7-8-2023

# Dynamics of Business-IT Alignment: A Complex Adaptive System Model

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# Dynamics of Business-IT Alignment: A Complex Adaptive System Model

*Completed Research Paper*

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## Abstract

*Although information systems (IS) scholars have long recognized that business-information technology alignment (BITA) is a dynamic process instead of a static end-state, our understanding of how senior managers' behaviors and external environmental dynamism affect the dynamic evolution of BITA, especially* at the strategic level, *is still limited. Based on complex adaptive systems (CAS) theory, this paper regards BITA as a dynamic coevolutionary process and conducts a simulation study to investigate how different attributes and behavioral rules of business and IT managers influence the dynamic changes of BITA degree. Results indicate that business and IT managers with high cognitive capabilities can achieve a better degree of BITA. Mutual communication can offset their cognitive gap and deficiency. Environmental dynamism increases the fluctuation of the BITA coevolutionary process. Through the lens of CAS theory, this paper fills gaps regarding the dynamics of BITA, which makes significant contributions to both IS research and practice.*

**Keywords:** Business-IT alignment, dynamics, complex adaptative system, simulation

## Introduction

Business-information technology alignment (BITA) refers to the degree of fit and integration among business strategy, business structure, IT strategy and IT structure (Henderson and Venkatraman 1993). In the past three decades, BITA has been one of the top ten hot topics published by the Society for Information Management (SIM) and since 1994, BITA has always occupied the top three positions (Kappelman 2018; Kappelman et al. 2022). What's more, BITA is also one of the top concerns of business executives and IT specialists (Chan and Reich 2007; Luftman et al. 2004). A large number of theoretical and empirical studies have shown that BITA can improve organizational performance (Byrd et al. 2006; Chan et al. 2006; Kearns and Sabherwal 2006; Tan and Gallupe 2006; Yayla and Hu 2012). Nevertheless, most of the existing studies adopt the simple cause-and-effect deterministic logic (Benbya and Mckelvey 2006), treat BITA as a static result, and use cross-sectional data to study BITA's influence on organizational performance.

Some studies have also considered BITA as a dynamic process and applied the Co-evolutionary theory or Punctuated Equilibrium Model (PEM) to explore its dynamics. Research topics include the dynamic process of BITA (Benbya and Mckelvey 2006; Sabherwal et al. 2001), the factors that induce BITA revolutionary changes (Sabherwal et al. 2001; Wang et al. 2011) and the path to achieving dynamic alignment between business and IT (Benbya and Mckelvey 2006; Hirschheim and Sabherwal 2001). For instance, based on PEM, Sabherwal et al. (2001) divide BITA's dynamic process into two steps, slow evolution and rapid revolution and find that five factors, namely, environmental shifts, sustained low performance, influential outsiders, new leadership and perceptual transformation, have influences on its revolutionary changes. Benbya and McKelvey (2006) apply co-evolution theory to construct a multi-level coevolution model of

BITA and regard BITA as a dynamic process of interaction and adjustment among three levels, individuals, operation and strategy. Further, Zhang et al. (2021) validated this process by examining the impact of three principles (knowledge sharing, mutual communication, and intelligence level) on the coevolution of IT alignment at the *social/individual level*.

These studies have deepened our understanding of the dynamics of BITA. That is, BITA is a complex coevolutionary process in which business and IT managers' behaviors, such as cognition, mutual communication and learning as well as external environmental dynamism, have positive effects on the coevolution of business and IT at the social level (Zhang et al. 2021) or trigger BITA's revolutionary changes (Wang et al. 2011). Cognitive capability refers to the managers' abilities of perception attention and problem-solving and reasoning (Helfat and Peteraf 2015), which can help them recognize the opportunity and design the business model to obtain the alignment between business and IT strategies. Social and communication can help them reconfigure the alignment and overcome executives' resistance to change. Environmental dynamism is another important determinant of firm strategies (Sabherwal et al. 2001).

These existing studies, however, be it either a conceptual model of BITA's dynamics (Benbya and Mckelvey 2006) or an empirical analysis of the influencing factors of BITA's revolutionary changes (Sabherwal et al. 2001; Wang et al. 2011), have limitations in two ways. First, prior research has applied only case studies to explain the effects of managers' behaviors, which has limited generalizability and cannot fully reveal the coevolutionary mechanisms of BITA, and a comprehensive method that can more precisely depict the dynamics of BITA is warranted. Second, the impact of business and IT managers' cognition capability and mutual communication on the dynamic evolution of BITA, especially at the *strategic level* (versus *social level*), has received little attention (Zhang et al. 2021) and needs to be further explored.

To address these limitations, based on the complex adaptive system (CAS) theory, this paper regards BITA as a continuous coevolutionary and emerging process and builds a CAS model of BITA. Through setting the attributes, behavioral rules and interaction patterns of different agents (i.e., managers), we apply the agent-based modeling and simulation methods to offer a holistic lens to capture the dynamics of BITA. Our research question is: *How the cognitive capabilities of business and IT managers and their mutual communication affect the dynamic coevolution of BITA under different levels of environmental dynamism?*

Our simulation yields several major findings. First, IT and business managers with high cognitive capability are better able to achieve BITA. Second, the mutual communication between IT and business managers has different effects on BITA under various contexts of managers' cognitive capabilities. Also, effective communication can offset their cognitive gap and deficiency. Third, dynamic environments will increase the volatility of BITA, which is more pronounced when the cognitive capability of both business and IT managers are low. Additional empirical analysis with survey data from the Chinese shipbuilding industry further strengthens the external validity of the simulation results. By integrating the literature in the fields of IT alignment and CAS, this paper provides some new and interesting insights into the dynamics of BITA.

# Theoretical Background

## *BITA Definition*

Based on Henderson and Venkatraman's (1993) strategic alignment model, BITA has four dimensions: business strategy, IT strategy, business structure and IT structure and subsequently generates six different types of alignment by considering the combination of any two dimensions: strategic alignment (business and IT strategies), structure alignment (business and IT structures), business alignment (business strategy and structure), IT alignment (IT strategy and structure), and two cross-domain alignments (business strategy and IT structure, IT strategy and business structure) (Wang et al. 2011). In this study, we mainly explore the dynamics of these four dimensions, which constitute the strategic level of BITA.

According to Sabherwal et al. (2001), business and IT strategies and structures can each be assessed using multiple attributes. For example, we can describe business strategy using Miles and Snow's (1978) typology of prospector, analyzer and defender. We assess business structure using decentralized, centralized and organic (Jelinek and Schoonhoven 1993). IT strategy can be grouped into three categories: efficient, flexible and comprehensive (Camillus and Lederer 1985). IT structure is identified by methods similar to the business structure, including centralized, decentralized, and shared (Brown and Magill 1994). This classification of the four dimensions has also been recognized by most scholars and has achieved fruitful research results (Hu et al. 2022; Yayla and Hu 2012).

Business and IT managers have long been recognized as the decision-makers of business and IT strategies and structures (Wang et al. 2011). In this paper, we contend that the mutual communication and interaction between business and IT managers will form the consistency between the two sides in the cognitive structure and content. Ultimately, based on their cognitive capabilities and mutual communication, business and IT managers respectively determine business strategy and structure, IT strategy and structure (choosing different attributes as above) under the context of the external environment. Their choices of strategies and structures that have been made are adjusted and thus form the dynamic evolution of BITA.

## *Complex Adaptive System Theory*

A complex adaptive system is defined as a "system composed of interacting agents described by rules" (Holland 1995). CAS theory regards the members who constitute the system as the agents with active and adaptive behavior (Nan 2011). Many scholars have applied the concepts of CAS to IS research (Benbya et al. 2020), including IT-enabled organizational learning (Kane and Alavi 2007), IT-supported team or organizational process (Canessa and Riolo 2006; Curşeu 2006), IT use and IT-based work performance (Nan 2011), software reuse (Vial 2023) and information systems architecture (Haki et al. 2020).

After more than two decades of application, three core elements in CAS have been recognized: agents, interactions, and environment. These three basic components of a CAS collaboratively create observations at the macroscopic level (Nan 2011). CAS allows researchers to capture the interactions between agents and their relationships with the environment, and to analyze their influence on macroscopic observations.

Agents are the basic entities of action in a CAS. Each agent is described by attributes and behavioral rules. Attributes can be fixed (such as gender) or modified over time (such as age) (Epstein and Axtell 1996), and it is an important determinant of agents' behavioral rules. Behavioral rules are the schemata managing an agent's actions, which can be considered as a set of input/output statements (Holland 1995). Through interaction with the environment and other agents, the focal agent constantly learns and accumulates experiences to maintain or change the attributes or behavioral rules. Interactions refer to the mutually adaptive behaviors of agents in a CAS (Drazin and Sandelands 1992), which can be elaborated by connections and flow. Connections are relational links among agents that occur whenever interactions take place. Due to the limitations of their own attributes and behavioral rules, agents may choose different other agents for the connection. Flow refers to the movement of resources through the web of agents and connections, such as goods, knowledge, or information. Environment is the medium through which agents operate and interact (Epstein and Axtell 1996). It provides conditions for actions and interactions to unfold.

## *Extending CAS Theory to BITA Context*

Scholars have suggested that BITA shows the characteristics of CAS (Vessey and Ward 2013; Zhang et al. 2021; Zhou et al. 2018), indicating its applicability in exploring BITA. The CAS model of BITA is premised on its dynamic and interactive feature, and it was developed to provide a theoretical lens to examine and observe the macroscopic emergence process in which behaviors of agents collaboratively create BITA patterns and outcomes. Karahanna and Preston (2013) contended that the social capital of the relationship between the business manager and the IT manager is a key determinant of IS strategic alignment. Through frequent interaction, business and IT managers will share a common language and terminology, and they can better envision how IT can enable business strategy and can align the organization's IT and business strategies to achieve desired organizational goals (Preston et al. 2008).

Thus, based on the existing research, this paper applies CAS theory to BITA, focuses on human actors (e.g., business and IT managers), business strategy and structure, IT strategy and structure, as well as the environment, and constructs a BITA coevolution model based on CAS. As shown in Table 1, the emergence process of BITA was conceptualized as a CAS by mapping the concepts of BITA to the basic elements of CAS.

Figure 1 shows the established BITA coevolution model from the perspective of CAS. Based on the definition of CAS, the agents in this model include two types of actors, business manager and IT manager. They are responsible for deciding the strategies and structures. In addition, their cognitive capability, management levels, and mutual communication play a critical role in deciding the outcome of BITA. Specifically, business and IT managers select and adjust business strategies and structures, IT strategies and structures based on their cognitive capabilities and certain behavioral rules. In addition, considering the differences in cognitive capabilities, we assume that the higher the cognitive capabilities of business and IT managers are, the stronger their ability to adapt to environmental dynamism will be. Therefore, these two types of managers can effectively adjust strategies and structures in a timely manner to maintain a perfect BITA.

| CAS | BITA | Description |
|---|---|---|
| **Agent** | Business personnel | Actors in business management, such as business manager |
| | IT personnel | Actors in IT management, such as the IT manager |
| ● Attribute | Individual differences | The internal states of human actors, such as cognitive capability |
| ● Behavioral rules | Inner activity | Individual cognitive and emotion activities such as the choosing of strategies and structures |
| **Interaction** | Interpersonal interactions | The mutually adaptive behaviors between business and IT personnel |
| ● Connection | Business and IT personnel interactions | The mutually connection between business and IT personnel |
| ● Flow | Movements of resources | The movement of information, knowledge, beliefs among agents |
| **Environment** | Environment | The social organizational contexts |
| ● Structure | Structure | The place provided for organization to operate and interact |
| ● Market | Competition/ Innovation | The adjustment of business strategy to respond to the competitive markets |

**Table 1. Mapping Between CAS and BITA Concepts**

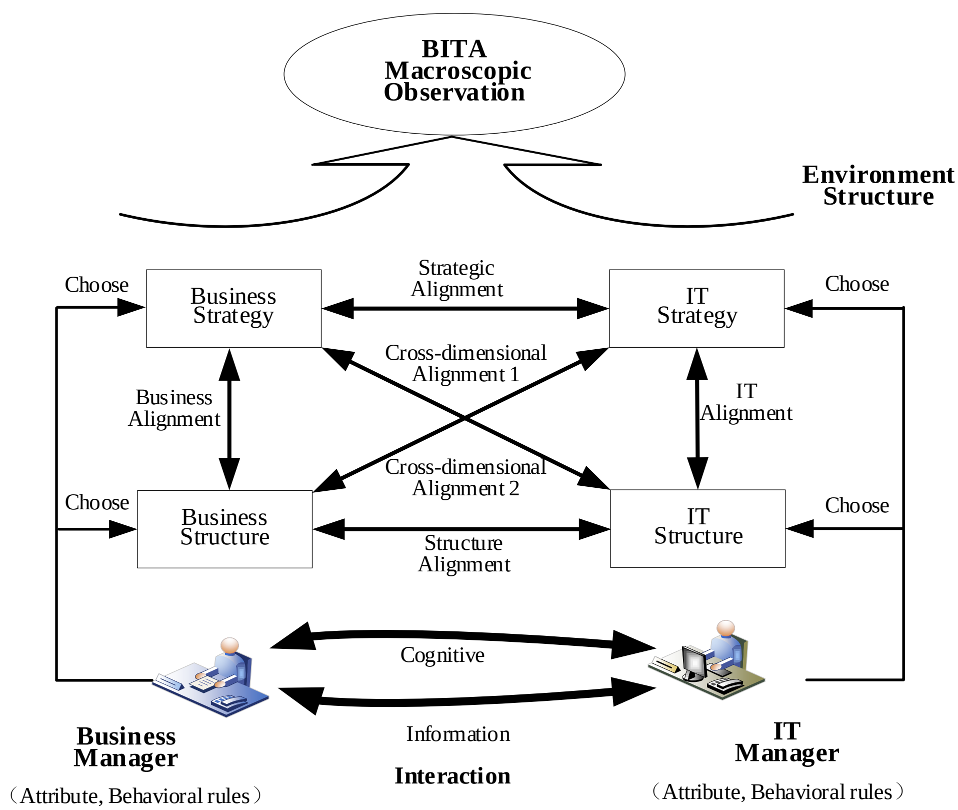


**Figure 1. BITA Coevolution Model based on CAS**

The mutual adaptive behavior among agents is called interaction. In this dynamic evolutionary process, mutual adaptation behavior refers to the interaction and communication between business and IT managers, which is an important determinant of BITA patterns and outcomes. However, we still have little understanding of the role of interaction among managers in the BITA coevolutionary process. Thus, by describing interactions via the concepts of connections and flows, we can specify how interactions arise from factors such as attributes, behavioral rules, relationships, and resource movements, and explore their effects on BITA. We assume that the higher the degree of communication between the business manager and the IT manager, the higher the possibility of realizing a high degree of BITA.

The environment has long been recognized as a critical factor in shaping the degree and outcomes of BITA in the IS literature (Chan et al. 2006; Sabherwal et al. 2001). In this CAS model, the concept of environment can be modeled as an element of the social or organizational contexts. These contexts form a medium for agents to interact with and act on. Environment dynamism refers to market dynamics. To obtain competitive advantages, organizations need to adjust their strategies to respond to market changes. Although previous studies have explored the relationship between the environment and the BITA revolution (Sabherwal et al. 2001; Wang et al. 2011), there is no precise description of the mechanisms behind these relationships. In the CAS model, the structure of the environment is intrinsically linked to the evolution of BITA, which allows researchers to analyze in detail how the structure of the environment changes the behavior and interaction of agents. In our model, environment (e.g., markets) will influence the formulation of business strategy and IT strategy. For the sake of simplifying the model, this paper mainly explores the dynamic change in business strategy brought about by environmental change, leading business manager and IT manager to respond to these changes and then adjust the relevant strategies and structures. As we mentioned above, the attributes of the four BITA dimensions constitute the adjustment sets (as shown in Table 2), and different values (shown in the parentheses in Table 2) of different dimensions will bring about various dynamic macroscopic emergence of BITA.

| | **Choose dimensions** | **Adjustment attributes** | | |
|---|---|---|---|---|
| **Business managers** | Business strategy | Defender (1) | Analyzer (2) | Prospector (3) |
| | Business structure | Centralized (1) | Organic (2) | Decentralized (3) |
| **IT managers** | IT strategy | Efficient (1) | Comprehensive (2) | Flexible (3) |
| | IT structure | Centralized (1) | Shared (2) | Decentralized (3) |

**Table 2. Adjustment attributes of four Dimensions**

The research logic and ideas of this paper are as follows, business manager and IT manager choose the corresponding strategies and structures based on their cognitive capability. When external environment changes lead to the adjustment of business strategy, agents interact with other agents or with the environment, exhibit self-organization behavior, respond to the external turbulence and make some adjustments to the business and IT strategies and structures. Ultimately, the macroscopic emergence will be shaped. This emergence here refers to the degree of BITA, which can be calculated by averaging the six different types of alignment (Sabherwal et al. 2001; Wang et al. 2011). Through the analysis of relevant results, our purpose is to explore the unintended and unforeseeable results of the behavioral rules and interactions of the agents and to reveal the dynamic emergence mechanisms and evolution rules of BITA.

## The Agent-based Modeling of BITA

### *Agent-based Modeling*

In CAS research, agent-based modeling is a computational simulation tool that has been widely adopted (Epstein and Axtell 1996; Nan 2011; Nan and Tanriverdi 2017; Ross et al. 2019). Consistent with the concepts of CAS, an agent-based modeling encompasses three key elements, agents, interactions, and environment. The core idea of agent-based modeling is to allow individual actors (e.g., agents) to interact with others and the environment according to certain rules and to observe the macroscopic structures emerging from these interactions (Amaral and Uzzi 2007). All of these reflect this principle, adaptation creates complexity (Holland 1995). Apart from Schelling's (1969) segregation model, agent-based modeling has been applied to many social science domains such as organizational design (Rivkin and Siggelkow 2003) and firm performance (Canessa and Riolo 2006).

Although agent-based modeling involves simulation, it is not intended to provide a real-world accurate calculation version (Axelrod 1997). Instead, its goal is to operate the CAS model with as simple calculation parameters and algorithms as possible, which will enable researchers to gain insight into the real world by observing the result generated by these simple algorithms. Currently, most scholars apply object-oriented programming (OOP) language (e.g., C++, JAVA) to operate agent-based models, and used computer codes to represent the interaction between the agents and the environment. These advanced programming technologies provide a natural scheme for representing agents and their interactions in a CAS. The process of codifying a CAS model involves: (1) specifying the computational parameters and algorithms reflecting this model, and (2) building the agent-based modeling with an appropriate programming tool.

Using modern computing technologies to operationalize agent-based modeling can offer several analytical advantages for exploring the emergence process of BITA. First, computer programming uses codes to capture the dynamic relationships between the two types of managers and organizational strategies or structures, which are difficult to describe verbally, thereby providing researchers with accurate measurements and operations on key variables. Second, computer programming allows researchers to easily and flexibly control the simulation model, visualize the emerging process, observe the patterns and outcomes of BITA in real-time, and collect data on the attributes or behaviors of agents in the model at any point in time (Harrison et al. 2007).

## *Model Design of BITA Coevolutionary Process*

According to the CAS model of BITA dynamic evolution process, the agent-based model shown in Figure 2 is constructed. The details of this model are explained in Table 3. A business manager's cognitive capability is signified by a probability $p_1 \in [0,1]$, indicating the business manager's likelihood of adjusting the business strategy and structure. The behavioral rules for business managers' adjusting of the business strategy and structure are implemented as an IF/THEN statement (depicted as arrow "a" in Figure 2): if in a simulation process, the business structure is different from the business strategy, then the business structure is changed to the value of the business strategy depends on the business manager's cognition capability.

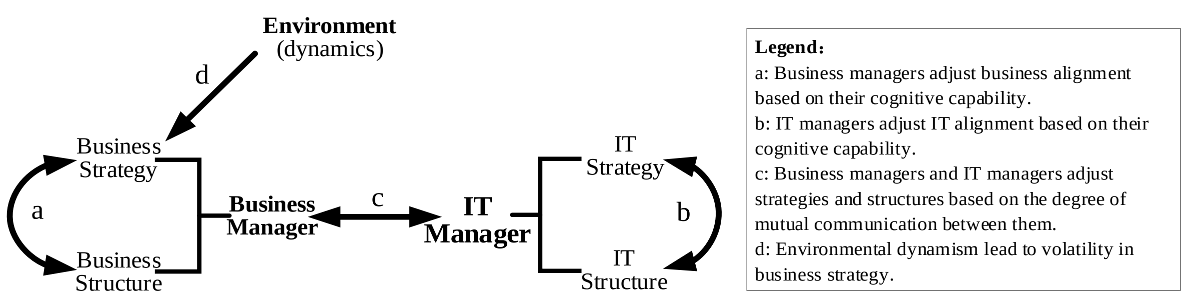


**Figure 2. The Design of Agent-based Model**

Similarly, the IT manager's cognitive capability is signified by a probability $p_2 \in [0,1]$, indicating the IT manager's likelihood of adjusting the IT strategy and structure induced by his cognition capability or via interactions with the business manager. The behavioral rule for IT manager (depicted as arrow "b" in Figure 2) is implemented in this way: if IT structure is different from IT strategy, then IT structure changes to the value of IT strategy depending on IT manager's cognition capability; if IT strategy is different from business strategy, then IT strategy changes to the value of the business strategy depend not only on the IT manager's cognitive capability but also on their mutual communication. The mutual communication between business manager and IT manager is signified by a probability $p_3$. The value of $p_3$ varies from 0 to 1 (depicted as arrow "c" in Figure 2). The higher the $p_3$ is, the more frequently they communicate and interact with each other, and then they are more likely to achieve a perfect alignment.

The degree of environmental dynamism is signified by a probability p. The value of p varies between 0 and 1, indicating the business strategy's likelihood of adjustment (depicted as arrow "d" in Figure 2). For example, when p is lower, then the environment in which the organization operates is stable and business strategy is unlike to change. However, an organization's business strategy can be variable in the case of a higher p, and then the degree of BITA may be turbulent.

The macroscopic observation of the BITA coevolutionary process is the degree of BITA. As described above, the BITA is a combination of six different types of alignment: business alignment, structure alignment, strategy alignment, IT alignment, and two types of cross-dimensional alignments, representing the final alignment state of the organization. Sabherwal and Chan (2001) and Bergeron et al. (2004) put forward a criterion for measuring the degree of alignment between any two dimensions, which will be illustrated in combination with Table 2 as follows: if the value of the selected strategy or structure of the two dimensions in a type of alignment is equal, then the alignment degree is high; if the value differs by 1, then the alignment degree is middle; if the difference is 2, then the alignment degree is low. Therefore, there are three final alignment states based on these six different types of alignment, high, middle and low: if the quantity of high alignment of these six types of alignment is greater than the quantity of low alignment, then the overall BITA degree is high; if the quantity of high alignment is less than the quantity of low alignment, then the overall BITA degree is low; if they are equal, the overall BITA degree is middle. To quantifiably represent the degree, we make some changes based on this measurement, and map the degree of six different types of alignment to the number axis: 1 is used to indicate a high degree of alignment; 0.5 refers to the middle degree of alignment and 0 means a low degree of alignment. Thus, the final BITA degree is the average of these six different types of alignment.

| **Element** | **Conceptual definition** | **Computational representation** |
|---|---|---|
| **Business managers** | Business department manager | Business managers set business strategy and structure. Dynamic adjustments occur due to differences in cognitive capability and communication and environmental turbulence. |
| Individual Differences | Cognitive capability | Cognitive capability of business manager is represented by $p_1$ (0-1), indicating the likelihood for business managers to change the business strategy and structure. |
| Behavior activities | Adjusting the business strategy and structure | If business strategy and structure at a certain moment isn't a high alignment state, then the possibility of business manager adjusting the alignment in time is $p_1$. The greater this value, the better the final alignment degree. |
| **IT managers** | IT department manager | IT managers set IT strategy and structure. Dynamic adjustments occur due to differences in cognitive capability and communication and environmental turbulence. |
| Individual Differences | Cognitive capability | Cognitive capability of IT manager is represented by $p_2$ (0-1), indicating the likelihood for IT managers to adjust the IT strategy and structure. |
| Behavior activities | Adjusting the IT strategy and structure | If IT strategy and structure at a certain moment isn't a high alignment state, then the possibility of IT manager adjusting the alignment in time is $p_2$. The greater this value, the better the final alignment. |
| **Interpersonal interactions** | Mutual communication between business manager and IT manager | $p_3$ (0-1) represents the degree of mutual communication between business manager and IT manager. The greater the value is, the higher the degree of mutual communication is, and thus the managers can respond to environmental dynamism and make effective adjustments timely. |
| **Environment** | Environmental dynamism | Environmental dynamism is represented by p (0-1). The higher the value is, the higher the environmental turbulence is. Here, it refers to the dynamic change of business strategy. |
| **Macroscopic level** | BITA degree | The overall BITA degree is calculated according to the degree of six different types of alignment. |

**Table 3. Summary of the Agent-based Model Design**

Finally, the agent-based modeling of the BITA coevolution process was implemented using the NetLogo programming tool (Wilensky U 1999), which is especially suitable for building dynamic evolution models of complex systems.

## *Simulation Experimentation Design*

Based on the defined simulation parameters and the grammar rules of NetLogo, the BITA dynamic coevolution simulation flow chart is established as shown in Figure 3. Each simulation cycle consists of six steps: the first step is the initial phase, defining and initializing parameters. The second, third, and fourth steps sequentially perform algorithmic procedures of cognitive capability, mutual communication, and environmental dynamism to adjust the determined business and IT strategies and structures to achieve a better BITA outcome. The fifth step calculates the degree of BITA. Finally, this simulation process is over, and the next simulation process will start from Step 2.

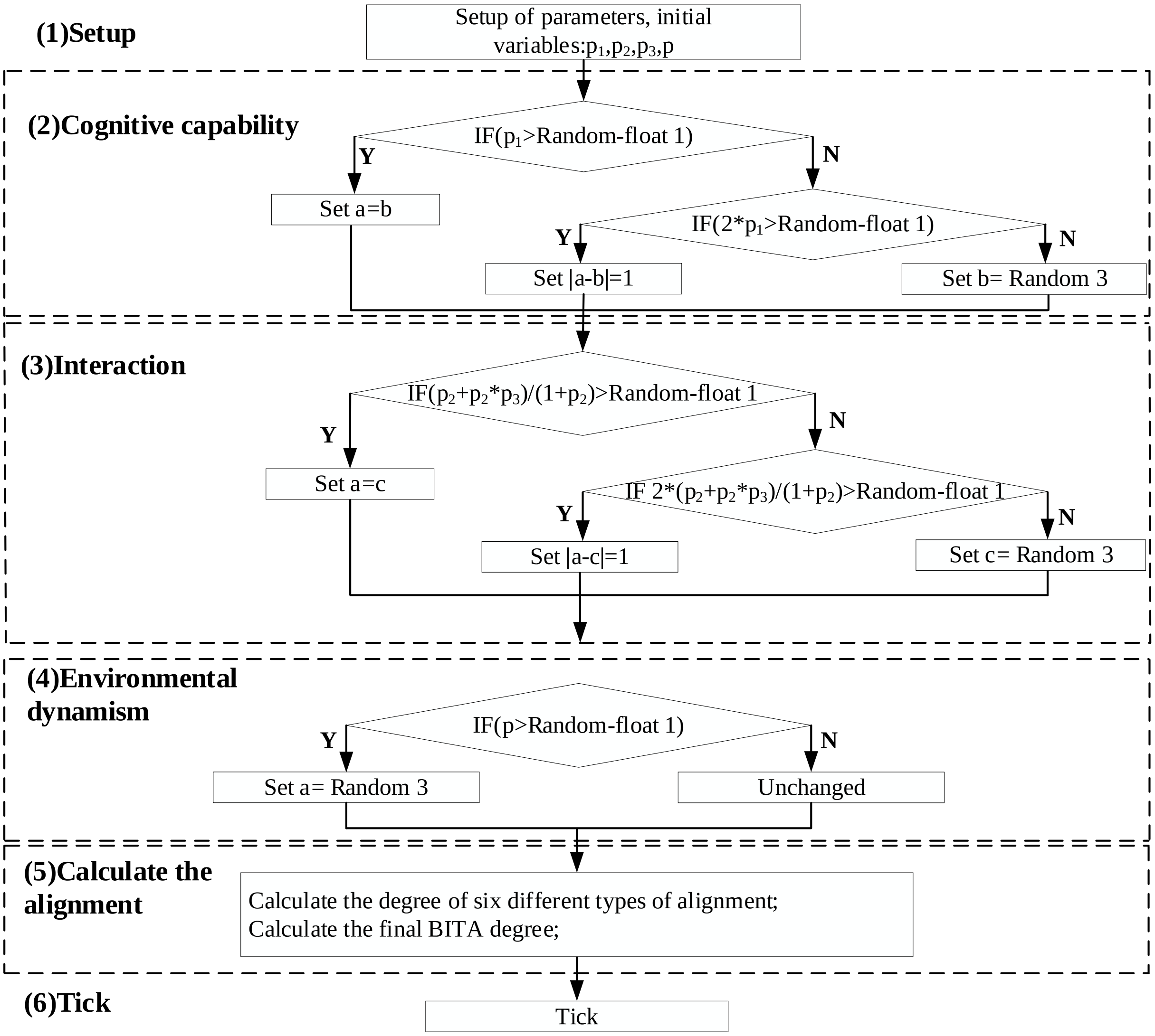


**Figure 3. Simulation Flow Chart**

To comprehensively reveal the influence of the agent's cognitive capability, inter-agent mutual communication and environmental dynamism on the degree of BITA, we conduct three experiments as shown in Table 4. Each simulation experiment was performed 300 times, and each time running 50 ticks (300*50). Once a simulation session terminated at the $50^{th}$ tick, the degree of each type of alignment, as well as the final BITA, was measured and obtained.

| Experiment | Treatment |
|---|---|
| Cognitive capability (arrow a, b) | Varying the cognitive capability $p_1$ and $p_2$ from 0.1 to 0.9 using 0.4 increments |
| Mutual communication degree (arrow c) | Varying the mutual communication degree $p_3$ from 0.1 to 0.9 using 0.4 increments |
| Environmental dynamism (arrow d) | Varying the environmental dynamism p from 0.1 to 0.9 using 0.4 increments |

**Table 4. Simulation Experiment Treatment**

In addition, to illustrate these effects graphically, we did the following work: by combining different levels of cognitive capability and mutual communication degree, this paper calculated the degree of BITA under three different environmental dynamism levels (i.e., p=0.1, 0.5, 0.9). Through constructing the fitness landscape, we can more visually describe the macroscopic emergence and dynamic evolution of BITA.

## Simulation Findings

### *Fitness Landscape of BITA*

To generate the adaptive map, we construct a coordinate system with cognitive capability and mutual communication as the two axes. We took 10 points on both axes, ranging from 0.1 to 1 and thus obtained 100 pairs of points. The degree of BITA was calculated for each pair of points in the coordinate system to create a three-dimensional evolution map. We then created three maps according to three levels of environmental dynamism, namely, low (Figure 4), medium (Figure 5), and high (Figure 6). In addition, to quantitatively describe the dynamic evolution process of BITA, we selected the simulation process corresponding to the five combination points of (0.1, 0.1), (0.1, 0.5), (0.1, 0.9), (0.5, 0.5), and (0.9, 0.9). Then we analyzed the changes in BITA degrees for the 50 simulation ticks in each process, and the relevant descriptive statistical results were shown in Table 5.

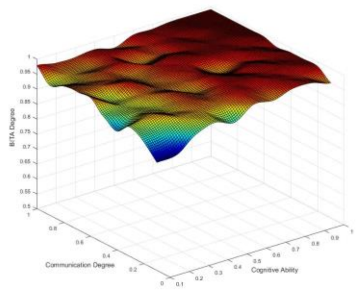


**Figure 4. BITA Degree under Low Environmental Dynamism**

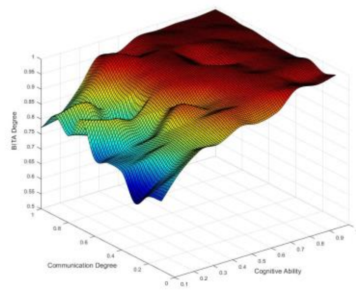


**Figure 5. BITA Degree under Medium Environmental Dynamism**

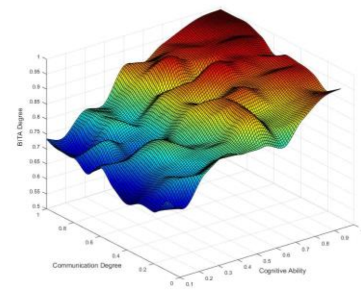


**Figure 6. BITA Degree under High Environmental Dynamism**

| Different Combinations | Environmental dynamism | MAX of BITA degree | MIN of BITA degree | VAR of BITA degree |
|---|---|---|---|---|
| (0.1, 0.1) | Low | 1 | 0.333 | 0.052 |
| | Middle | 1 | 0.333 | 0.054 |
| | High | 1 | 0.333 | 0.061 |
| (0.1, 0.5) | Low | 1 | 0.333 | 0.036 |
| | Middle | 1 | 0.333 | 0.042 |
| | High | 1 | 0.333 | 0.051 |
| (0.1, 0.9) | Low | 1 | 0.333 | 0.026 |
| | Middle | 1 | 0.417 | 0.038 |
| | High | 1 | 0.333 | 0.051 |
| (0.5, 0.5) | Low | 1 | 0.5 | 0.011 |
| | Middle | 1 | 0.5 | 0.013 |
| | High | 1 | 0.5 | 0.032 |
| (0.5, 0.9) | Low | 1 | 0.5 | 0.08 |
| | Middle | 1 | 0.5 | 0.015 |
| | High | 1 | 0.5 | 0.029 |
| (0.9, 0.9) | Low | 1 | 0.5 | 0.005 |
| | Middle | 1 | 0.5 | 0.006 |
| | High | 1 | 0.5 | 0.007 |

**Table 5. Statistical Analysis of Simulation Results under Different Combinations**

It was shown that, overall, these three maps all displayed a rising slope trend, which indicated that no matter how dynamic the environment changes, with the degree of cognitive capability and mutual communication increase, the overall BITA degree would be significantly improved. Then we anatomized these three maps separately and found some differences. When the dynamism of the environment was low, the current business strategy was relatively stable, and the internal and external challenges faced by the organization were relatively small. Therefore, it was no need to over-demand the cognitive capability of managers as well as their mutual information exchange to obtain a better BITA state.

However, in the context of high environmental dynamism, as can be seen in Table 5, the variance of BITA degree was always greater than the situation of moderate or low environmental dynamism, regardless of the selected points. It can also be seen from Figure 5 and Figure 6 that, compared with Figure 4, the degree of fluctuation is intensified, and the higher the environmental dynamism, the greater the volatility of the map. This further confirmed that when the environment was more dynamic, firms needed to adjust their strategies or structures in almost real-time to find a better alignment, thus the adaptive map was rugged. In addition, in the latter two figures, it was difficult for firms to achieve the best alignment state, only when both the business and IT manager's cognitive capability and the degree of their mutual communication were high. In turn, when the degree of managers' cognitive capabilities and their mutual communication were high, regardless of the dynamics of the environment, firms could always find the best alignment degree. These conclusions help us further verify the internal validity of the BITA coevolutionary model.

## *Impacts of Cognitive Capability, Mutual Communication and Environmental Dynamics on BITA Degree*

(1) Managers with high cognitive capabilities can achieve a better BITA.

Figure 7 shows the influence of different cognitive capabilities ($p_1$=$p_2$=0.1/0.5/0.9) on BITA degree ($p_3$=1, p=1). The result indicated that as the degrees of managers' cognitive capabilities increase, a more perfect BITA degree can be achieved in a shorter run. High-cognitive managers could adjust BITA in time to quickly "emerge" with a consistently high degree of BITA. However, managers with low cognitive capabilities were unable to make timely adjustments to the current alignment, resulting in a sustained low degree of alignment and frequent turbulence, and finally, organizations' BITA degree reach a "bottleneck" state. Under this circumstance, if organizations want to achieve a better BITA, it is important and necessary to improve the cognitive capabilities of managers.

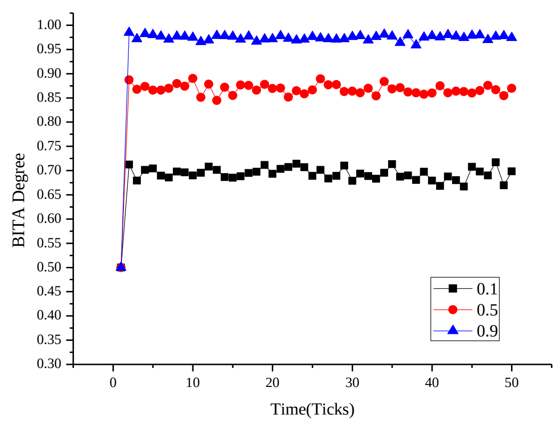


**Figure 7. BITA Degree with Varying Managers' Cognitive Capabilities**

To further validate the effectiveness of the influence of cognitive capability on BITA, we conducted the *t-test* between pairs of the simulation results under different degrees of cognitive capabilities. It was found that the BITA degree for different cognitive capability situations (i.e., Low-Middle, Low-High and Middle-High) is significantly different, and all the P values are less than 0.001. These results further indicated that managers with higher cognitive capabilities tend to achieve a higher degree of BITA.

(2) Mutual communication has different effects on BITA degree under different situations of managers' cognitive capabilities.

As shown in Figure 8 ($p_1$=$p_2$=0.1, p=1, $p_3$=0.1/0.5/0.9), this is the case when both business manager and IT manager were low-cognitive, indicating that they had few management experiences and could not deal with basic business and IT needs. Results showed that, in this context, mutual communication had no different influence on BITA. The final degree of BITA was hovering around 0.7. In addition, the *t-test* results showed that there was no significant difference in the degree of BITA under different degrees of mutual communication, and the P values of pair test results were 0.792, 0.783 and 0.574 (i.e., Low-Middle, Low-High and Middle-High), respectively.

However, when the cognitive capabilities of business and IT manager were high, we could see from Figure 9 ($p_1$=$p_2$=1, p=1, $p_3$=0.1/0.5/0.9) that, with the degree of mutual communication increase, in this context, business and IT manager can adjust business strategy, business structure, IT strategy and IT structure in time, so as to achieve a high degree of BITA. Also, the *t-test* results showed that the influence of different communication degrees on the BITA degree is significantly different, all the P values were less than 0.001.

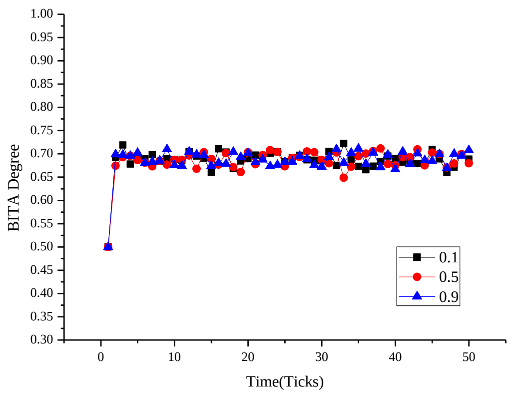


**Figure 8. BITA Degree with Varying Mutual Communication Degree (Both Business and IT Managers are Low Cognitive Capabilities)**

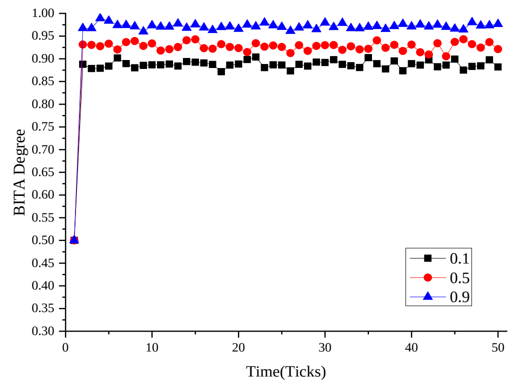


**Figure 9. BITA Degree with Varying Mutual Communication Degree (Both Business and IT Managers are High Cognitive Capabilities)**

(3) Mutual communication can offset the cognitive gap and deficiency of managers, and the higher the degree of mutual communication, the better the alignment.

Figure 10 ($p_1$=0.1, $p_2$=0.9, p=1, $p_3$=0.1/0.5/0.9) showed the influence of mutual communication between business manager and IT manager on BITA, and it was on the situation that the business manager's cognitive capability was low, the IT manager's cognitive capability was high and the environment was highly dynamic. The results showed that with the increase of mutual communication, the degree of BITA would also increase, which indicated that the mutual communication between business manager and IT manager would offset their cognitive gap and deficiency. Through mutual interaction, managers could learn from each other to form a higher degree of BITA. In addition, the *t-test* results showed that the influence of different degrees of mutual communication on the BITA is significantly different, all the P values were less than 0.001.

Similarly, Figure 11 ($p_1$=0.9, $p_2$=0.1, p=1, $p_3$=0.1/0.5/0.9) showed the effects of mutual communication when the business manager's cognitive capability was high, the IT manager's cognitive capability was low and the environment was highly dynamic. The results showed that with the increase of mutual communication, the degree of BITA increased slightly, which also validated the results obtained from Figure 10. The *t-test* results further showed that there were significant differences in the degree of BITA under different degrees of mutual communication between business manager and IT manager.

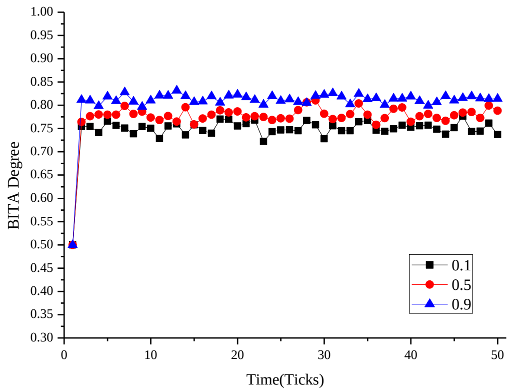


**Figure 10. BITA Degree with Varying Mutual Communication Degree (Business Managers are Low Cognition, IT Managers are High Cognition)**

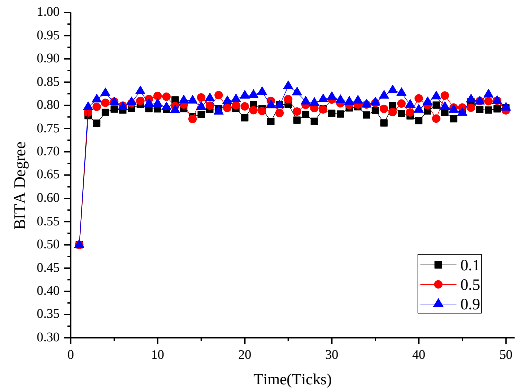


**Figure 11. BITA Degree with Varying Mutual Communication Degree (Business Managers are High Cognition, IT Managers are Low Cognition)**

(4) The influence of environmental dynamism on BITA was more significant when both business and IT managers are low cognition, and the higher the degree of environmental dynamism, the greater the volatility of BITA.

As shown in Figure 12 ($p_1=p_2=0.1$, $p_3=1$, $p=0.1/0.5/0.9$), the cognitive capabilities of business manager and IT manager were low and the degree of their mutual communication was high. When the degree of environmental dynamism was low, business and IT managers could achieve a high degree of BITA through effective communication, even though this takes more time. However, when the degree of environmental dynamism was high, the business strategy was unstable. In this case, due to the limitations of cognitive capability and management experience, it is difficult for managers to maintain a stable and efficient BITA state even with a high degree of mutual communication, and thus the overall BITA coevolutionary process generated large fluctuations. However, when both the business manager and IT manager had high cognitive capabilities, as shown in Figure 13 ($p_1=p_2=1$, $p_3=1$, $p=0.1/0.5/0.9$), they could achieve and maintain a high degree of BITA quickly and efficiently in the context of low environmental dynamism. Even when the environment changes drastically, the overall coevolutionary process still showed a high degree of BITA with only slight turbulences.

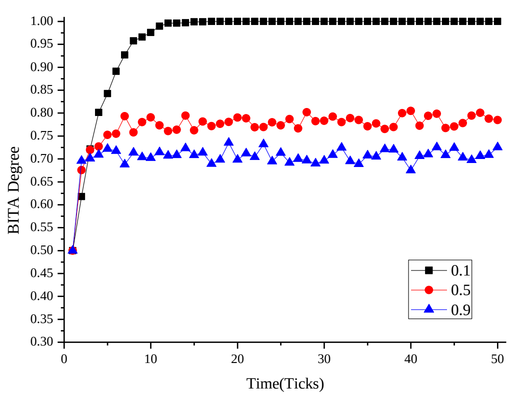


**Figure 12. BITA Degree with Varying Environmental Dynamism (Both Business and IT Managers are Low Cognitive Capabilities)**

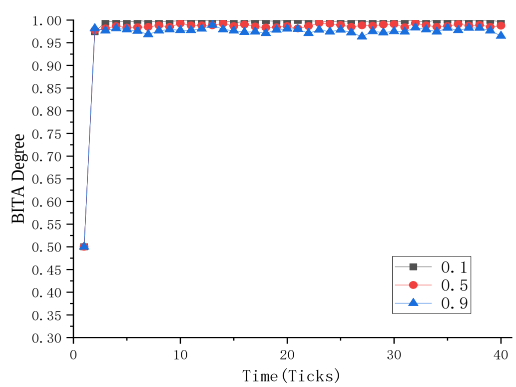


**Figure 13. BITA Degree with Varying Environmental Dynamism (Both Business and IT Managers are High Cognitive Capabilities)**

## Empirical Analysis Findings

To further validate the external validity of the simulation results (Dong 2022), we complement an empirical analysis with survey data from the Chinese shipbuilding industry. Confronted with the international financial crisis and the US-China trade war, the Chinese shipbuilding industry has experienced turbulent environmental changes (Hu et al. 2022; Liang et al. 2017). To thrive or even survive in this hypercompetitive environment, shipyards or other supporting firms sought to apply IT (e.g., ERP, cloud computing and Internet of things) to support business operations, explore new business models, and achieve the alignment between IT and business for competitive advantage. Thus, in the dynamic market environments, different organizations in this industry take various measures to obtain BITA suits our research context well.

Given that the purpose of our simulation model was to explore how the cognitive capabilities of business and IT managers and their mutual communication affect the dynamic coevolution of BITA under different levels of environmental dynamism, we construct a new research model of social alignment, systems of knowledge, environmental dynamism and strategic IT alignment, and examine the impacts of social alignment and systems of knowledge on strategic IT alignment and the moderating effects of environmental dynamism. To ensure reliability and validity, we draw on well-established scales in the existing literature for construct measurement (Karimi et al. 2004; Liang et al. 2017; Preston and Karahanna 2009).

Data analysis and model estimation are performed on a matched-pair survey of 429 survey data by using the structural equation model (SEM). The empirical analysis results show that social alignment positively affects strategic IT alignment, which validates our simulation findings that managers with a high level of knowledge and cognition can always achieve a high degree of BITA. Other results about the effects of mutual communication (i.e., systems of knowing) and environmental dynamism almost all support our simulation conclusions. Although we cannot fully reproduce the complex simulation contexts through an empirical model, these analysis findings can further validate the results obtained by the computer simulation model to some extent. For brevity, the details of measurement, model and SEM results are not provided in the text.

## Discussion

In today's dynamic environments, the established alignment between business and IT may no longer be suitable and firms need to construct or reconstruct their strategies or structures to meet new requirements. Thus, the dynamics of BITA have attracted scholars' attention and generated many profound insights (Sabherwal et al. 2001; Zhang et al. 2021).

However, a thorough literature review revealed that prior studies only construct the theoretical model of BITA's dynamics or analyze the influencing factors of its revolutionary changes through the case study, which are difficult to capture the complexity of BITA coevolution. In order to fill these gaps, this study considers BITA as a continuous coevolutionary and emerging process and focuses on the behaviors of business and IT managers. By applying CAS and ABM, we have developed a simulation model that examines how the cognitive capabilities of business and IT managers and their mutual communication affect the dynamic coevolution of BITA under different levels of environmental dynamism. Through conducting a series of simulation experiments, we finally come to several key findings.

First, managers with high cognitive capability can achieve a better degree of BITA. That is, no matter how dynamic the external environment changes, in the context of a high level of mutual communication, the improvement of managers' cognitive capabilities can enhance the efficiency and effectiveness of achieving a high degree of BITA. The three adaptive maps also confirm this conclusion.

Second, mutual communication between business and IT managers has different effects on the degree of BITA under different cognitive capabilities of managers. When both the business managers and IT managers are low cognitive capability, the improvement of mutual communication between them has no significant effect on the improvement of BITA. However, when the cognitive capabilities of business and IT managers are high, their mutual communication can increase the degree of BITA significantly.

Third, the mutual communication between business managers and IT managers can offset their cognitive gap and deficiency, and the higher the degree of mutual communication, the better the achieved alignment. Fourth, research on environmental dynamism finds that the influence of environmental dynamism on BITA was more significant when both business and IT managers are low cognition, and the higher the environmental dynamism, the greater the volatility of the BITA coevolutionary process.

## *Theoretical Implications*

This paper makes three significant theoretical contributions to IS research. First, it extends the dynamics of BITA literature based on the CAS theory. Although the dynamics of BITA has attracted scholars' attention (Benbya and Mckelvey 2006; Chan and Reich 2007), most of the prior research uses cases to analyze the influencing factors of BITA's revolutionary changes (Sabherwal et al. 2001; Wang et al. 2011), which has limited generalizability and cannot fully capture the complex and coevolutionary characteristics of BITA. In addition, existing studies have also recognized that BITA exhibits the characteristics of CAS (Vessey and Ward 2013; Zhou et al. 2018), that is, business strategies and structures, IT strategies and structures, as well as decision-makers (e.g., business and IT managers), should be aligned with each other to achieve a state of harmony. Thus, based on CAS theory, this paper applies agent-based modeling and computer simulation and maps the coevolutionary process of BITA into three key elements of a CAS, agents, interaction and environment. By constructing a coevolution model of business and IT managers and business and IT strategies and structures, our study offers some novel insights into the dynamics of BITA.

Second, this paper focuses on the effects of business and IT managers' cognition and behaviors on the coevolution of the strategic level of BITA. Prior research has long explored the behaviors and explained the effects of employees and executives on the dynamics of IT alignment (Wang et al. 2011), however, we still have a limited understanding of the effects of cognitive capabilities of business and IT managers and their mutual communication and external environmental dynamism on the dynamic coevolution of the *strategic-level* (*versus the social-level*) BITA (Zhang et al. 2021). With the application of agent-based modeling, simulation results show that managers with high-cognition capabilities can achieve a better degree of BITA, and effective mutual communication can offset their cognitive gap and deficiency. In addition, the environment increases the fluctuation of the BITA coevolutionary process. By integrating human actors and strategy artifacts, this paper further enriches the understanding of the effects of managers' behaviors on the dynamic evolution of business and IT strategies and structures.

Third, this paper also makes a methodological contribution by applying the CAS theory and agent-based modeling and proposing a simulation framework to quantitatively investigate the dynamics of BITA involving human actors, strategies and structures. In addition, this paper further expands the application field of NetLogo and provides some references for future research.

## *Practical Implications*

Our study offers three suggestions for practice. First, business managers and IT managers should improve their cognitive capabilities and management experience as much as possible. Managers with high cognitive ability tend to make the right adjustments to achieve a better degree of BITA. Second, effective mutual communication between business managers and IT managers can also offset their cognitive gap and deficiency and improve the BITA. The business and IT departments within the organization should thus provide a good communication and cooperation channel, and use emerging IT such as E-mail, video conference and web conferences to break the traditional communication manner, thus promoting the rapid emergence of overall alignment between business and IT. Third, external environmental dynamism exacerbates the fluctuations in the overall alignment process. Organizations should actively respond to the environmental dynamism, make timely adjustments to strategies and structures, dare to innovate and reform, and most importantly, improve business and IT managers' cognitive capabilities and enhance their mutual communication, thereby obtaining a perfect BITA.

## *Limitations and Future Research Directions*

There are several limitations in our research. First, our BITA dynamic coevolution model only considered the effects of the cognitive capability of business managers and IT managers, their mutual communication and environmental dynamism on BITA. In the follow-up study, other attributes of the agents and the influence of different organizational contexts (e.g., organizational size, organizational culture, and strategic orientation) on alignment should also be considered to reveal the emergence process of BITA more comprehensively and clearly. Second, our CAS model of BITA should also further consider some outcome measures, such as performance, organizational agility or cost, so as to conduct a comprehensive study of IT alignment.

## Conclusion

In this study, arguing that our theoretical understanding of the dynamic coevolutionary and emergence of BITA remains limited, a complex adaptive system model of BITA is thus constructed. Through the lens of the CAS, this paper carried out a series of simulation experiments based on ABM. First, we drew the adaptive maps of the effects of the cognitive capabilities of business and IT managers and their mutual communication on BITA under three types of environmental dynamism, which allowed us to understand the evolutionary trends and mechanisms of BITA intuitively and clearly. Second, we analyzed the impacts of these three factors (cognitive capability, mutual communication and environmental dynamism) on BITA under different contexts, filling the gaps in the literature about the limited understanding of the relationship between individual actors and the coevolution of business and IT strategies and structures. Complemented with an empirical analysis of the survey data from the Chinese shipbuilding industry, the external validity of the simulation results is further strengthened. Our findings can not only help practitioners better understand the role of cognitive capabilities and communication in achieving and maintaining BITA under different levels of environmental dynamism, leading to improved organizational performance, but also help organizations develop more effective strategies and tactics for better alignment between their business and IT goals, leading to improved competitiveness and long-term success. In addition, we believe that the CAS analytical framework, which focuses on the interactions between the elements and the environment, can be applied to many other IS research communities and achieve more novel results and breakthroughs.

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