. After being popular in the 1970s and early 1980s, matrix forms were often wrongly adopted and implemented leading Peters and Waterman (1982) to call matrix structure as their: “… favorite candidate for the wrong kind of complex response …” (p.306). Galbraith (2009) called it ”[T]he price to pay for of placing equal priority on being global and on being local is the complexity of managing in a two - boss structure.” As a result, matrix structures proved difficult to implement (Westney & Zaheer, 2001). Galbraith (2009) estimates a 75% failure rate for attempts to implement matrix structures, and the complexity and inertia they have created have forced MNCs to experiment with simpler structures (Brock & Birkinshaw, 2004). However, more recently the research has revived the interest in matrix structures as having more potential to address the contextual heterogeneity and complexity of todays’ MNCs (Wolf & Egelhoff, 2012).

Finally, there is an increased interest recently on regional structures and more specifically the role of regional headquarters (Ambos and Schlegelmilch (2010) report an increase of 76% in the number of European regional headquarters over the last decade alone) as an important additional source of knowledge and a bridge between local subsidiaries and global corporate headquarters (Mahnke et al., 2012).

Only few studies have empirically compared *across* structures. Wolf and Egelhoff (2002) distinguished among different structural dimensions of functional, international, and product divisions as well as geographic regions with matrix organizations combining any two or all three of functional, product, and geographic dimensions. Their study of 95 German manufacturing companies was concerned with the effects of structures on product diversity and size of foreign operations, manufacturing, and R&D, rather than performance. In a more recent empirical study of 169 international knowledge transfer projects, Ciabuschi, Dellestrand, and Kappen (2011) examined the effect of using vertical hierarchies or lateral cooperation among subsidiaries on knowledge transfer efficiency and effectiveness finding that centralization has a negative effect on transfer effectiveness and efficiency, while previous lateral cooperation has a positive effect on transfer effectiveness.

The review so far suggests that performance comparisons across different MNC-structures leave us with inconclusive results. However, in order to understand the effect of organization structure on performance, we also need to take into account the complexity of organizational structures, our second construct of interest. Different structures can have the same complexity and the same structure can have different levels of complexity. Therefore, structure type and complexity are to some degree independent dimensions of a given MNC structure and our fundamental proposition is that both structure and complexity determine MNC performance.

Complexity, in general, is defined as the number of elements in a system and the number of interactions among these elements (Anderson, 1999; Simon, 1962; Skyttner, 2006). In the context of our discussion of MNC structure, we call internal complexity or simply complexity the number of interactions among different subsidiaries and the headquarters of an MNC. Unfortunately, the research of complexity in the context of MNCs is very scarce and lacks proper operationalization and testing of the effect of complexity on performance. Previous research on MNC complexity helps, however, identify the costs and benefits related to increasing the level of complexity. Some studies, for instance, argue that high levels of complexity have a negative effect on performance due to high coordination and maintenance costs (Ambos & Birkinshaw, 2010; Bouquet & Birkinshaw, 2008; Gomes & Ramaswamy, 1999; Wiersema & Bowen, 2011), while other studies find that low complexity too is problematic due to reduced opportunities to generate economies of scale and/or scope (Forsgren & Pedersen, 2000).

To summarize, the literature on MNC-structure reviewed above has identified hierarchies (matrix and regional) and networks as the most common MNC-structures, but has also shown that it is difficult to decide empirically the conditions that support the use of one or another structure. The literature on MNC-complexity is relatively less developed, but it seems to suggest that intermediate levels of complexity are the best choice. However, proper tests of this proposition have not been conducted. As we'll see below, the NK-methodology helps address research questions related to effects of structure and complexity on MNC-performance.

3. Theoretical Perspective of Decision Interdependence

One of the important ways in which MNC structure and complexity affect performance is through the interdependence of decisions made by an MNC's units, both between HQ and subsidiaries and among subsidiaries. In an organizational structure diagram, the pattern of lines that connect subsidiaries to each other and to HQs represent lines of reporting, but they also represent interactions among units. The interactions which concern us here are the interdependencies of decisions. Interdependence of decisions in the context of the structure – performance relationship means that the contribution to overall performance of a decision made in one of the units depends on the decisions made in one or more other units. The reasons for these dependencies vary according to the activities and roles of the different MNC units, such as budget allocation, procurement, R&D, manufacturing, customer facing, and global supply chain activities. One subsidiary's decisions may be dependent on approval or budget from HQ, but it also may be dependent on knowledge, technology, components, materials, closing sales, and sales forecasts from the other units. While a particular subsidiary decision may maximize the performance of that subsidiary, it might not optimize overall MNC-performance due to the interdependencies of subsidiary decisions. We contend that a decision interdependence theoretical perspective enables us to simultaneously take into account the effects of many MNC subsystems and activities that affect performance.

Our view is that a perspective that focuses on authority as the only linkage among MNC units is an oversimplification. Characterizing MNC interactions by focusing only on authority, or lines of reporting, is incomplete, and offers only a partial explanation of performance. While headquarters has authority and budget control over subunits, all important decisions that affect MNC performance cannot be made by the headquarters. Thus many operational and technological decisions that affect overall MNC performance are delegated to subsidiaries who have knowledge of the issues and experience in the trade-offs involved in decision choices. Subsidiaries themselves might take the initiative in pursuit of international market opportunities (Birkinshaw, Hood, & Jonsson, 1998). Therefore, although the lines of reporting for subsidiaries eventually terminate at HQ, authority subsystems in organizations are “loosely coupled” to operational and technological subsystems (Weick, 1976).

We argue that a particular value of firm performance is affected by not only how these decisions are dependent on each other, as determined by structure, and the number of these decisions, as reflected in complexity, but also by the specific choices made in these decisions. MNC performance is more likely to be at a peak when the particular decision choices made by the subsidiaries reinforce each other and align with HQs towards achieving a synergy of action. This is the best case scenario where all subsidiaries and HQs have “their noses pointed in the same direction” as the Dutch idiom states. However, this best case scenario may not happen because, while all subsidiaries have accountability to headquarters, each subsidiary may have different objectives, resources, constraints, and different agendas which cause a subsidiary to make decisions which it believes will optimize its own performance. In a situation where a subsidiary prioritizes its own performance over overall firm performance, MNC performance may initially be low if the interdependent decisions made by the units counteract, or act to oppose each other. An MNC HQs may need time to detect and turn around this latter scenario by resetting subsidiary objectives and better aligning subsidiaries with each other and HQs to optimize overall MNC performance – a process of experimenting and local search that we seek to model using NK-methodology.

4. An NK Simulation Model for the MNC

4.1 Simulation Methods and the NK-Model

Simulation is a method for using computer software to model the operation of "real world" processes, systems, or events (Davis et al., 2007; Law & Kelton, 1991), a simplified picture that has some, but not all, of the characteristics of that world (Lave & March, 1975). Such methods are especially useful for theory development when the phenomena of interest involve multiple and interacting processes. In contrast to other methods, they allow researchers to run experiments with large number of subjects and for long periods of time with virtually no physical, temporal, coordinating, and monetary constraints (Carley, 2001) and help them to understand the outcomes of the interactions among multiple underlying organizational and strategic processes as they unfold over time (Davis et al., 2007). They are characterized by construct validity or the correct specification and measurement of constructs, and internal validity due to computational rigor and precise specification of constructs, assumptions, and theoretical logic, while convergent and discriminant validity are not an issue since simulation eliminates the measurement errors usually associated with empirical data (Campbell & Fiske, 1959; Campbell & Stanley, 1966; Cook & Campbell, 1979; Davis et al., 2007).

Within the family of simulation methods, the NK-methodology has been very useful in addressing the performance implications of tight vs. loose coupling in complex systems. Its origins are in the field of biology where it is used to model the evolution of biological systems towards greater fitness. Kauffman and Johnsen (1991) and Kauffman (1993) are credited with the introduction of NK methods although the idea of the ‘fitness landscape’ dates back decades (Wright, 1931; 1932). In the domain of social sciences, the notion of alleles is replaced by decisions and epistasis by interdependence (Ganco & Hoetker, 2009). Levinthal (1997) first introduced NK methodology into the management and organizational theory literature to examine complexity in an organizational context. Also, in an important contribution, McKelvey (1999) translated the NK-model into a firm context by using value chain competencies as “parts” of firms, which in turn are further reduced to discrete random behavioral events. McKelvey (1999: 304) even states that “the assumptions for firms are actually more straightforward than for organisms.” Since then, more than thirty papers published in leading management journals use NK modeling (Ganco & Hoetker, 2009). Many of these studies examine the pattern of interaction among different parts / units of organizations and how it affects different organizational outcomes. For instance, using NK-simulation Ethiraj and Levinthal (2004) explore the effects of modularization on the dynamics of innovation and performance in complex systems, Ghemawat and Levinthal (2008) look at how the level of articulation of a strategy or set of policy choices affects performance, Rivkin (2000, 2001) investigates the relationship between the complexity of a successful business strategy and its ability to deter its imitation, and Rivkin and Siggelkow

(2007) examine patterned interactions in complex systems and their implications for organizational exploration.

NK-methodology enables insight into theory because it models a controlled system, free of limitations of empirical approaches, which in face of combinatorial complexity is constrained by the expense and practical challenges of studying real-world systems (Lazer & Friedman, 2007: 672). In McKelvey's (1999: 313) words, the use of this methodology allows us "…. to go beyond the loose insights of natural history case studies, to pursue questions about intricate complexities impossible to study in real world analyses."

In the simplest form of organizational research N represents the number of units in an organization. In each unit a decision is made that can take one of two values. However, the payoff or the contribution to overall organization's fitness or performance of choosing one or the other value in one particular unit depends on decisions made in other K units (see McKelvey, 1999 for a thorough explanation). Once such payoffs are generated taking into account the interdependencies, a performance landscape is created as a mapping from the N subunits' choices to a payoff value (Gavetti & Levinthal, 2000). In other words, a performance landscape is a graphic depiction of the relation of inputs to the output (Levinthal, 1997).

N and K jointly determine how 'rugged' the fitness landscape is. When there is little interaction (low K) among the parts, there is one, or few optimal combinations or 'hills' and the landscape is 'smooth' (see Figure 2a). On the other hand, as shown in Figure 2b, firms with a high degree of interaction among its subunits (a higher K value) result in more rugged, multi-peaked performance surface, since a change in one choice will influence many of the other subunits. The organization then moves on this landscape in search for higher performance.

Notwithstanding NK's proven track record and acceptance in other fields, it has yet to be applied in the field of IB despite its potential contribution. In the rest of this section, we explain our application of NK methodology to model the effects of complexity and organizational structure on MNC performance. We proceed step by step to explain in detail the adaptations we make to better reflect the specific needs of the MNC context required to explore our research questions.

4.2 The NK Model, MNC Structure and Performance, and Decision Interdependence

Our NK model simulates how the interdependence of the MNC's internal decisions affects performance for a given structure with a certain complexity. N represents the number of units in an MNC, while K the level of complexity. Complexity and structure are captured in the *number* and *pattern* of interdependent decisions, respectively, and a given set of choices made in each of the MNC-units results in a certain level of MNC performance. The mapping of all possible choices for all firm decisions onto the corresponding performance levels is called a performance landscape maps, which is often visualized as a three dimensional geometric map (see Figure 2, where the two dimensions that form the base of the map reflect choices made for firm decisions, and the third or vertical dimension is the corresponding performance). Different MNC structures result in different decision interdependencies which are exhibited in the terrain of the landscape map. One can observe the landscape of Figure 2b is more rugged or "spiky" than that of Figure 2a. The more rugged landscape has a greater change in MNC performance as its decision choices change. What we can observe in one point of the landscape tells us little about what is going on in adjacent points (Gill, 2008). This greater variance in performance is due to the structure of decision dependencies within the firm.

The NK methodology also models firm’s search for better performance over time. An MNC starts at a point on the landscape determined by its initial set of decision choices. When the MNC changes its decisions over time, it is said to “move” or “step” through the landscape. This movement of the MNC across the landscape is constrained to be incremental. This reflects the tendency of MNCs to not routinely make wholesale changes in all decisions across the MNC at a point in time, but rather to make incremental decision changes and observe the performance results – a sort of fine tuning through trial and error. In this process, the MNC retraces its steps to where it was before if the performance decreases, and only moves to a new operating position if it increases MNC performance. However, when moving across a rugged landscape, the MNC may arrive at a local performance peak, which may not be the highest peak in the landscape or the global maximum achievable. While stationary at such a peak, the MNC will hesitate to move for two reasons. First, the MNC is reluctant to step to surrounding operating points that have lower performance than the local peak. Second, since MNC decision making is through experiential trial and error, the entire set of alternative performance levels is not known in its entirety (Simon, 1957) including the set of decision choices which will result in the global maximum. That is, the MNC does not know how “far away” on the landscape the global maximum is, or whether in fact there is another higher peak.

[Insert Figure 2 about here]

4.3 An NK-Model of MNCs

We start by showing in Figure 3 an overarching ‘roadmap’ of the steps we go through to build our model illustrating with a very simple example of an MNC consisting of four units. Beginning at the left, we show the MNC organizational structure (step 1: a) and then transform this structure into an adjacency matrix (step 2: b). Following the pattern of interdependencies in this matrix, we generate randomly a performance landscape (step 3: c). Finally, we let the MNC move on this landscape in search of better performance (step 4: d). In the following paragraphs, we zoom in and explain each step more in detail following our simple example and then generalize our model.

[Insert Figure 3 about here]

Figures 4 (a) and 4(b) presents a more elaborate version of Figures 3(a) and 3(b), respectively. It shows on the left the MNC structure and next to it its adjacency matrix. The MNC we are using for illustration purposes consists of four units (N=4): the headquarters (C1 in Figure 3), an R&D department (C3 in Figure 3); and two subsidiaries located in foreign countries (C2 and C4). The arrows between the subunits indicate interdependencies of unit decisions that affect overall firm performance. Note that the arrows do not necessarily indicate authority, or the hierarchy of reporting level, nor do they represent communication or knowledge flows. All the subunits report to the headquarters, which has oversight over the subunits. However, each unit has the independence to make some business decisions regarding operations and allocation of its resources, and overall firm performance is affected by the interdependence of these decisions. To illustrate the interdependence of the decisions made at different units, let’s assume first that each of the units will have to make a decision with two possible choices (0 or 1) and that the outcome of the decision making will have implications for MNC performance. More specifically, the headquarters will have to choose between a strategy of global integration (0) or local responsiveness (1). The R&D department is considering whether to dedicate resources to process innovation (0), which would result in a generic product to be sold in all countries where the MNC operates, or to introduce a portfolio of customized products to be sold in individual countries (1). Finally, both foreign subsidiaries (C2 and C4) are considering similar decisions: to grow by acquiring local firms that offer similar products, which are more customized to country's specific preferences (0), or by aggressively marketing their existing standardized product (1).

[Insert Figure 4 about here]

To understand the interdependencies among units, let's start with the arrow connecting HQs to the R&D-unit. It shows that the contribution to overall MNC-performance of having the R&D-unit choose one or the other option depends on the decision made at HQs. For instance, if the R&D-unit decides to develop a portfolio of products while HQs decides to allocate resources to pursue a global integration strategy (see for instance Dellestrand & Kappen, 2001 for a discussion of headquarters' resource allocation for innovation transfer projects), this would create inconsistencies within the organization and lead to inferior performance. Likewise, the contribution to overall performance of choosing the growth strategy at subsidiary in C2 or C4 depends on the decision made at the R&D-unit (C3). Again, it would create inconsistencies if the subsidiaries go for the acquisition, while the R&D-unit focuses on the perfection of the generic product. On the other hand, since both subsidiaries are relatively small and account for a small portion of sales, the input they could give to the R&D-unit and/or the HQs is deemed of little importance and hence there is no arrow going from the subsidiaries to the R&D-unit or HQs. Finally, while HQs exercises influence over C2 (HQ-->C2), C4 is unaffected by HQ. In other words, the subsidiary in C4 is dependent on the MNC-network's technical know-how (R&D-unit), but independent strategically.

The specific pattern of interdependence described above is reflected in the adjacency matrix in Figure 4 (b). We create a column and a row for each unit and in the intersection of a row and a column we put a 1 if the row-unit depends on the column-unit and a 0 otherwise (we obviously have 1s in the main diagonal of the matrix). For instance, the second row in the adjacency matrix of Figure 4 (b) is (1, 1, 1, 0), meaning that C2 depends on C1 and C3, but not on C4. Finally, a column has been added to the right that shows the number of *other* units on which the row unit depends (for instance, C1 doesn't depend on any other unit; C2 depends on two). In this structure each unit depends on average on one other unit (K=1).

In Figure 5 we show the same MNC in terms of units and their roles, but with a higher level of interdependence. Now the subsidiaries (C2 and C4) account for a substantial part of the total sales and they are still influenced by HQs and the R&D-unit but also influence them. Also, the choices in the R&D-unit influence those in the HQs. This results in the highest level of interdependence: every unit depends on every other unit (K=3).

[Insert Figure 5 about here]

In the more general case, when the payoff for the organization of having a 1 or 0 in unit X depends also on the value (1 or 0) in unit Y, we say that Y influences X. Unlike the original NK model, in which each subunit depends on exactly K other subunits, we need a finer-grained conceptualization of K in order to reflect the differences between various types of MNC-structures and hence introduce network differentiation instead of uniform centrality. More specifically, let k_j be the number of other units on which unit j depends and $K = (\Sigma_{i=1 \text{ to } N} k_i)/N$, i.e. we allow different units to have different Ks. Further, we use the adjacency matrix (e.g., Ghemawat & Levinthal, 2008; Rivkin & Siggelkow, 2007; Ethiraj & Levinthal, 2004), a NxN matrix in which an element is 1 if the column influences the row and 0 otherwise, to present the pattern of interdependence in a compact way. In addition, as described earlier, there will be 1s in the main diagonal of the adjacency matrix. In this matrix, k_i is the sum of the 1s on the i-th row without considering the main diagonal. Adjacency matrices allow us to investigate both the effects of structure (by keeping K constant) and K (different levels of K for the same structure).

4.4 Generating the Landscape of Performance Values

To understand the implications of structure and level of interdependence on performance, let's return to the MNC shown in Figure 3(a) and also in more details in Figure 4(a). With four units and a decision made in each unit that takes on one of the two values (0 or 1) we have a total of 16 possible combinations (2^4) of 0s and 1s shown in the first four columns (c1-c4) of Figure 3(c). The next four columns (w1-w4) show the performance contributions of having a value of 0 or 1 in c1-c4, respectively. The values for w1-w4 are generated randomly. A closer look at Figure 3(c) reveals that there are only two different values in w1-column (0.81 for the first eight rows and 0.15 for the remaining eight), reflecting the fact that c1 is completely autonomous in its decision-making. The situation is different in column w2: there are eight different values (2^3), because the value changes any time c1, c3, or c2 itself changes (e.g., compare the values in rows 1 and 3), but remains the same if the values in c1, c2, and c3 remain unchanged regardless of the value of c4 (e.g., compare values in rows 3 and 4). Finally, the W-column (last column in Figure 3(c)) shows the performance for the entire combination as the average of the four values in columns w1, w2, w3, and w4. While an exact 3D-visualization of the 'landscape' is not possible, in Figure 3(d) we combine the values of c1 and c2 in the x-axis, of c3 and c4 in y-axis, and finally the performance in the z-axis.

In the more general case, N represents the number of units in different countries in which an MNC has or can have operations (the decision might be to enter a new country or not). Each of the country units will have to make a decision of choosing between two options (the general case of more complicated decisions – i.e. decisions that take more than two values – may be reduced to a sequence of binary choices; see McKelvey, 1999). In other words, in this ‘world’ of N countries, each MNC is represented as a vector (x_1, x_2, …, x_n), where each of the x_j has a value of 1 or 0 and hence the landscape is composed of 2^N possible choices.

The performance contribution of having x_i set at 1 or 0 can be represented by the following expression: $f(x_i \mid x_{i1}, x_{i2}, \ldots, x_{iKi})$, i.e. for each unit, 2^{Ki+1} different values will be generated randomly from the uniform distribution from 0 to 1[1], depending on the value of the country x_i itself (either 1 or 0) and the value of the K_i other countries on which it depends (each also taking on a value of 1 or 0). The overall performance value associated with the full vector $F(x_1, x_2, \ldots, x_N)$ is simply the average of the individual contributions: $\Sigma_{i=1 \text{ to } N} f(x_i \mid x_{i1}, x_{i2}, \ldots, x_{iKi})/N$.

4.5 NK Adaptive Walk to Search for Maximum Performance

Once the performance landscape is generated, the organization moves on the landscape in search of locations with better performance, which we call adaptive walk. An MNC could theoretically go through the exercise of generating such a landscape, which, following our example in Figure 3(c), would mean estimating each and every of the 64 elements (columns w1-w4), calculating the overall performance for each row (column W), and finally finding the maximum value in that column, i.e. the combination (0, 1, 0, 1). In practice, however, this process is very difficult for two reasons. First, the estimation of the values becomes increasingly difficult and inaccurate when the unit in question is influenced by many other units due to lack of data, large number of variables involved, and their interactions. Second, it is the sheer number of elements to be estimated, and since the number of possible combinations grows exponentially with the number

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[1] While the distribution from which payoff values are randomly drawn could affect the outcome (for instance, a Gaussian distribution could be used), Kauffman points to the fact that the statistical features of the resulting landscapes are "largely insensitive to the choice made for the underlying distribution" (1993, pp. 44-45).

of units, time resources put constraints on finding the global optimum (Frenken, 2006; Simon, 1969). In a not so rare case of an MNC that operates in 100 countries (Siemens operates in 190 countries), the number of values to be estimated would be $100x2^{100}$! Instead, the MNCs try – as do the organizations in general – to make adjustments one step at a time, i.e. looking for better solutions in the area surrounding their existing position consistent with the principle of satisficing (Simon, 1957) and local search (Cohen & Levinthal, 1990; March & Simon, 1958).

In our model we take exactly this approach. To illustrate, let's turn to our example. Figure 3(d) shows schematically how the MNC moves from position 1 to 2 to 3 and finally reached a peak at position 4 (see also Figure 3(c) in which the same positions have been shown next to their performance values). The MNC starts at (1, 0, 1, 1) with a performance value of 0.387. Then it changes one element (c2 from 0 to 1) and considers a new solution (1, 1, 1, 1) – shown as position 2 in Figures 6 and 7 – without having to generate the entire landscape. Since the performance value is higher (0.432) the MNC moves to that position. From there it moves to position 3 by changing c3 from 1 to 0 and then finally to position 4 by changing c1 from 1 to 0 (performance value: 0.635). Once at position 4, the MNC can't find any better position in the surrounding area and hence stays there. Two comments are in order. First, this approach doesn't guarantee that the MNC will find the best possible position, only that it will achieve a local peak. Second, there might be more than one path to achieve the same peak depending on which neighbor is explored first (another potential and longer path would be: (1, 0, 1, 1) → (1, 0, 1, 0) → (1, 0, 0, 0) → (0, 0, 0, 0) → (0, 0, 0, 1) → (0, 1, 0, 1)).

In order to explore the performance implications of complexity and organizational structure, we build below different types of structures at different levels of complexity, generate in each case a performance landscape and then have the organization ‘walk’ through the landscape in search of high fitness locations.

5. Applying the NK Model to Examine MNC Structure, Complexity, and Performance

Following the conceptual examples of NK modeling in the previous section, we use the exact same approach to model the regional, network, matrix structures. Our choice of these structures reflects the effect of the environmental conditions and their interaction with MNC strategies. As described earlier in our literature review, focusing on these MNC organizational archetypes is a way to endogenize the environmental conditions.

Compared to purely domestic companies, MNCs face additional differences among their units (in terms of institutional environments, culture, geography, etc.), which make it unrealistic to consider high levels of internal complexity (e.g., an MNC with 10 units in which every unit is on average dependent on 8 other units). With this in mind, the levels of complexity that we use in the paper are those that make more sense in the context of MNCs.

Overall, our model is based on the assumption that MNCs’ choices reflect both the attempt to match the variety of the environment and organizational, firm-specific considerations. We achieve that by conducting basically two types of experiments: one in which the structure is largely predetermined by characteristics of the MNC's environment, in which case the firm makes a choice about complexity, or the environment largely predetermines complexity, in which case the strategic choice variable of the MNC is the structure. We consider older industries with their oligopolistic history and structure as a good example of the former and younger high-tech industries of the latter (for instance, in pharmaceutical or biotech R&D MNCs, the government regulations, technical standards, and customer expectations largely determine the level of complexity, but less the organizational structure).

In more technical terms, in order to be able to create more realistic structures, we use an N=10 and assign different value of Ks to the model. For each type of structure and level of K, we specify the corresponding adjacency matrices.

We perform two sets of analyses using NK modeling. In the first set we look at the effects of MNC-complexity on performance. Given some previous results regarding this relationship – albeit not specifically for MNCs – this set serves as verification of the accuracy of the model, establishes the internal validity, and enhances the confidence in the model (Davis et al., 2007). More specifically, for a given MNC structure, we simulate MNC's performance landscape by varying the level of complexity (K), from 1.4 to 4.5 within each structure. Again, environmental conditions constrain us to explore only a limited range of K. Indeed, in the case of MNCs and various types of distances between units (geographic, economic, cultural, and institutional) it is not realistic to consider MNCs of 10 units where each unit depends on average on eight other units.

In the second set of analyses we examine the effect of MNC-structure on performance. Here rather than confirming in the context of MNCs existing theoretical predictions, we intend to advance new theoretical propositions. To do this, we set complexity K as a constant, and examine MNC's performance across different organizational structures. We repeat the same set of simulations for different Ks. We operationalize organizational structures according to their theoretical features. Figure 1 has examples of organizational structure as we discussed previously in the literature review.

5.1 Design of organizational structures

First, Philips is an example of *network structure*. Philips's headquarters is in the Netherlands with subsidiaries in many different geographic areas. Philips has frequent interactions among subsidiaries. In such structures, the emphasis is on non-hierarchical coordination and non-dominant vertical relationships within the MNCs with subsidiaries relatively free to choose the other units with which to interact. To model these structures we made each subsidiary dependent on the HQ; the other links (depending on K) are generated randomly. The second structure is *matrix structure*. ABB clusters its units by geographic area and by product. ABB allows two-way interaction between organizational units. Accordingly, we assign the role of the HQs to one unit and create the regional and product centers and make every other unit dependent on a product and a geographic region. Finally, *regional structure* clusters organizational units by geography. In order for a P&G Asia office to interact with its beauty product office, the office goes through P&D's HQs in Cincinnati. Apart from the HQs, we assign two units as regional HQs and make every other unit part of one of the clusters; no links are modeled across the clusters. Table 1 shows all different adjacency matrices that we created for each structure and K combination.

[Insert Table 1about here]

5.2 Model specification and assumptions

In order for our model to isolate the influence of structure and complexity on performance, we make the following assumptions in our models. First, we assume fixed firm size for each MNC. An MNC has 10 units, including HQs and subsidiaries. Units are of equal size. Each unit is equipped with fixed amount of resources, and their capability to adapt to the environment is equal. Second, each interaction has equal strength. Third, MNCs' international experience is constant for all simulations. Fourth, the local knowledge is the equal for all subsidiaries. Lastly, we assume that the impact from macroeconomics is equal for all MNCs. Table 2 summarizes variable definition and model specifications.

[Insert Table 2 about here]

For each adjacency matrix (corresponding to a particular MNC-structure and a value of K), the simulation software generates a performance landscape (in the same way as illustrated in Figure 3). Then, an initial position on the performance landscape is chosen randomly (i.e. a 1xN vector of 0s or 1s) and the MNC starts ‘moving’ from this initial position in search of better performance. In each step of this search, the MNC moves to the neighboring location if it results in an improvement in performance, otherwise it stays in the original position. We allow each MNC to perform up to 50 such steps to optimize its performance to the local environment.[2] It may be that an MNC reaches a local optimum in less than 50 steps if a neighboring location does not improve performance in the subsequent steps. We call this 50-step process a round of simulation. The simulation software records the MNC performance achieved after each simulation round.

The results of such a round can and will depend on both the random assignment of values we use to generate the performance landscape and the random choice of the initial position. In order to eliminate this dependence, we repeat each round of simulation 1,000 times. In other words, for each MNC-structure / K combination, we generate 1.000 different landscapes and every time start at a randomly chosen initial position. By doing so, we obtain statistical significance below 0.01 (Ganco & Agarwal, 2009). The values presented below in the results section are averages of the MNC performance from 1,000 rounds of simulation. For instance, if in the next section we report that the performance of the network structure with K=4.5 after 20 steps is 0.64, we mean that 0.64 is the average of the performance values recorded for the 1,000 different rounds of the same structure/K combination after the first 20 steps.

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[2] Performance for all K's converges around step 50. We tried models with more steps, and results are consistent. Thus at here we report models running 50 steps.

6. Results

We first examine the result from NK modeling by type of organizational structure for different levels of K. While we report performance levels after 50 simulation steps for each of three types of structures at different levels of complexity, illustrated in Figure 6,– we chose the network structure and show for each level of K a separate graph that tracks the performance levels from Step 1 to Step 50. The results referring to the network structure show that a moderate level of complexity, e.g., K=3.5 results in best performance; while low and high complexity (K=1.4 and K=4.5, respectively) fare worse.

[Insert Figure 6 about here]

Likewise, the simulations for the regional structure show that the highest performance is achieved for a K=2.4. The least complex structure (K=0.9) reports lowest performance, and the more complex structures of K=3 or higher have average performance. Compared with the network structure, the regional structure reports a performance peak at a lower level of complexity.

Results are similar for matrix structures, where a moderate level of complexity (K=2.4) performs better than other levels of complexity. Again, the least complex structure of K=1.4 reports the lowest performance, and the performance of more complex structures of K=3 or higher fall in the middle range. This result is very similar to what the results of regional structure show. Both matrix and regional structure achieve better performance when the complexity is low to moderate, and both structures report worsening performance for very low complexity.

Summarizing, for all three types of MNC structures, there seems to be an intermediate optimal level of complexity. A too high or too low level of complexity has a negative effect on performance (Eisenhardt & Piezunka, 2011). These results suggest an inverted U-shaped relationship between complexity and firm performance. In order to better illustrate our finding, we use performance data points generated from NK modeling for three different types of structure, each at different Ks, and fit them with quadratic curves as shown in Figure 7. For example, the network performance values plotted in Figure 7, leftmost graph, correspond to the performance values shown in the network performance graph of Figure 6 after 50 steps, the rightmost values, for several simulation runs. In order to contrast the results across structures, we normalize the values of performance used in Figure 7. To ensure model robustness, we also fit the data with curvilinear model where performance is regressed on complexity (K) and its squared term. Results in Table 3 corroborate our finding of the inverted-U relationship between complexity and firm performance that for the simple model main effect of complexity is positive and squared of the effect is negative.

[Insert Figure 7 and Table 3 about here]

The fitted curves suggest that a moderate level of structure complexity has the optimal performance for all three types of structure in test. MNC performance depends on the relationship between its degree of complexity and the organization structure. The inverted-U relationship has consistently shown in all three types of organization structure we investigate.

Our second set of analyses was concerned with comparisons across MNC-structures with the same level of K. Again, we show as an illustration the case of K=2.4 and present a separate graph for each structure that tracks performance values after each of the 50 simulation steps (see Figure 8), and similar analyses were conducted for various levels of K. In each case we also conducted t-tests to compare the means. At a very low level of complexity (K=1.4) we found that the regional structure achieves a significantly higher performance than both the matrix and network structure and that the matrix marginally outperforms the network (let's call this situation for simplicity R>M>N). Then we increased gradually the level of complexity. For values of K of 1.8 and 2.4 the results were similar: the regional and matrix structures consistently and significantly outperform the network structure and the regional structure performs better than the matrix in both cases, but significantly only for K=2.4. Increasing K further to 2.7 the R>M>N order is preserved, but none of the comparisons is significant showing that at this ‘medium’ level of complexity the regional and matrix structures start losing their advantage over the network structures. The results for K=3 show that again there are no significant differences among the structures. However, interestingly the regional structure is now last in terms of performance. This trend is reinforced by the results for K=3.5, which show that the matrix and network structures are both better than the regional, but only the first marginally significantly (i.e. the order is now M>N>R). Finally, to complete the trend, the order for K=4 becomes N>M>R, in which the network – regional comparison is significant while the network-matrix and matrix-regional comparisons are not. To summarize, the results of this set of analyses show that at high levels of complexity the network structure outperforms both the matrix and the regional structure. However, at medium and low level of complexity, the network structure performs worse than matrix and regional structures. The comparisons between matrix and regional structures show that matrix outperforms regional structure at high levels of complexity, but the opposite is true at low levels (K=1.4). At the intermediate levels the differences are less conclusive. Our findings directly address the debate about which organizational structure is better for MNC.

[Insert Figure 8 about here]

Taken together, we conclude two main findings. First, a network structure is better for MNC with a higher degree of complexity; the matrix structure is best for intermediate and the regional for low levels of complexity.

7. Robustness Tests and Extensions

In this section we summarize additional tests we conducted to both test the robustness of our previous findings. More specifically, we conducted two separate sets of tests: 1) considering other levels of N and 2) using non-uniform distribution of weights among different units in calculating the overall performance.

Regarding the first set of analyses, we created new adjacency matrices for N=12 and N=14. In order to get as close as possible to capturing the effects of the increase in N, the original 10x10 matrices were kept unchanged in first 10 rows and columns of the new, larger matrices. In each case we added the appropriate number of units (2 or 4) and links in such way that the overall features of the structures were preserved. Regarding the levels of K, we followed two different approaches. For the first approach, we preserved the levels of K of the original 10x10 matrices. In other words, the added units (2 for N=12 and 4 for N=14) were influenced on average by the same number of other units as in the original structures. In the second approach, research (e.g., Kauffman, 1993; McKelvey, 1999) has shown that K should be understood as relative to N, i.e. optimal levels of K might depend on the level of N. Therefore, for the second approach we preserved the N/K ratio when moving from N=10 to an N of 12 or 14. Following these two approaches for three types of structures and six different levels of K resulted in 36 new adjacency matrices. Using these matrices as inputs, we tested again the effect of the level of complexity (K) on performance by first running simulations for 12 sets of matrices. These twelve sets results from one set for each of three structures, multiplied by two for an N of 12 or 14, and two from the two cases of keeping constant either K or the N/K ratio. Each set is comprised of six matrices corresponding to the six levels of K. We used the simulation results to regress the MNC-performance on K and the K-squared. In all but one of the cases the coefficient of the K-squared was negative and highly significant, suggesting an inverted-U shape relationship, consistent with our previous results. The one exception was for the network structure, N=12 and constant K, the coefficient of K-squared was negative but not significant. However, when the N/K ratio was constant it became significant, consistent with our previous finding that the optimal K for network structures is higher than for matrix and regional structures.

For each of N=12 and N=14 we also compared across structures while keeping K constant (six different levels of K). Our tests confirmed the results of our previous analyses: for low levels of K, matrix and regional structures outperform the networks, at intermediate levels of K the differences are not significant, and finally at high levels of K network structures perform significantly better than both matrix and regional structures and matrix structures better than regional structures.

In our second set of robustness tests we kept N=10, but explored the potential effect of attaching unequal weights to the performance of different units in calculating overall MNC performance. In applying such NK models with unequal weight distribution (Solow, Burnetas, Roeder, & Greenspan, 1999; Solow, Burnetas, Tsai, & Greenspan, 1999) we took into account the specific nature of different MNC structures. More specifically, for matrix structures we used three different levels of weights: the highest for the HQs, the second highest for the geographic and product HQs, and the lowest for the remaining units. We created two different types of such distributions for the matrix structure with highest, second highest, and lowest weights being (0.3; 0.125; 0.04) and (0.2; 0.125; 0.06), respectively. We approached the regional structure similarly: the highest / second highest / lowest level of weight were assigned to HQs / regional HQs / rest of units, respectively, and two different distributions were created: (0.36; 0.11; 0.06) and (0.23; 0.14; 0.07). Finally, considering the approach used to generate the network structures, the only change made was the weight of HQs vs. the rest of units, i.e. two different levels of weights within the distribution. Two different distributions were used with weight levels (0.19; 0.09) and (0.37; 0.07), respectively. All the tests of the effect of K on performance provided significant results, supporting an inverted U-shaped relationship. In addition, consistent with our previous findings, K seems to peak at a higher level for networks compared to matrix and regional structures.

Finally, we used unequal weight distribution also to compare across the different structures while keeping K constant. Of course, we had to apply the same distribution across structures and, since the network structure restricted us to use only two levels of weights (HQs and the rest of units), we used two different weight distributions: (0.19; 0.9) and (0.37; 0.07) for all three structures at different levels of K. The results for the most part were produced similar results to the original ones, in that regional and matrix structures outperform networks at low levels of K, but the opposite is true for high Ks. However, the use of unequal weights brought about a change in the matrix-regional comparison. The regional structure with the weights described above outperforms the matrix structure at all levels of Ks, not only at low levels as in the original tests.

8. Managerial Applications of the NK-Model of the MNC

In the previous sections we discussed the important role simulation models and especially NK-models play for theory in comparing ideal representations of regional, network, and matrix structures. However, in this section we discuss how NK-models might be used by practitioners to model their specific MNC organizational structures. There are four parameters of the NK model that can be changed to model any MNC: N, K, weights assigned to a unit's decisions in contributing to overall MNC performance, and the number of decisions that can change at one step, or simulation time interval. We discuss how these parameters might change for other MNC models in the following paragraphs. Before suggesting ways of customizing the model, however, it is important to understand that a simulation attempts to strike a balance between parsimony and accuracy, and between simplicity and elaboration by trying to capture the main phenomenon of interest while disregarding the nonessential (Davis et al., 2007; Harrison, Lin, Carroll, & Carley, 2007). With this caveat in mind, we still think that the NK-modeling is a powerful tool not only for academic research, but for practical use as well.

Regarding the structure, we tested only three structures: matrix, regional and network, since these coincide with the most widely used and IB researched structures. However, mixed models or hybrid structures are not unusual. For instance, an MNC diversified in two different industries may partially use a regional structure in one industry and a matrix for the other. These hybrid forms of structure can be captured in the adjacency matrix, Table 1 and Figure 3 are examples. The size of the adjacency matrix, N, will be equal to the number of units modeled. The model can, of course, accommodate larger Ns than 14. If large Ns are modeled, the issue is computational rather conceptual with the number of calculations increasing exponentially with N.

As far as K is concerned, we used average Ks that are reasonable for real organizations. However, the underlying drivers of the decision interdependence can differ according to the MNC. For instance, we'd expect linkages among interdependent decisions that drive performance to be different for market-seeking than for efficiency-seeking MNCs. Once the interdependency of an MNCs decisions are mapped among the MNC's subunits, one can construct the appropriate customized adjacency matrices by following the example described in Section 4.3 and illustrated in Figure 4.

Following mainstream NK-research, we also assumed in our main model that all units have the same importance. Again, depending on the particular case, the model can be modified in such way that one or more units are given higher relative weights when performance is calculated. Such models have been introduced first by Solow, Burnetas, Tsai, and Greenspan (1999) and we illustrated them in our robustness tests and sensitivity analyses. Obviously, there is an infinite number of ways to distribute weights and the model has no problem to accommodate any distribution.

Finally, we assumed local search with only one decision changed at a time. However, this assumption can also be relaxed to allow 'longer jumps' in which more than one decision is changed at each step if it's deemed fit. In conclusion, the NK-model can be customized in many ways and therefore can be used not only for theoretical research, but also as a tool of international management.

9. Discussion and Conclusion

9.1 Discussion and Practical Implications

Although one of our main goals is to explain and introduce NK modeling to IB, our results themselves constitute important contributions to the IB research stream on the relationships of MNC structure and complexity to MNC performance. Starting with the structure, by bringing the environmental specificity into the equation, we make the comparison of organizational structures more practically meaningful and persuasive. In particular, our model makes it possible to conceptualize the difference between the hierarchical (matrix and regional) and network structures. Our contribution here is twofold. First, we help conceptualize the differences among these three types of structures. Second, our simulation helps practitioners and theorists to anticipate how the effects of these organizational differences could impact performance.

We provide quantitative support that goes beyond the longstanding theoretical debate in the IB literature on matrix, or other hierarchical, structures versus network structures (Hedlund, 1986; Wolf & Egelhoff, 2012). The results show a network structure – relative to other structures – performs best at a high level of complexity than low or medium complexity. This is because more interaction is directly between subsidiaries as decision making is pushed down from HQs to subsidiaries, thereby alleviating regional HQs or product business head units as a bottleneck (Wolf & Egelhoff, 2010).

On the other extreme, at low levels of complexity the more hierarchical, or vertical, the structure the better the MNC performance. A possible explanation is that at these levels of complexity the regional HQ or product division head units are not bottlenecks and the decision making direction from the top facilitates these subsidiary decisions to be aligned in a way that support, or reinforce, each other. While these arguments have been made in the literature on a theoretical level, quantitative support has not been previously presented.

Another debate in international business research that has debated the optimal level of complexity in MNCs (Forsgren & Pedersen, 2000; Gomes & Ramaswamy, 1999; Hitt et al., 1997; Tallman & Li, 1996; Wiersema & Bowen, 2011). Most importantly, our findings quantitatively show that complexity is as an important determinant of MNC performance as is structure. The implication is that any comparison of MNC structures' effectiveness is inadequate if it does not take into account the degree of MNC complexity.

The inverted U relationship between complexity and performance that we found, illustrated in Figures 6 and 7, implies that too little or too much complexity is detrimental to performance regardless of whether the structure is matrix, regional, or network. A low level of complexity, the case in which the MNC units' decisions are mostly independent and thus made in relative isolation, makes it less likely that there will be a synergy among units' decision-making towards achieving improved overall MNC performance. An example of this synergy is an MNC's performance advantage through economies of scale and scope across subunits. Subsidiaries making decisions autonomously certainly gives them the flexibility to create their own competences, but a subsidiary's effort spent in developing its own competencies at the expense of transferring them from other units might have a negative effect on MNC effectiveness (Forsgren & Pedersen, 2000). At the other extreme, the level of internal complexity is high when almost all decisions among subsidiaries are highly dependent on the headquarters and each other. This decision interdependence can overburden the MNC with coordination costs and one unit's bad decision can influence many other subunit decisions, both of which reduce overall MNC performance (Ambos & Birkinshaw, 2010; Bouquet & Birkinshaw, 2008; Gomes & Ramaswamy, 1999; Hitt et al., 1997; Tallman & Li, 1996).

The practical implications from our findings on complexity is that MNCs should strive to achieve a moderate level of complexity to optimize overall MNC performance, regardless of whether they have a matrix, network, or regional structure. More specifically, the range of the number of interdependent decisions among subunits that resulted in the inverted U performance is relatively narrow. For our simulation of each structure configured with 10 units including HQs and subsidiaries, performance was suboptimal at the low end of the inverted U with 18 interdependent decisions, or interactions. Likewise, at the high end each structure performed suboptimal with 40 interdependent decisions. The optimal point ranged from 24 to 35 interactions depending on the structure. Therefore, the ratio of the number of interactions at one end of the U to the other suboptimal end is about 2.2, and the ratio of interdependent decisions from the optimal to suboptimal is about 1.6. Therefore managers need to be aware that MNC performance is sensitive to complexity, and 60% change above or below the optimal point results in worse performance. To achieve optimum performance, MNC managers should strive for a K, or ratio of MNC interdependent decisions to MNC units, between 2.4 and 3.5.

9.2 Contributions, Limitations, Future Research, and Conclusion

Our contributions to the IB literature are threefold. First, the main goal of this paper was to introduce NK-simulation methods to an IB-audience. We showed NK methodology can be applied to model the MNC in a way that provides insights to several fundamental IB research questions. Our NK-model of the MNC reflects two different types of environments: those that mainly have an influence on the organizational structure and others that have an influence on complexity variable K. With these parsimonious assumptions, the model can be used to conceptualize different types of MNC environments and should be of real utility to both theorists and practitioners.

In particular, we model three MNC configurations where the pattern of connections among MNC-units is reflected in the decision interdependence among these units. While the representation of an MNC as a network of units and ties among them might seem as an exercise in network analysis, NK methodology is a dynamic simulation whereas network analysis is static (McKelvey, 1999). In our example, the model's dynamic nature is used to simulate the MNC steps to increase performance using a trial and error process. Therefore, while NK simulation models the complexity of MNC as a static attribute for a specific organizational design, it also dynamically models the steps a firm takes to increase performance over time.

Our second contribution is the field of complexity theory (Brown and Eisenhardt, 1997; Eisenhardt and Piezunka, 2011), a field whose research has been underrepresented in IB. The concept of complexity has been discussed in different terms in specific contexts of organizational structure, such as the dimensions of matrix structures in Galbraith's work (2009). However, we introduce the construct of complexity as the number of interdependent of decisions among different units of an MNC. Our complexity construct definition cuts across all forms of organizations, and is thus explored as an antecedent to performance in all three structures. Our analysis compares of the optimal level of complexity across MNC structures, and the inverted U relationship between MNC complexity and MNC performance is a significant contribution to highlighting complexity as an important parameter in the debate on organizational structure.

Our third contribution is to the IB research stream on MNC organizational structure. The theory on organizational structure is mostly descriptive based on case studies (Bartlett & Ghoshal, 1989; Galbraith, 2009; Wolf & Egelhoff, 2012) with a few exceptions (Wolf & Egelhoff, 2002). Furthermore, the effect of structure on MNC performance is far from being well understood and difficult to isolate in a field study – the ideal situation for taking advantage of simulation methods (Davis et al., 2007). Our results show that a network structure is able to perform better higher levels of complexity, whereas the regional structure has better performance at lower levels of complexity, with the matrix structure in between.

Our study, like other simulations, has limitations due of the simplifying assumptions made for the sake of parsimony. For example, we purposely ignore environmental effects such as industry, and managerial effects such as international experience, to mention a few. The simulation model we use ignores costs or the level of resources required to implement the decisions. Finally, while our results suggest the existence of an intermediate, optimal level of complexity for MNC performance, the optimal values of K by themselves do not represent a recipe for MNC success.

We hope this study will be a foundation towards a more extensive use of NK-models to examine other IB phenomena. Future research can expand in several directions. A promising area of research would be the study of knowledge combination and integration within MNCs based on how subsidiaries share knowledge (Lee et al., 2014). Another NK application is modeling value chains to better understand the performance tradeoffs among the degree of "finer-slicing" of value chain activities, as well as the trade-offs between centralizing a value chain activity and replicating it in geographically dispersed locations (Mudambi, 2008). Another possibility would be to drop the assumption of 'local search' and allow MNCs perform longer jumps, or change more than one decision in a single step. The role of international experience can also be investigated by distinguishing between incumbent MNCs and new entrants (Ganco & Agarwal, 2009).

Finally, we'd like to note that the role of environmental conditions for MNS performance is twofold. First, they together with MNCs' strategies determine the structures used, but also put constraints to the level of complexity that is realistic. Second, even if the structure and level of complexity has been chosen correctly, other environmental conditions such as level of competition or collaboration will continue to affect performance directly or by moderating the other relationships. We were able to incorporate in our model the former. Regarding the second role, future research could expand so as to include the effects of the environment letting units interacting not only within, but also between MNCs. This would allow the investigation of a different set of questions in which both internal and external complexity could be constructs of interest. These possible future applications of NK modeling may facilitate the development of new IB theories not possible previously.

In conclusion, we argue that there is room in IB research on MNC performance and organizational structure for many methodologies, and that NK simulation complements current case study and empirical research methods. Each methodology has its different advantages and disadvantages. Empirical field studies provide statistical significance but can be constrained by limited data availability and confounded by the dozens of antecedents and contingencies that can affect MNC performance. Case studies offer rich descriptions but suffer from small sample sizes and samples idiosyncratic to a particular geographic region or industry. The disadvantage of NK methodology, as in any simulation, is the simplifying assumptions for the sake of parsimony. However this parsimony enables NK methodology to explore theories and test propositions that would be otherwise difficult to accomplish due to limited data availability, confounding variables, or idiosyncratic samples. The advantage of NK methodology is that analysis is highly controlled by setting all parameters equal in the models compared, other than the antecedents manipulated in the experiment. By using these multiple methodologies together in concert to understand the complex relationships involving MNCs, we can hope to develop and test better IB theories than by limiting ourselves to a single methodology.

Considering that NK-modeling has been widely used in the management literature on organization theory (Rivkin & Siggelkow, 2003), management cognition (Gavetti & Levinthal, 2000), and strategy (Ganco & Agarwal, 2009; Ganco & Hoetker, 2009), it is perplexing that NK methodology has yet to be used in IB literature despite its ability to fill a need which can’t be addressed by empirical studies or case studies. The results we describe and discuss show that

NK applications can offer new insights into fundamental IB questions. Therefore, we conclude that the introduction of NK methodology into IB research is long overdue, and we believe the explanation and example contained herein is a foundation for its continued use in IB research.

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Appendix

Table 1: Organization structure examples, and corresponding matrices (number of units, N, is 6)

Degree of complexity	Organizational structure		
	Network	Matrix	Regional
High (K=3.5)	(a) $\begin{vmatrix} 1 & & 1 & & 1 & & 1 & & 1 & \\ 1 & 1 & & & & & 1 & & 1 & \\ 1 & 1 & 1 & & 1 & & & & & \\ 1 & & 1 & 1 & 1 & & & 1 & 1 & 1 \\ 1 & & & & 1 & & & & & \\ 1 & & 1 & 1 & 1 & 1 & 1 & & 1 & \\ 1 & & & 1 & & & 1 & 1 & & 1 \\ 1 & & & & & 1 & & 1 & & \\ 1 & & 1 & 1 & & 1 & & & 1 & \\ 1 & & & & 1 & & & & & 1 \end{vmatrix}$	(b) $\begin{vmatrix} 1 & & & & & & & & & \\ 1 & 1 & & & 1 & 1 & & 1 & & \\ 1 & & 1 & 1 & & 1 & 1 & & 1 & \\ 1 & & 1 & 1 & & & & 1 & & 1 \\ 1 & 1 & & & 1 & & 1 & & & 1 \\ & 1 & 1 & & & 1 & 1 & 1 & & \\ & & 1 & & 1 & 1 & 1 & & 1 & \\ & 1 & & 1 & & 1 & & 1 & & 1 \\ & & 1 & & & & 1 & & 1 & \\ & & & 1 & 1 & & 1 & 1 & & 1 \end{vmatrix}$	(c) $\begin{vmatrix} 1 & 1 & 1 & & & & & & & \\ 1 & 1 & & 1 & 1 & 1 & 1 & & & \\ 1 & & 1 & & & & & 1 & 1 & \\ & 1 & & 1 & 1 & 1 & 1 & & & 1 \\ & 1 & & 1 & 1 & 1 & & & & \\ & 1 & & 1 & 1 & 1 & 1 & & & \\ & 1 & & 1 & 1 & 1 & 1 & & & \\ & & 1 & & & & & 1 & 1 & 1 \\ & & 1 & & & & & 1 & 1 & 1 \\ & & 1 & & & & & 1 & 1 & 1 \end{vmatrix}$
Moderate (K=2.4)	(d) $\begin{vmatrix} 1 & & & 1 & & & & & & \\ 1 & 1 & & & 1 & & 1 & 1 & 1 & \\ 1 & 1 & 1 & & & & & & & \\ 1 & & & 1 & & & 1 & & 1 & \\ 1 & 1 & & 1 & 1 & & & & & 1 \\ 1 & & & & & 1 & 1 & & & \\ 1 & & & & & & 1 & & 1 & \\ 1 & & & & & & & 1 & & \\ 1 & & & 1 & & & & & 1 & \\ 1 & & 1 & & & & & & & 1 \end{vmatrix}$	(e) $\begin{vmatrix} 1 & & & & & & & & & \\ 1 & 1 & & & 1 & 1 & & 1 & & \\ 1 & & 1 & 1 & & & 1 & & 1 & \\ 1 & & 1 & 1 & & & & & & 1 \\ 1 & 1 & & & 1 & & & & & 1 \\ & 1 & 1 & & & 1 & & & & \\ & & 1 & & 1 & & 1 & & & \\ & 1 & & 1 & & & & 1 & & \\ & & 1 & & 1 & & & & 1 & \\ & & & 1 & 1 & & & & & 1 \end{vmatrix}$	(f) $\begin{vmatrix} 1 & 1 & 1 & & & & & & & \\ 1 & 1 & & 1 & & & 1 & & & \\ 1 & & 1 & & & & & 1 & 1 & \\ & 1 & & 1 & 1 & & & & & 1 \\ & 1 & & 1 & 1 & & & & & \\ & 1 & & & & 1 & 1 & & & \\ & 1 & & & & 1 & 1 & & & \\ & & 1 & & & & & 1 & 1 & \\ & & 1 & & & & & 1 & 1 & 1 \\ & & 1 & & & & & & 1 & 1 \end{vmatrix}$
Low (K=1.4)	(g) $\begin{vmatrix} 1 & & & 1 & & & & & & \\ 1 & 1 & & & & & & & & \\ 1 & 1 & 1 & & & & & & & \\ 1 & & & 1 & & & & & & \\ 1 & & & & 1 & & & & & \\ 1 & & & & & 1 & & & & \\ 1 & & & & 1 & & 1 & & & \\ 1 & & & & & & & 1 & & \\ 1 & & & & & 1 & & & 1 & \\ 1 & & 1 & & & & & & & 1 \end{vmatrix}$	(h) $\begin{vmatrix} 1 & & & & & & & & & \\ 1 & 1 & & & & & & & & \\ 1 & & 1 & & & & & & & \\ 1 & & & 1 & & & & & & \\ 1 & & & & 1 & & & & & \\ & 1 & 1 & & & 1 & & & & \\ & & 1 & & 1 & & 1 & & & \\ & 1 & & 1 & & & & 1 & & \\ & & 1 & & 1 & & & & 1 & \\ & & & 1 & 1 & & & & & 1 \end{vmatrix}$	(i) $\begin{vmatrix} 1 & 1 & 1 & & & & & & & \\ 1 & 1 & & 1 & & & 1 & & & \\ 1 & & 1 & & & & & & 1 & \\ & 1 & & 1 & & & & & & \\ & 1 & & & 1 & & & & & \\ & 1 & & & & 1 & & & & \\ & 1 & & & & & 1 & & & \\ & & 1 & & & & & 1 & & \\ & & 1 & & & & & & 1 & \\ & & 1 & & & & & & & 1 \end{vmatrix}$

Table 2: NKC Model Parameter Summary

Parameter	**Description**	**Value used**	**Underlying assumption**	**Possible empirical proxies**
N	Headquarters, and number of foreign subsidiaries	10, 12, 14	Fixed subsidiary size; fixed resources and capability; same distance	Product divisions, regional headquarters, R&D center, local office
K	Number of interdependent decisions among HQ and subsidiaries	0.9, 1.4, 1.8, 2.4, 3.0, 3.5, 4.0, 4.5	Links have equal strength	Resource dependencies, line of authority, operational or value chain dependencies
Steps	Number of search	50		Adjustments take to optimal firm performance
Simulation runs	To obtain 1% significance for the mean	1000		

Table 3: Regression result

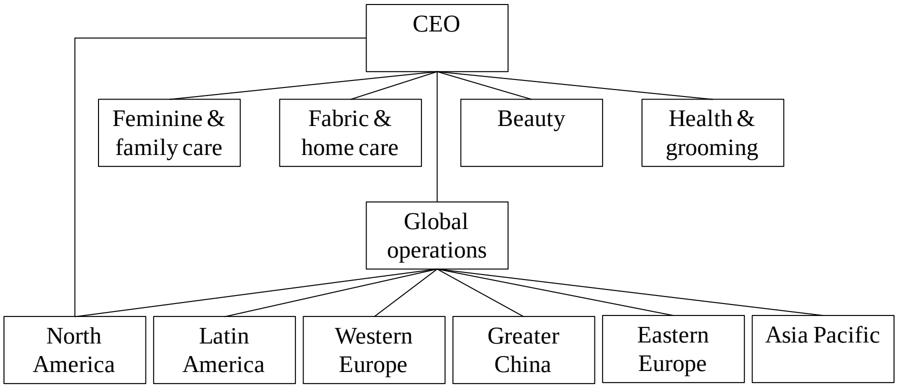
OLS, Dependent variable: Fitted performance

	Network	Regional	Matrix
Complexity	95.24^{***}	66.32^{***}	100.7^{***}
	(5.63)	(6.01)	(7.84)
Complexity, squared	-66.19^{**}	-42.09^{**}	-79.50^{***}
	(-3.35)	(-3.01)	(-4.64)
Observations	21	18	18
R^2	0.8983	0.9101	0.9215

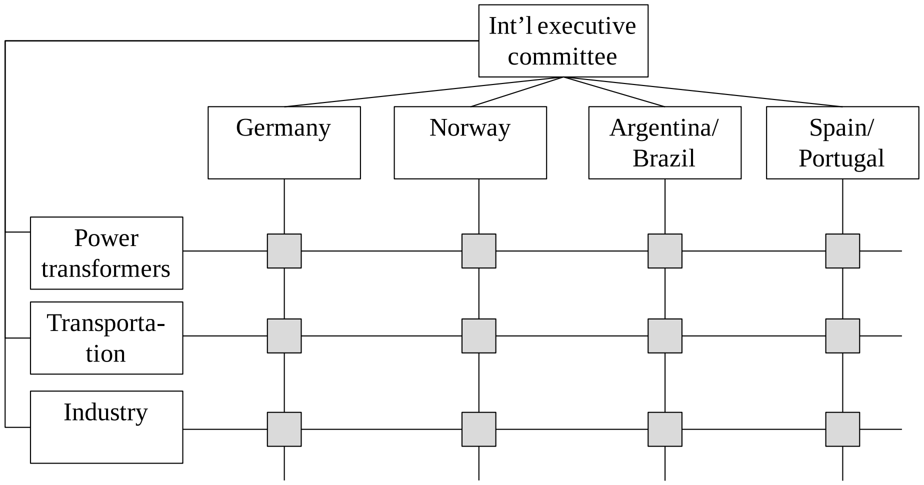
t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 1: Examples of organizational structure

(a) P&G's regional structure



(b) ABB matrix structure



(c) Philips network structure (excerpted from Ghoshal and Barlett (1990))

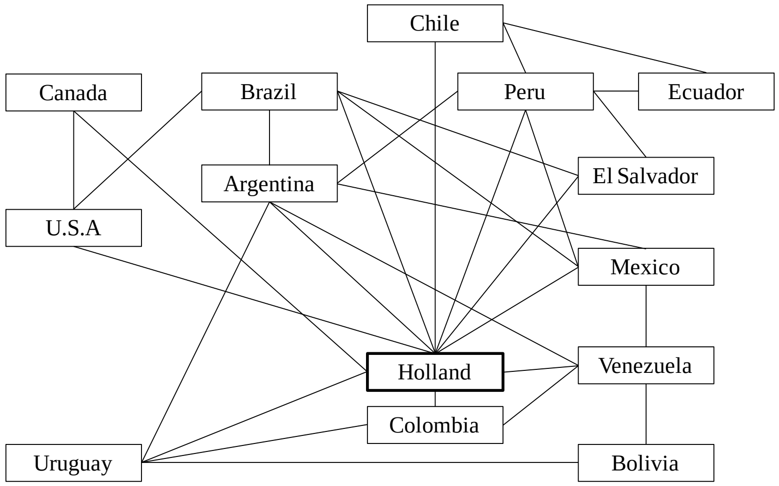
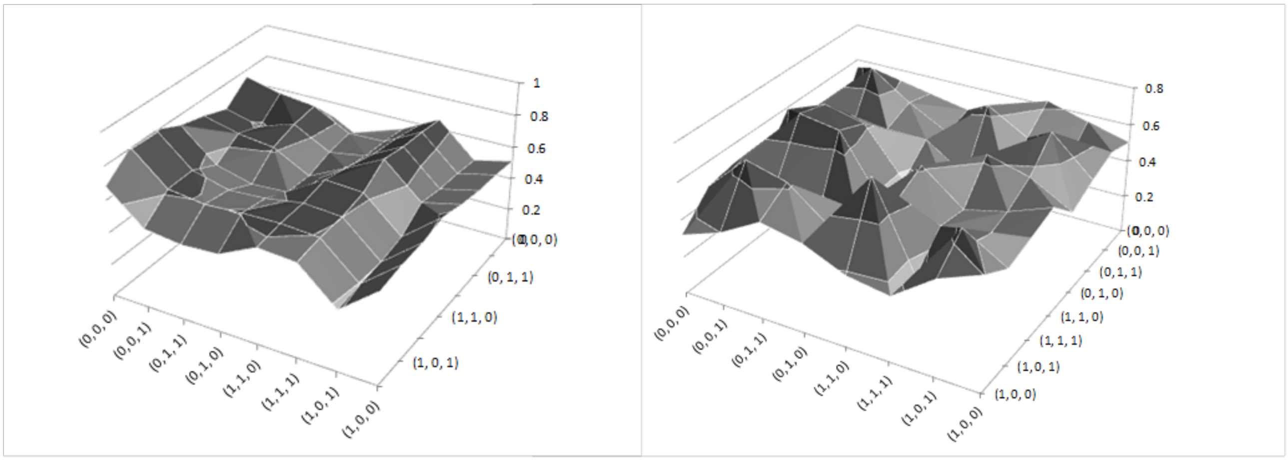

Chile
Canada
Brazil
Peru
Ecuador
Argentina
El Salvador
U.S.A
Mexico
Holland
Venezuela
Colombia
Uruguay
Bolivia

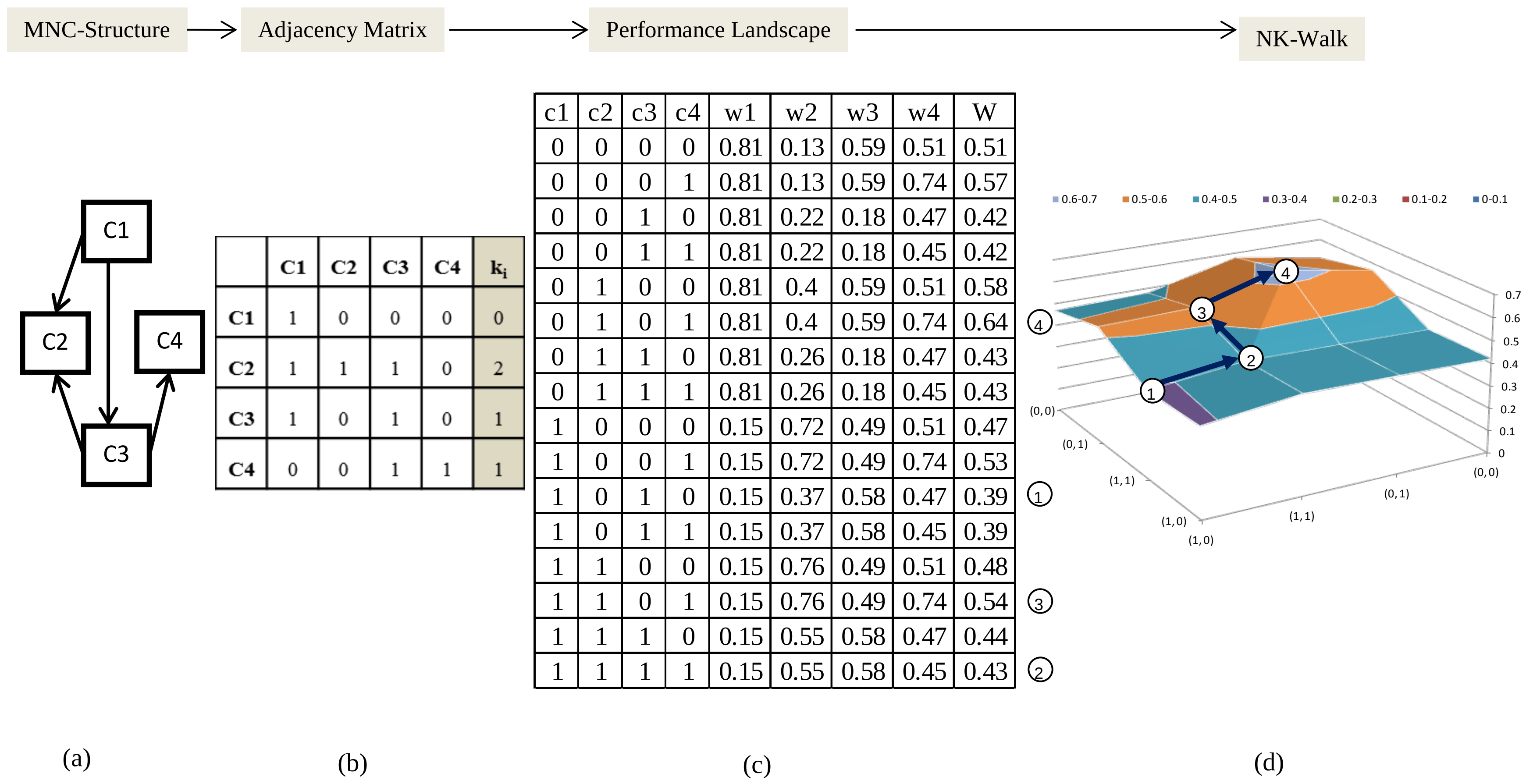
Figure 2: NK-landscapes



(a)

(b)

Figure 3: Methodological roadmap

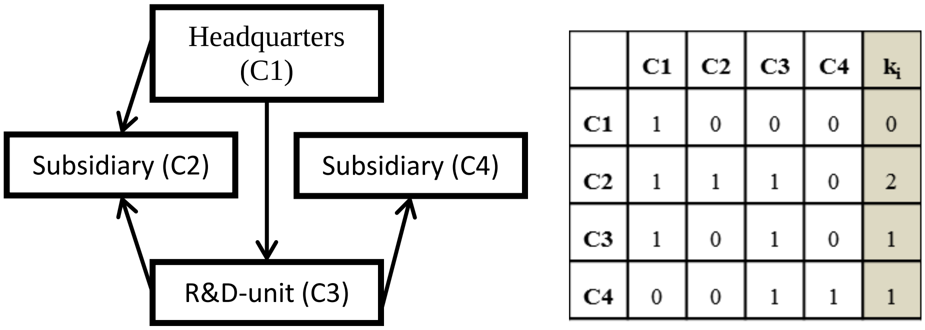


	C1	C2	C3	C4	k_i
C1	1	0	0	0	0
C2	1	1	1	0	2
C3	1	0	1	0	1
C4	0	0	1	1	1

c1	c2	c3	c4	w1	w2	w3	w4	W	
0	0	0	0	0.81	0.13	0.59	0.51	0.51	
0	0	0	1	0.81	0.13	0.59	0.74	0.57	
0	0	1	0	0.81	0.22	0.18	0.47	0.42	
0	0	1	1	0.81	0.22	0.18	0.45	0.42	
0	1	0	0	0.81	0.4	0.59	0.51	0.58	
0	1	0	1	0.81	0.4	0.59	0.74	0.64	④
0	1	1	0	0.81	0.26	0.18	0.47	0.43	
0	1	1	1	0.81	0.26	0.18	0.45	0.43	
1	0	0	0	0.15	0.72	0.49	0.51	0.47	
1	0	0	1	0.15	0.72	0.49	0.74	0.53	
1	0	1	0	0.15	0.37	0.58	0.47	0.39	①
1	0	1	1	0.15	0.37	0.58	0.45	0.39	
1	1	0	0	0.15	0.76	0.49	0.51	0.48	
1	1	0	1	0.15	0.76	0.49	0.74	0.54	③
1	1	1	0	0.15	0.55	0.58	0.47	0.44	
1	1	1	1	0.15	0.55	0.58	0.45	0.43	②

(a) (b) (c) (d)

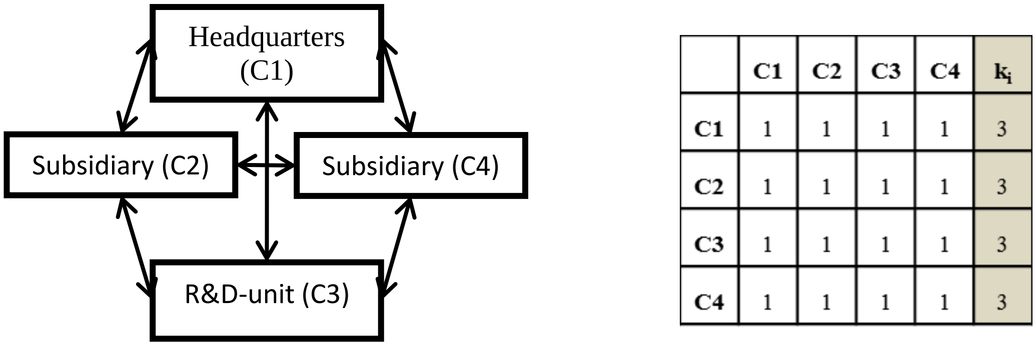
Figure 4: Example of an MNC and its adjacency matrix: K=1



	C1	C2	C3	C4	k_i
C1	1	0	0	0	0
C2	1	1	1	0	2
C3	1	0	1	0	1
C4	0	0	1	1	1

(a) (b)

Figure 5: Example of an MNC and its adjacency matrix: K=3



	C1	C2	C3	C4	k_i
C1	1	1	1	1	3
C2	1	1	1	1	3
C3	1	1	1	1	3
C4	1	1	1	1	3

(a) (b)

Figure 6: NK modeling performance result-- different K's for network structure

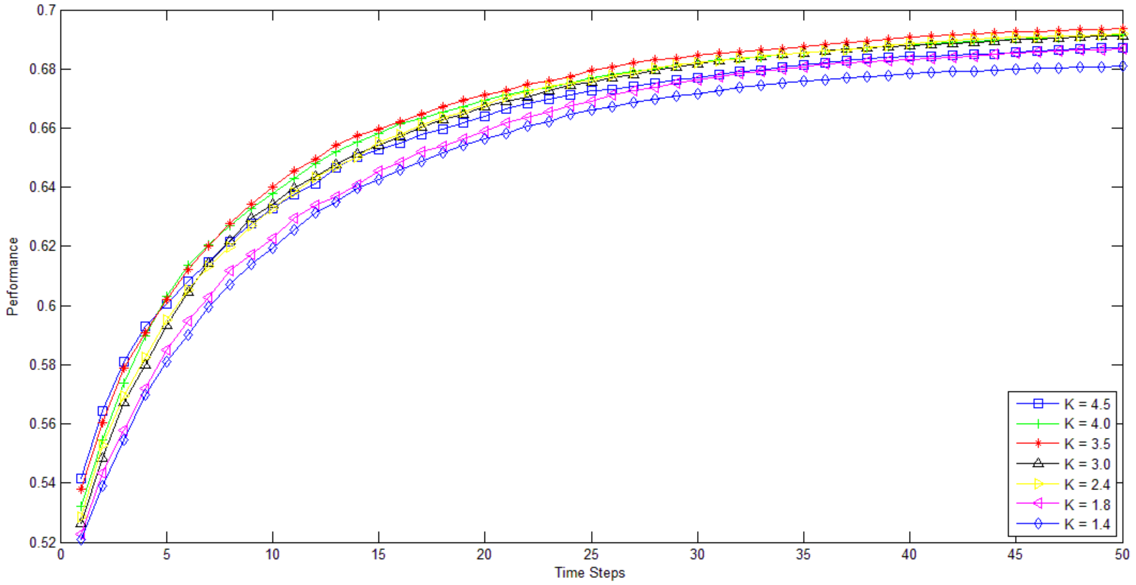


Figure 7: Fitted performance curves versus K times 10)

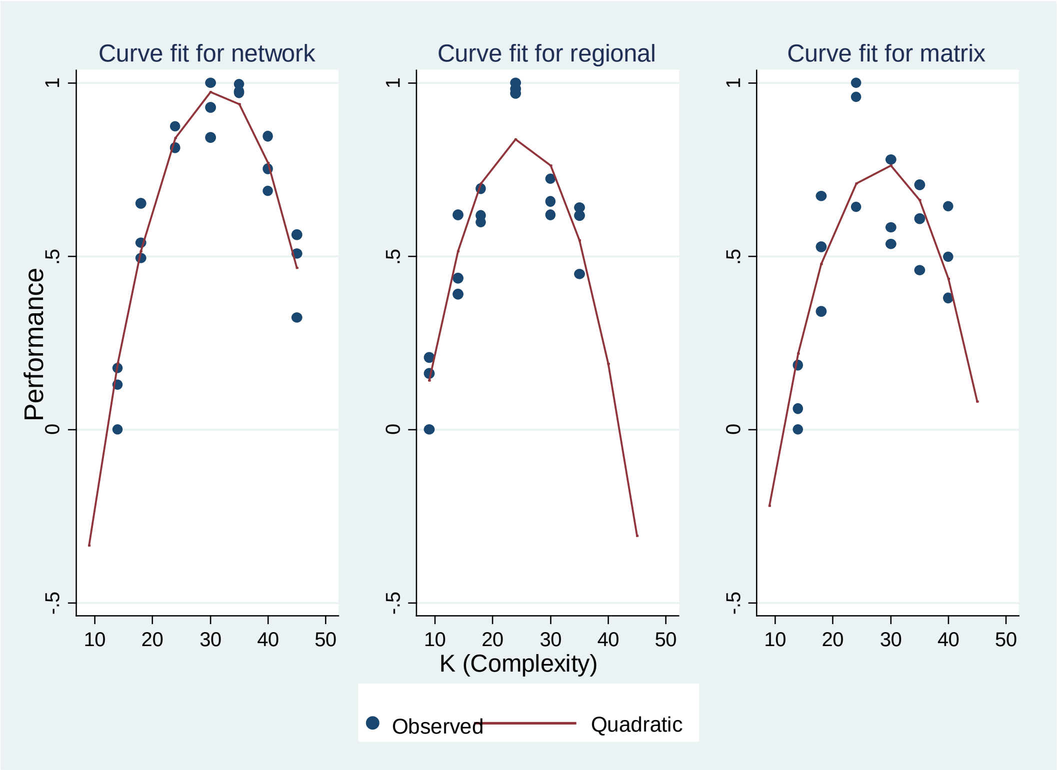
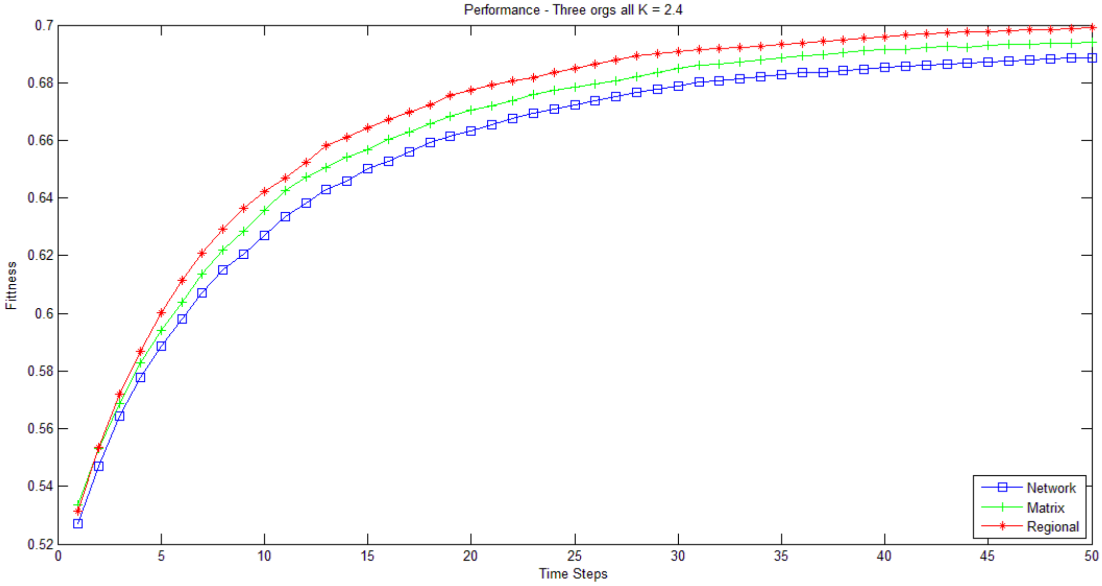


Figure 8: NK modeling performance result— K=2.4; different structures


Performance - Three orgs all K = 2.4
Fittness
Time Steps
0.7
0.68
0.66
0.64
0.62
0.6
0.58
0.56
0.54
0.52
0
5
10
15
20
25
30
35
40
45
50
Network
Matrix
Regional