Patterned Interactions In Complex Systems: The Role Of Information Technology For Re-Shaping Organizational Structures

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Abstract

The complex relationships between organizational practices have been the focus of information technology business value (ITBV) research in recent years. There appears to be a discernible trend toward a more nuanced view in which the effects of information technology (IT), various organizational practices and their complex interactions are systematically investigated. Building on the theoretical perspective of configurations, we embedded four distinct organizational typological patterns into a simulation model to study IT-related transformations by specifically focusing on the impacts of IT in different organizational structures. Our approach augmented configurational theory into a NK simulation model developed in theoretical biology to compare and contrast IT business value impacts between centralized and decentralized organizational structures. We found that when IT is a core component (to influence outcome); it has the potential to enable the firms to achieving the highest level of performance when comparing it to a periphery component (being influenced) in the centralized organizational pattern.

Keywords: Organizational Complexities, Pattern Interactions, Congurational Theory, fuzzy-set Qualitative Comparative Analysis, IT Business Value

1 Introduction

In recent decades, the effects of the proliferation of new information and communications technologies (IT) on economic structure and performance have received a lot of attention. The main focus is on the firm level connection between the use of IT and business value. One important issue that emerged in this context is the "enabling" played by IT in organizations. Apart from being a type of input capital that is directly used in the organizational process, IT also enables changes in work systems, organizational redesign, and new business processes (Bresnahan and Trajtenberg, 1995).

The resource-based view, proposed by Penrose (1959), conceptualized a firm as a collection of resources within an administrative framework, where the speed of accumulation and assimilation of resources is the key to firm growth as firms continually search for innovative ways to enhance performance. Practices such as business process re-engineering (Barua et al, 1996), job rotation and team work (Arvanitis, 2004) are believed to affect the production processes in different ways, thereby affecting the arrangement and utilization of all inputs and therefore the output performance. Although many research studies have investigated complementary factors that influence IT payoff through various organizational practices, little work has been conducted on the linkage between IT and broader indicators of organizational structures (with a few exceptions like Rivkin and Siggelkow, 2007). The theory of "complementarities" has offered valuable insight in the study of complex relationships between organizational practices and the use of IT (Venkatraman, 1998, Aral et al, 2012; Barua et al, 1996; Poon et al. 2009, 2010). The concept of "web of complementarities" described in Milgrom and Roberts (1995) marked a paradigmatic shift in conceptualizing other complex dynamics among organizational practices. It has contributed to our understanding of whether and how complementary relationships (in the forms of interactions) among organizational practices lead to significant increases in performance. However, model construction is still a critical problem in studying complementarities due to the following reasons: (1) simultaneously interacting organizational factors need to be considered together, (2) performance generations can vary significantly between different interaction structures; (3) there can be many complex interaction structures among the complementary factors.

The aim of this research is to investigate the fitness landscape of a firm evolving by the complex relationships of a range of organizational factors and IT, hence to examine the benefits and risks of the evolution with respect to the structure of interaction among organizational factors. These suggest that technology in general and IT in particular, are beginning to have an impact on structural patterns of organizational processes and strategies. An important research question is not only to understand how the use of IT in different organizational structures influences business values, but the question also extends to discovering the forms of complex interaction patterns between IT and organizational practices that can affect performance outcomes. This current study addresses these complex questions of organizational interaction structures. It has profound implications for the welfare of the firm and particularly for the design of strategies and transformation of organizational structure.

2 Relevant Literature

2.1 IT and Organizational Structures

Beede and Montes (1997) argued that the convergence of IT has enabled computers to become powerful communication tools and that networks have enabled new work organizations. The potential of IT to change the way individuals and businesses interact appears enormous and has inspired considerable research on how IT may affect firm structure, improve economic efficiency and provide the potential for economic growth (Poon et al. 2006). Brynolfsson et al. (1994) examined the relationship between IT investments and the shifting of economic activity to smaller firms using industry-level data on IT capital and various measures of firm size. They found evidence that IT investment is significantly associated with decreases in the average size of firm and is correlated with decreases in the number of employees per business unit and per firm in all sectors, where decreases in firm size are most pronounced a few years after IT investment is made. Gurbaxani and Whang (1991) used the insights of transaction cost economics together with agency theory to discuss the impacts of IT on organizations and markets. They found a negative relationship between IT investments and vertical integration, and then inferred links between IT and various components of new organizational forms such as the choice between centralized and decentralized authority within or between firms. They concluded that IT can potentially alter the cost of coordinating activity within firms (internal coordination) as well as between firms (external coordination).

Hitt (1999) found that IT investments produce not only higher stock valuations in firms but, more importantly, confirmed that IT is related to changes in the structure of the firm such as vertical de-integration and reduction in the firm size. Pinsonneault and Kraemer (2002) also found that IT plays a facilitating role in organizational downsizing. They found that IT was used to facilitate work redesign in a convergent change strategy and to facilitate more significant structural work redesign in a strategic reorientation. Other studies looked at different combinations of IT and work practices and found that firms that couple IT investments with decentralized work practices were much more productive than those which do neither (Brynjolfsson and Hitt, 1998). They also had a disproportionately positive effect on firm market value (Brynjolfsson et al, 2002). Hollenstein (2004) concluded that the adoption of IT is strongly linked to the adoption of "new workplace organization". He showed that information technologies are not only cost-reducing and efficiency enhancing technologies, but they also exhibit a great potential to generate competitive advantages based on output characteristics in terms of product innovations and improved customer-orientation.

Brynjolfsson et al. (2002) examined the influences of a number of important organizational factors and management practices in conjunction with the effects of IT investments on organizational performances. Bresnahan et al. (2002) surveyed approximately 400 large firms to obtain information on aspects of organizational structure such as allocation of decision rights, workforce composition, and investments in human capital. They found that these work practices are correlated with each other (and particularly with IT use). They argued that these practices are part of a complementary system. They defined "organizational capital" as the built-up knowledge in a firm's routines, procedures, reporting structures, staff training, work flows, and company positioning, decentralized organizational structure and IT investment which in combination contribute to productivity growth.

2.2 Studies of Structures of Complex Interactions

The study of organizational performance is often very difficult because of the complexity that arises via "differentiation in structure, authority and locus of control, and attributes of personnel, products, and technologies" (Dooley, 2002). This is because performance is usually the result of the interdependent effect of multiple conditions (Ragin, 2008) that are often tightly coupled and so one element of the system would both require and affect change in many or all other elements in the system (Milgrom and Robert, 1995), reinforcing systems thinking towards the relationship among the organizational mechanisms. Luhmann (1995) stated that "we will call an interconnected collection of elements complex when, because of imminent constraints in the elements' connective capacity, it is no longer possible at any moment to connect every element with every other element…..Complexity in this sense means being forced to select; being forced to select means contingency; and contingency means risk" (p. 25). This concept points to the argument that complex systems are composed of mechanisms that are interdependent in complex ways.

Empirical studies (like Poon et al., 2009) found that the set of interrelated organizational practices that complement positively to IT use is different from the set of practices hindering IT use, and concluded that organizational factors may have different pathways to affect organizational performance. Such organizational practices have often been overlooked and yet, they can play a weak yet non-trivial role in production and organizational processes. This phenomenon was explained by the importance of contextuality (Porter and Siggelkow, 2008). In their work, in-depth case studies on individual firms (such as Urban Outfitter) were carried out in studying contextual interactions in firms. They concluded that generic activities often have very low or no independence with other activities within the firm and so yield similar or the same contribution toward the total firm performance across all firms, which could make firms susceptible to imitation and hence lose their competitive advantage in the market.

Rivkin and Siggelkow (2007) studied 10 different interaction patterns (such as Random, Local, Small-world, Block-diagonal, Preferential attachment, Scale-free, Centralized, Hierarchical, Diagonal and Dependent) and found that underlying interaction patterns affect firm performance substantially in unexpected ways. For example, they found a general pattern showing an increase in the number of interactions raises the number of local performance optimums (i.e. local peaks) regardless of the interaction patterns. In addition, they also identified that particular interaction patterns (like dependent, diagonal, and to a lesser degree, local and block-diagonal) tend to generate performance landscapes with substantially more local peaks than random interaction pattern, while centralized and hierarchical interaction patterns typically lead to substantially less local peaks. To investigate effective organizational configurations, Fiss (2009) proposed a framework which argued that organizational typologies often have core and periphery elements. Core elements are essential (i.e. causal conditions with evidence indicating a strong causal relationship with the outcome of interest). Peripheral elements are less important and perhaps even expendable or exchangeable by comparison (i.e. causal conditions with evidence indicating a weaker causal relationship with the outcome of interest).

3 Research Methodology

Complex Adaptive Systems (CASs) simulation models have been considered as effective tools in modeling elements/agents within an organization because they allow the study of interdependencies and fitness between agents employed to produce outcomes (e.g. Levinthal, 1997; Rivkin and Siggelkow, 2007). This is made possible because organizations like CASs, tend to self-organize such that patterns and regularities emerge without the intervention of a central controller. *NK* Model is one of the CASs frameworks that have "made the transition to management science" (Rivkin and Siggelkow, 2007) and was originated from theoretical biology (Kauffman and Levin, 1987). It has been used to study organizations holistically as CASs. For example, Levinthal (1997) used the NK Model to model the processes of organizational change in a business environment. In the NK model, N refers to the number of components or agents (X) of the system and K refers to the degree of interaction between the components with the total interactions being $N * (K + 1)$. This model captures the essence of contingency theory or "system fitness" where each component in the model contributes to the overall total performance measure of the system based not only on its own value, but also on the values of K other components (Kauffman, 1993).

In order to analyze the complex interdependencies across different contexts, a novel NK Simulator is developed in this study and applied to different interaction patterns, intensity and also the different ways of deploying IT within a firm. The causality theories of organizational complexity, contingency and configuration are encapsulated by using set theoretic described in Fiss (2009) as the support for the conceptual model of complex interdependencies behind the simulator.

3.1 Data Description (Cases of IT Business Value)

The data set used for our analysis was originally collected by the Australian Department of Communication, IT and Arts in 2004 (details can be found in Gregor et al, 2004). It is based on a questionnaire and contains responses from 1050 Australian firms of different industries and organizational sizes. It provides information about organizational practices (as IT complementary resources) that firms used as well as the benefits they gained from their IT investments. The questionnaire has been developed based on a collection of previous research with a focus on organizational transformation and IT investments. It provides an ideal dataset to test our approach for analyzing IT business value causality. The original dataset contains four dimensions of IT business value and eleven organizational practices. After removing records with incomplete data, a sample of 558 organizations was subject to analysis. In Table 2, the measure of IT resource and the eleven organizational resources (X) and in Table 1, the three IT Business Value dimensions (Y) are described.

Variables (Xi)	Descriptions	Mean (sd)
IT latent value (IT, X_1)	This value was calibrated using Exploratory Factor Analysis of six Technical IT Resources and Human IT Resources, followed by Confirmatory Factor Analysis to verify a model fit.	1.49 (0.59)
IT opportunism (ITOPPT, X_2)	The frequency of recognizing and achieving significant additional benefits which were initially unanticipated	3.28 (1.11)
IT Skill Level (ITSKILLDEV, X_3)	The frequency of achieving valuable increases in IT skill level within the organization	3.41 (1.10)
Business Strategy Planning (BUSSTRAT, X_4)	The frequency of engaging in formal business strategic planning	3.42 (1.29)
IT Strategic Planning (ITSTRAT, X_5)	The frequency of engaging in IT strategic planning	3.06 (1.37)
Industry Leadership (INDUSTLEAD, X_6)	The frequency of seeking to be an industry leader in adopting new IT	2.72 (1.43)
Formal Contracting (FORMALCON, X_7)	The frequency of establishing formal contractual arrangements for IT investments	2.88 (1.45)
IT Integration (ITINTEGRATE, X_8)	The frequency of integrating new IT into existing business processes across key functional areas	3.63 (1.15)
Formal Project Management (FORMALMETH, X_9)	The frequency of applying formal project management methodology	3.12 (1.49)
Business Case (BUSCASE, X_{10})	The frequency of developing business case	3.18 (1.49)
Post Implementation Review (POST, X_{11})	The frequency of having post implementation review performed	3.23 (1.40)
Change Management (EXT, X_{12})	The frequency of employing external change management specialists	2.08 (1.24)
Note: The IT complementary resources X_2 to X_{12}were originally rated by management executives based on how often their organization performs certain practices, ranging from 1 (never) to 5 (always)		

Table 1. IT Resource and Organizational Practices

Outcomes: (Y)	Descriptions	Mean (sd)
Strategic ITBV (SBV, Y_1)	Strategic benefits include the ability to create competitive advantage, align business strategies to directly support organizational goals, provide new products or services, and improve relationships with customers	6.74 (1.83)
Informational ITBV (IBV, Y_2)	Informational benefits include faster and easier access to internal and external information, more useful, accurate and reliable information, and increased flexibility for manipulation of content and format of information	7.67 (1.64)
Transactional ITBV: (TBV, Y_3)	Transactional benefits include operational and cost savings, supply chain management savings, staff cost savings, and improved business efficiency of employees, business processes and financial resources.	6.23 (1.86)
Note: The 3 dimensions of ITBV were collected on a scale of 1 (never achieving BV) to 10 (always achieving BV).		

Table 2. IT Business Value Dimension

3.2 Simulation Model

The novel NK simulator, developed using Matlab, is an extension to the original concepts of *NK* Model (Kauffman, 1993; Kaul et al, 2006), where N is the number of agents to be studied (i.e. 12 in this study) and *K* refers to the interaction intensity ($K \in \mathbb{Z}+$). Similar to previous studies (Kaul et al, 2006; Rivkin and Siggelkow, 2007; Porter et al, 2008), each agent or element can take 2 states (where $p \in \{0,1\}$) and so there are 2^{12} total possible combinations of resources (i.e. binary configurations). There are three essential steps in the simulation process: (1) the generation of influence matrix, which defines influencer-influencee relationship within the landscape, (2) the creation of performance landscape that involves the calculation of overall performances using set theoretic-based analysis, and (3) landscape characterization which quantitatively describes the features of the landscape.

3.2.1 Generation of influence matrix

Based on Rivkin and Siggelkow (2007), interaction patterns are indicators of the essential underlying processes and structure that are maintained in firms. "Influence matrices" represent interaction patterns and are used to record the interaction flow between elements. Given *N* is the number of binary decisions a firm is assumed to make about how to configure its activities, an "adoption configuration" summarizes the adoption of firm resources that could affect its performance and is represented as $L = X_1, X_2, ..., X_N$, with each X_i taking the value of either zero or one. The matrix will be of size $N*N$. The rows in the influence matrix represent the influencee (i.e. the element being influenced: X_i) while the columns represent the influencer (i.e. elements that are influencing X_i: X_j). An entry (i, j) is set to 1 if X_i is influenced by X_j, and 0 if X_i is not influenced by X_j. Since each element affects itself along with X_j, a diagonal line of 1s is drawn for each influence matrix regardless of the underlying pattern.

Given that organizational, social, and technological systems are often highly patterned (shown in Rivkin and Siggelkow, 2007), this study has adopted the Core and Periphery Framework (Fiss, 2009). The *NK* simulator allows the prioritization of agents within the systems by manipulating the positioning of elements in the adoption configuration via landscape sampling, enabling the allocation of core and periphery roles onto the *N* elements. For example, with a 3×3 influence matrix, all possible positioning of elements should be considered ($L=\{X_1,X_2,X_3\}$ or $L=\{X_3,X_1,X_2\}$ or $L=\{X_3,X_2,X_1\}$) to imitate the different roles that IT plays within an organization. The random, scale-free, blocked and centralized interaction patterns are adopted in this study to represent common organizational structures in firms and the influence matrix form of these interaction patterns are shown graphically in Figure 1.

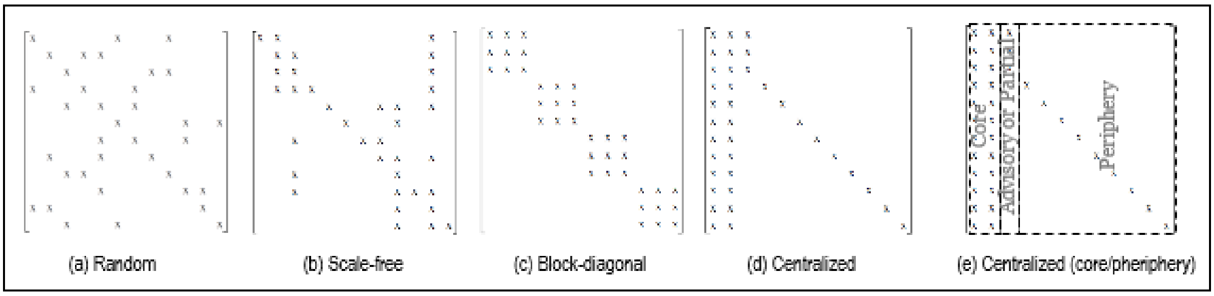

*Figure 1. The influence matrix form of Centralized, Random, Scale-free and Block-Diagonal Interaction Patterns using N = 12, K = 2 with the total maximum interaction = N (K+1) = 12*3 = 36.*

<u>*Random interaction pattern*</u>: Each element is influenced by exactly *K* other elements that are randomly assigned. Starting with 1s along the main diagonal, this matrix is created by randomly assigning 1s to exactly *K* other elements per row. Refer to Figure 1(a) for a graphical representation.

<u>*Scale-free interaction pattern*</u>: This assumes the degree of interaction amongst elements follows a power law distribution which has been shown to exist in many social systems (Rivkin and Siggelkow, 2007) and particularly in organizations (Siggelkow, 2002). The corresponding influence matrix is created by first filling the main diagonal with 1s and then in each column, M off-diagonal 1s are added, where M lies between 0 and (N-1), such that $Prob(M)=(M+1)^{-\gamma}$ where γ is determined such that average the total number of 1s in each influence matrix = $N(K+1)$. Thus, plotting the number of decisions (M) that a given decision affects against the probability of this occurrence yields a straight line on a log-log scale: $(ln(Prob(M))=-\gamma * ln(M+1))$. Refer to Figure 1(b) for graphical representation.

<u>*Block-diagonal interaction pattern*</u>: This assumes that elements are separated into groups and every element within the group affects all others within the group but there are no cross-group interactions. This matrix is created by placing (K+1)2 sized blocks of 1 diagonally across the matrix until the matrix contains a total of $N(K+1)$ interactions. Refer to Figure 1(c) for graphical representation.

<u>*Centralized interaction pattern*</u>: assumes that there exist some elements which will affect all other or most of the decisions, while other decisions only affect themselves. Starting with 1s along the main diagonal, this matrix is created by adding 1s into the first column, then into the second column, etc., until the matrix contains a total of $N(K+1)$ interactions. See Figure 1(d) for graphical representation.

The "Centralized" interaction pattern is used in this study to imitate the various types of centralized firms where IT plays a core, partial core (advisory) or periphery position in a practice bundle (i.e. a configuration of a set of organizational practices). When IT is the core element of the system, it has the ability to influence all other elements within the firm (note that core element in any pattern can only be influenced by other cores or partial core). When IT is a partial core, it will only be influenced by other cores within the firm and is labelled as playing "advisory" role within the firm. When IT is a periphery element, it will only influence itself and be influenced by the core(s), so it plays a "passive" role in the landscape. Given an *N* factor interaction structure, the characteristics of a typical centralized interaction pattern generally has *K* number of main core elements (i.e. columns with all 1s) and 1 partial core as advisory element (i.e. column with K+1 1s running down from the top of its column) and the rest are periphery (i.e. passive).

Figure 1(e) provides an illustration of the 3 roles of IT in a *N*=12, *K*=2 centralized interaction structure: In the first 2 columns (i.e. X_1, X_2) as one of the core elements that influence all other elements within the landscape; or in the 3rd column (i.e. X_3) as advisory element that influences only the core elements besides itself in the landscape, or in any of the remaining columns (i.e. X_4 through to X_{12}) as periphery elements that can only passively influence itself in the landscape.

3.2.2 Performance Landscape Creation

Contingency theory places great emphasis on careful management of firm resources to maintain a "good fit" because optimal firm performance is achieved through contingency on the state of other organizational mechanisms (Venkatraman, 1989). This study plans to explore the "fitness" between IT and other firm resources against different organizational designs. After an influence matrix is generated, for each of the possible adoption configurations (L_s) given the interaction structure, the simulator will generate a performance (i.e. overall fitness) of the resource adoption configuration and the inter-dependencies between them (including the emergent capabilities) by creating performance landscapes for each L_s. Two steps are involved in the creation of performance landscape: (1) creation of contribution matrices and (2) the calculation of the overall performance.

In creating the contribution matrices, the model assumes each element X_i contributes C_i (X_i; other X_j) amount of "energy flow" (Anderson, 1999) toward the overall fitness of the system (i.e. overall performance) where "$X_j s$" are the resources that influence X_i and its contribution toward the overall performance as specified by the influence matrix. For each $2^{(\text{total number of elements involved in the interaction})}$ possible binary realization of X_i and the other relevant $X_j s$, a performance level is allocated using a set-theoretic approach described in Ragin (2008), called Fuzzy Set Qualitative Comparative Analysis (*fs*QCA) , to score how sufficient these X_i; other $X_j s$ are in causing the outcome configurationally.

The subset relation suggests multiple causes leading to high firm performance. As it is possible that $|X|<|Y|$, i.e. *X* is not equal to Y which suggests that adopting resource *X* is only one of the paths to achieving higher firm performance. In this case, adopting resource *X* is said to be "sufficient" but not "necessary" for high performance (Ragin, 2008). It is important to note that the theory that "firms adopting resource *X* are high performers" specifically refers to a causal sufficient argument, that may not be necessary for yielding the outcome. In general, QCA methods rely on set-subset relationships like consistency which can be used to represent the theory for resource or combination of resources being necessary and/or sufficient in causing outcome.

$$consistency(X_i \leq Y_i) = \frac{\sum_i m_{x_i \cap y_i}}{\sum_i m_{x_i}} \quad (1)$$

The causal consistency model is given by (1), where *X* represents the causal set and *Y* is the outcome, m_{x_i} refers to case i's membership score in the set of the cause *X*, m_{y_i} indicates case i's membership score in outcome *Y*, and $m_{x_i \cap y_i}$ defines case i's membership score in the intersection set of *X* and *Y*.

According to Ragin (2008), the steps in *fs*QCA can be divided into two stages. The first stage involves calibrating the values of the variables for each observation into fuzzy membership scores. This can be done using the direct method of calibration which requires the researcher to supply qualitative anchors for defining the membership score of a given variable. Anchors are used to map the links between specific scores on continuous variables (e.g. an index of wealth) and fuzzy set membership (e.g. degree of membership in the set of rich countries), indicating what value constitutes full membership, full non-membership and the cross-over point. The 11 organizational practices were rated by management executives based on how often their organization performed those practices, in the range of 1 (never) to 5 (always); these values were dichotomized with the following anchor: 1; 2 → 0 and 3; 4; 5 → 1. The justification of using a coarser dichotomized measure is to broaden the impact of use to particularly reflect the intangible enabling potentials of inputs (Banker and Johnson 1995). An alternative method can be used is dominance based rough sets approach described in Peters and Poon (2011). The second stage uses the Truth Table algorithm (Ragin, 2005) to sort the cases or instances into a truth table in which sufficiency analysis can be carried out. Truth tables of the X_i; other $X_j s$ set of explanatory variables are then used as the contribution matrix C_i (X_i; other $X_j s$). The overall performance associated with a specific binary configuration (L_b) of a Landscape (L) is the average of the N contributions:

$$Performance(L_b) = \sum_{i=1}^{N} \frac{c_i(X_i; other\ X_j s)}{N} \quad (2)$$

The creation of performance landscape is completed when all overall performance of L_b are calculated.

3.2.3 Landscape Characterization (Parameterization of Interaction Intensity)

A key characteristic of a landscape is the number of local performance optimums (or local peaks) each landscape contains where a local peak is a binary configuration such that no other configuration exists that differs from it, in only one decision has higher performance than it (Rivkin and Siggelkow, 2007). It can be used to measure flexibility or stability of the landscape which could indicate how adaptable the firm is to its environment given the specified K interaction intensity and underlying interaction pattern (Porter and Siggelkow, 2008). Kauffman (1995) suggested that if small changes in behavior lead to only a small improvement in performance then the firm's performance can never improve much. However, if small changes in behavior can lead to wildly different fitness levels, then firms can reach extraordinary fitness peaks, but cannot remain on them. Hence, in order for the continual survival of firms, they must maintain a balance between flexibility and stability (Weick, 1979) because flexibility allows exploration to occur, which is essential for the continuous growth of a company.

Another main measurement used is the performance measure where the simulator will calculate the average performance of the landscape, the performance deviation within the landscape, best performance and the minimum performance. These measurements will assist users in answering the research questions as mentioned by indicating the variation in returns to investment and performance level across varying patterns, *K* and the roles played by specified elements.

4 Analytical Results

As shown in Table 3, firms' best performance and the number of local peaks is positively correlated to the interaction intensity (*K*) when IT is a main core resource and although the lowest performance follows a similar pattern, it experiences a slight setback at *K*=2, bringing down the average performance with it. On the other hand, when IT is either an advisory element or a passive element within the firm, all measurements is positively correlated. These trends are observed across all dimensions of business values.

Out of the three identified possible roles of IT, landscapes with IT as a main core element returns the lowest "average performance" even though it has the highest "Best Performance" across all three business values, resulting in the greatest performance variation. Furthermore, Landscapes with IT as an advisory element have the second lowest overall minimum performance and also the second highest overall best performance, hence making the overall average performance lower than when IT is a passive element across all *K* and dimensions of business benefit. Therefore, under a centralized landscape, the sole presence of IT as a core (*K*=1) is not sufficient to generate highest returns without being used in conjunction with other organizational elements. Upon a closer examination, when IT leads alongside with IT Opportunism (ITOPPT, X_2) and IT Skill Development (ITSKILLDEV, X_3) as the cores of the firms, firms will not experience the above mentioned performance volatility and will have the overall highest performance. As indicated from the left hand side of the chart, when IT & ITOPPT or IT & ITSKILLDEV are cores of the firms, the gap between best performance and min performance is the smallest. Similar trend can be observed for all *K* >2.

		IT is Core/ one of the cores				IT is Partial Core (Advisory)				IT is Periphery (Passive)			
	K	mean (SD)	max (SD)	min (SD)	Local Peak (SD)	mean (SD)	max (SD)	min (SD)	Local Peak (SD)	mean (SD)	max (SD)	min (SD)	Local Peak (SD)
Strategic benefit	1	0.656 (0.022)	0.913 (0.010)	0.398 (0.032)	1.000 (0.000)	0.779 (0.045)	0.861 (0.021)	0.694 (0.068)	1.460 (0.522)	0.792 (0.023)	0.856 (0.013)	0.723 (0.036)	1.460 (0.500)
	2	0.639 (0.150)	0.931 (0.045)	0.349 (0.233)	1.500 (0.500)	0.791 (0.065)	0.897 (0.020)	0.665 (0.104)	1.520 (0.500)	0.824 (0.023)	0.890 (0.011)	0.735 (0.043)	1.580 (0.510)
	3	0.684 (0.185)	0.953 (0.044)	0.406 (0.293)	1.500 (0.535)	0.802 (0.083)	0.917 (0.018)	0.656 (0.140)	1.760 (0.652)	0.848 (0.021)	0.904 (0.007)	0.750 (0.046)	1.750 (0.670)
	4	0.746 (0.193)	0.971 (0.041)	0.495 (0.309)	1.790 (0.670)	0.822 (0.101)	0.933 (0.019)	0.666 (0.168)	2.203 (0.860)	0.8657 (0.019)	0.914 (0.005)	0.763 (0.044)	2.130 (0.900)
Informational	1	0.718 (0.022)	0.965 (0.004)	0.472 (0.038)	1.000 (0.000)	0.884 (0.043)	0.944 (0.009)	0.823 (0.078)	1.636 (0.505)	0.900 (0.021)	0.943 (0.006)	0.858 (0.039)	1.700 (0.4600)
	2	0.691 (0.149)	0.975 (0.016)	0.410 (0.271)	1.560 (0.499)	0.877 (0.062)	0.964 (0.006)	0.784 (0.116)	1.709 (0.658)	0.918 (0.020)	0.961 (0.004)	0.867 (0.041)	1.690 (0.67)
	3	0.730 (0.184)	0.985 (0.014)	0.473 (0.340)	1.630 (0.626)	0.877 (0.083)	0.975 (0.005)	0.770 (0.156)	1.850 (0.816)	0.932 (0.02)	0.971 (0.003)	0.881 (0.042)	1.940 (0.880)
	4	0.788 (0.193)	0.992 (0.011)	0.575 (0.359)	2.060 (0.837)	0.887 (0.100)	0.981 (0.005)	0.779 (0.190)	2.158 (1.030)	0.944 (0.019)	0.976 (0.002)	0.896 (0.041)	2.160 (1.060)
Transactional	1	0.601 (0.022)	0.867 (0.014)	0.335 (0.027)	1.000 (0.000)	0.680 (0.045)	0.763 (0.032)	0.597 (0.056)	1.364 (0.505)	0.687 (0.023)	0.753 (0.018)	0.623 (0.029)	1.300 (0.471)
	2	0.585 (0.150)	0.875 (0.077)	0.299 (0.199)	1.327 (0.471)	0.698 (0.064)	0.806 (0.032)	0.581 (0.088)	1.346 (0.480)	0.724 (0.022)	0.791 (0.014)	0.643 (0.035)	1.416 (0.517)
	3	0.633 (0.185)	0.906 (0.082)	0.354 (0.256)	1.530 (0.542)	0.719 (0.084)	0.838 (0.035)	0.579 (0.121)	1.370 (0.567)	0.751 (0.021)	0.813 (0.012)	0.663 (0.039)	1.448 (0.587)
	4	0.697 (0.194)	0.936 (0.078)	0.436 (0.273)	1.700 (0.640)	0.745 (0.100)	0.866 (0.039)	0.592 (0.147)	1.630 (0.766)	0.772 (0.02)	0.828 (0.011)	0.68 (0.038)	1.690 (0.800)

Table 3. Landscape Characteristics of centralized pattern for the 3 business values dimensions

		Block Pattern				Scale-Free Pattern				Centralized Pattern (IT as core)			
	K	mean	max	min	Local Peak	mean	max	min	Local Peak	mean	max	min	Local Peak
SBV	1	0.779	0.866	0.692	5.00	0.767	0.859	0.671	1.89	0.656	0.913	0.398	1.00
	2	0.791	0.900	0.664	3.52	0.781	0.891	0.658	2.32	0.639	0.931	0.349	1.50
	3	0.803	0.919	0.655	3.97	0.813	0.917	0.679	2.68	0.684	0.953	0.406	1.50
	4	0.815	0.924	0.670	4.55	0.827	0.936	0.674	3.67	0.746	0.971	0.495	1.79
IBV	1	0.884	0.948	0.820	7.32	0.862	0.940	0.782	2.27	0.718	0.965	0.472	1.00
	2	0.877	0.966	0.782	4.77	0.867	0.959	0.770	2.96	0.691	0.975	0.410	1.56
	3	0.877	0.976	0.769	4.56	0.881	0.972	0.784	3.35	0.730	0.985	0.473	1.63
	4	0.887	0.977	0.785	6.36	0.894	0.981	0.795	3.72	0.788	0.992	0.575	2.06
TBV	1	0.680	0.767	0.595	3.33	0.667	0.770	0.563	1.62	0.601	0.867	0.335	1.00
	2	0.698	0.809	0.579	2.57	0.699	0.806	0.583	1.99	0.585	0.875	0.299	1.33
	3	0.698	0.809	0.579	2.57	0.727	0.845	0.591	2.03	0.633	0.906	0.354	1.53
	4	0.734	0.852	0.591	3.48	0.753	0.874	0.604	2.17	0.697	0.936	0.436	1.70

Table 4. Landscape characteristics of Scale-free, Random, Block, and Centralized Interactions

In comparison to the block-diagonal, scale-free interaction pattern (shown in Table 4), the centralized landscapes with IT as a main core still have the highest best performance across all business value and all *K* as well as having the highest performance variations that lead to a low average performance which is consistent with findings from Table 3. Under centralized interaction pattern, the number of local peak is only around 1 regardless of the role of IT across all business values and *K*. This is perhaps due to the fact that interactions are confined tightly within the centralized core elements.

5 Discussion

Proliferation of local optima makes it difficult for organizations to adjust successfully in the face of environmental change (Levinthal, 1997), to imitate the successes of others and to replicate their own successes (Rivkin, 2000). In this study, the centralized interaction pattern has consistently produced the least number of local peaks across all interactions intensities (*K*s) and all dimensions of business value. This implies that firms with a centralized organizational design will only achieve an acceptable performance level if the firm is not susceptible to involuntary changes as well as operating at an optimal configuration, because it is hard to reach the optimal configuration by means of exploration or making small changes within the firm. Furthermore, if centralized firms were to become vulnerable to involuntary changes, they are less likely to survive. This is reflected by increasing performance variations as *K* increases under centralized firms, which could be explained by the snowballing effect where resources that are not suitable to act as cores of the firms saturate the landscape sampling set and increase the performance variation dramatically.

Centralized interaction pattern should be considered when firms wish to exploit existing resources within the firm, whether it be refinement to existing business processes, strategy execution or improvement in resources. Decentralized organizational structure is desirable for exploration because it enables flexibility in the configuration of resources which allows firms the ability to experiment with new elements as well as to provide isolation to protect valuable assets within the firm against any harmful consequences that may result from these experiments, permitting firms to freely take risks and explore. Block diagonal interaction pattern (considered as decentralized organizational design) has an overall highest number of local peaks than centralized interaction pattern, which makes it the desired structure to use when exploring with technological innovations or technologies that are novel to the firm. However, centralized pattern returns higher best performance than decentralized interaction pattern, especially when IT is the core element for which the firm is centralized upon. This implies that IT's full potential can only be realized when the organization is centralized with IT as one of its cores along with IT opportunism or IT skill development. For risk adverse firms that wish to explore new IT opportunity, the advice is perhaps to decentralize only that small part of the firm needed to deploy the new IT while keeping the remaining bulk of the firm centralized.

In this study, we have shown that when IT is a main or partial core of the firm, performance will be maximized when IT is a periphery or passive element within the firm. However, IT also increases the variations of performance mostly due to lower minimum performance. This finding is consistent with the observation made by Brynjolfsson et al (1996) and Aral et al. (2012) that substantial variation exists in the returns to IT investments across firms. Upon closer examination, it can be seen that IT opportunism and IT skill development should occur alongside with IT to ensure the variations of IT performances are reduced across all *K*. Hence this finding could be explained by the fact that firms' ability to respond and adjust to external technology development within the competitive marketplace is critical in today's turbulent technology environments. This is because organizations with a high level of IT opportunism will continually scan for potential technological opportunities and threats (Daft et al, 1984) and at the same time respond to technological changes in its environment. Firms can improve on IT opportunism by having a future focus, top management IT advocate, and developing an adhocracy culture (Srinivasan et al, 2002). It is therefore vital that IT skill development within the firms needs to align to firm's strategies so that IT potential could be fully realized.

6 Conclusion

The novel NK Simulator developed in this study has enabled a holistic approach of context-specific examination of causal relationship under different organizational design structures and different interaction intensities. It takes into account causal complexity and so IT is able to be examined under the core and periphery framework. Organizations often need to decide between exploration and exploitation when making investment decisions. The concepts of exploration and exploitation have been studied under the technology context as a learning mechanism (March, 1991), innovation strategies (Benner and Tushman, 2003), strategic activities (Winter and Szulanski, 2001) and search processes (Rivkin and Siggelkow, 2007). Bocanet and Ponsiglione (2012) argued that organizations have to be able to continuously search for and identify new opportunities and, at the same time, be capable in developing its existing resources. Exploration is necessary for the continuous growth of a company and the adoption of Information Technology is considered a form of exploration. This study has indicated that the decentralized organizational structure seems to be more flexible for firms that are trying to adopt a new technology.

The limitation of this study is that the data size used in this study, so the accuracy of the simulation model is limited which leads to the restriction of the maximum number of interactions allowed between any given resource. Furthermore, the *fs*QCA method often encounters the limited diversity problem when examining social phenomena such that instances of all the configurational types are not available empirically which could complicate the analysis.

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