

Leveraging Open-standard Interorganizational Information Systems for Process Adaptability and Alignment: An Empirical Analysis

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Leveraging Open-standard Interorganizational Information Systems for Process Adaptability and Alignment: An Empirical Analysis

Abstract

Purpose: This study aims to understand the value creation mechanisms of open-standard inter-organizational information systems (OSIOS), which is a key technology to achieve Industry 4.0. Specifically, this study investigates how the internal assimilation and external diffusion of OSIOS help manufactures facilitate process adaptability and alignment in supply chain network.

Design/methodology/approach: A survey instrument was designed and administrated to collect data for this research. Using three-stage least squares (3SLS) estimation, we empirically tested a number of hypothesized relationships based on a sample of 308 manufacturing firms in China.

Findings: Our results show that OSIOS can perform as value creation mechanisms to enable process adaptability and alignment. In addition, the impact of OSIOS internal assimilation is inversely U-shaped where the positive effect on process adaptability will become negative after an extremum point is reached.

Originality/value: This study makes a contribution in terms of providing insights on how OSIOS can generate relational outcomes and thus to promote the achievement of industry 4.0. By revealing a U-shaped relationship between OSIOS assimilation and process adaptability, this study fills previous research gap by advancing the understanding on the value creation mechanisms of information systems implementation.

Keywords: inter-organizational information systems, open standards, Industry 4.0, supply chain integration, process adaptability

1 Introduction

The rapid growth and development in digital have provided great opportunities to evolve traditional businesses and industries. While most of the attention has been paid on the transformation of the digital economy, many of these advanced technologies are also re-shaping the traditional manufacturers. Driven by the aforementioned new technologies, many have viewed the next phase of industry development to have higher levels of operational efficiency and productivity due to supply chain integration and automation (Lu, 2017). This new phase of industry development is coined as Industry 4.0, and is characterized by 1) digitization, optimization and production customization, 2) automation and adaptation, 3) human machine interaction, 4) value-added services and businesses, and 5) autonomous data exchange and communication (Posada *et al.*, 2015; Roblek *et al.*, 2016).

Industry 4.0 is aimed at addressing the traditional manufacturers' supply chain deficiencies that have resulted in high costs and poor product and service quality. One of the fundamental keys to achieve Industry 4.0 is the interoperability and transparency of data which enables manufacturers to achieve supply chain integration (both horizontal and vertical), share and exchange data effectively and efficiently, and enable autonomous supply chains and smart factories (Lasi *et al.*, 2014). Despite the recent advent in computing

and in particular internet technologies, achieving Industry 4.0 is still some way off because of reported challenges faced by manufacturers (Gold, 2018). Notable among these challenges is the ability for manufacturers to implement the concept of a “virtual single factory” that vertically integrates supply chain partners’ systems to share information with each other (Kobusch, 2015). Open-standard inter-organizational information systems (OSIOS) have the ability to resolve these challenges and help manufacturers transform the concept of virtual single factory into reality (Sodero *et al.*, 2013). OSIOS refers to the kind of inter-organizational systems that use open standards which are the technical specifications to support, automate and coordinate the “interrelated, sequential tasks” such as inventory management, product development, and logistics (Bala and Venkatesh, 2007). These open standards are typically developed and approved by consortia of firms based on the negotiation, communication and coordination among the participants (Zhu *et al.*, 2006a), which are freely available for all potential adopters. Being used to create, sustain and develop inter-organizational relationships (Hagel and Brown, 2005), OSIOS provide the electronic enablement of extended enterprise which is a major source of relational assets and competitive advantages (Dyer, 1997; Dyer and Singh, 1998).

Despite the optimism about OSIOS in helping achieve Industry 4.0, the extent to which values are created from OSIOS remains a topic of intense debate. The slow, struggling process, or even the failures to capture value from OSIOS have long been a matter for concern by both scholars and practitioners (Saeed *et al.*, 2005; Rai *et al.*, 2006; Chang and Shaw, 2009). Given the maturity of related technology acceptance research about OSIOS, we argue that it is not a lack of understanding in the adoption factors hindering OSIOS implementation. Rather, it is important for manufacturers to understand the value creation mechanisms of OSIOS implementation to fully buy into its vision, and to collectively adopt OSIOS. The study of Malhotra *et al.* (2007) has provided rich insights into the value potential of OSIOS and suggested that the key value lies in the ability of OSIOS to enhance adaptability to manage extended enterprises (Malhotra *et al.*, 2007). In a volatile market environment, companies need to continually restructure their supply chain procedures, processes, activities, and inter-organizational relationships to adapt to external changes. The “plug-and-play” competency of OSIOS allows firms to exploit such process adaptability by reconfiguring their IT resources and business processes to react and adapt to market turbulence (Gosain *et al.*, 2004; Rai and Tang, 2010). Despite the merit of Malhotra *et al.* (2007) in unraveling the positive link between OSIOS deployment and adaptability, the assumption of a linear model might not adequately capture the complexity of leveraging OSIOS for supply chain collaboration. Although the use of IT can improve supply chain performance through enhancing collaboration (Croom, 2005), it might possibly erode a firm’s ability to make effective decisions and induce opportunisms in the supply chain when the level of collaboration reaches extremes, which suggests an existence of a possible inverted curvilinear relationship for future research to explore (Crosno and Dahlstrom, 2008; Villena *et al.*, 2011). However, most existing technology adoption studies have essentially used linear models that might oversimplify the underlying mechanism. Venkatesh and Goyal (2010) identify this research gap and call for future studies to propose and test more complex, nonlinear models to improve the understanding of technology adoption and deployment. Our study thus aims to reveal the nonlinear impact of OSIOS implementation by suggesting the possibility of an inverted U-shape relationship between OSIOS implementation and adaptability. When OSIOS is deployed to digitalize interfirm activities and relationships, it will contribute to process adaptability to a certain level, but beyond which a negative relationship will appear because system complexity and information redundancy become overwhelming for firms to manage and control, resulting in reduced process adaptability.

Even though process adaptability is important for supply chain operations, adaptability *per se* does not directly generate relational or operational value (Saraf *et al.*, 2007). Rather, supply chain partners attain relational value from developing relation-specific assets, knowledge exchange and joint learning (Dyer and Singh, 1998), which requires the alignment and integration of interfirm processes, i.e., process alignment. Therefore, we propose that process adaptability is an intermediate value creation mechanism through which OSIOS implementation enhances process alignment. Process adaptability can prevent existing business processes from being too rigid or even obsolete by dynamically adjusting and restructuring supply chain patterns (Gosain *et al.*, 2004; Malhotra *et al.*, 2007). Thus, companies can continually facilitate the coordination and joint optimization of activities with supply chain partners, making it possible to exploit process alignment. To gain a deep understanding of the value creation mechanism, it is important to test and establish the connection between process adaptability and process alignment.

Furthermore, OSIOS implementation requires a firm to make a strategic decision to determine how to assimilate OSIOS solutions internally across their supply chain activities and also, at the same time, diffuse them externally among the partners in the supply chain networks (Ranganathan *et al.*, 2004). In this study, we define *internal assimilation* as the extent to which OSIOS and related technological solutions have been deployed in the key supply chain activities to support inter-organizational relationships. *External diffusion* refers to the degree to which OSIOS and related technological solutions have been utilized to integrate supply chain partners and to conduct interfirm transactions (Ranganathan *et al.*, 2004; Zhang and Dhaliwal, 2009). After being adopted, a technology will be employed to support organizational routines and activities as well as the exchange of knowledge and technology across organizational boundaries. Internal assimilation and external diffusion, therefore, work together to contribute to the infusion stage of the overall diffusion process for a typical OSIOS technology (Premkumar *et al.*, 1994; Ramamurthy and Premkumar, 1995). This research therefore attempts to answer the following research question: *How can the internal assimilation and external diffusion of OSIOS create values for manufacturers in achieving process adaptability and process alignment?*

Our study contributes to extant literature on three fronts: 1) we extend previous studies conducted by scholars such as Gosain *et al.* (2004) and Malhotra *et al.* (2007) by showing that the relationship between OSIOS deployment and OSIOS enabled process adaptability followed an inverted U-shaped pattern; 2) by conceptualizing OSIOS implementation into internal assimilation and external diffusion, we enhance the knowledge about the post-adoption stages of OSIOS; 3) our research empirically confirms that OSIOS can enable companies to enjoy interfirm integration by developing adaptability to continually restructure supply chain processes and respond to external changes.

2 Research and Theoretical Background

2.1 Industry 4.0 and OSIOS

The 4th industrial revolution – Industry 4.0 – promotes changes in production systems and network through IT advancement beyond industrial automation, so as to achieve greater potentials and values in operations management (Lasi *et al.*, 2014). In this new paradigm shift, digitalization is the key, fundamental requirement and will be achieved through integrating internet technologies (incorporated with artificial intelligence, such as machine learning capability) and relevant objects (e.g., machines, products and humans)

with associated production processes (Marr, 2016).

In order to achieve digital transformation, Dallasega *et al.* (2018) pointed out that one of the four key issues is data standardization. One of the key technologies that can address data standardization issues is OSIOS. Successful OSIOS implementations can transform supply chain partners' way of doing businesses (Malhotra *et al.*, 2007; Sodero *et al.*, 2013). Supply chain partners can have better sharing of information while resulting in better collaborations, coordination, knowledge creations and assimilations (Sodero *et al.*, 2013). Similar to EDI, OSIOS enables the digital exchange of structured information between firms (Chong and Ooi, 2008). However, the key difference between EDI and OSIOS is that the latter defines the structure and content of e-exchanges based on a common agreed language. An example of this would be the RosettaNet, which was developed by an open standard consortium for the high-technology industry that creates, implements and promotes e-business process standards as well as data dictionary standards to describe products (Chong and Ooi, 2008). The quasi-open, multilateral nature of OSIOS makes it possible for 'many-to-many' communication while EDI allows only for a customized one-to-one exchange of information (Malhotra *et al.*, 2007). Extant research has been conducted to show how OSIOS can support exchanges of business processes between supply chain partners (Malhotra *et al.*, 2007; Pu *et al.*, 2018). From the view of Industry 4.0, OSIOS is an exemplary technology for enabling the modularized interoperability between supply chain partners (Bala and Venkatesh, 2007; Rai and Tang, 2010).

Compared to the advances achieved in comprehending the technical properties of OSIOS, there is much less progress being made in recognizing the wider implications of OSIOS implementation. Due to a paucity of studies on the applications of OSIOS, researchers have debated much on the extent to which value can be appropriated from OSIOS. There are researchers who on one hand regard OSIOS as the key technology that will pave the way for achieving Industry 4.0, centered on its ability to help supply chain network partners achieve automation and decentralization of business processes. On the other hand, there are also researchers who claim that it is too challenging to implement OSIOS as the current implementation roadmap and strategies are too simplistic (Damodaran, 2005), and the cost of investing in the technology bears little return on investment (Chang and Shaw, 2009; Sodero *et al.*, 2013). To address the preceding knowledge gap, our study attempts to shed light on the value creation mechanism of internal assimilation and external diffusion of OSIOS.

2.2 Internal Assimilation and External Diffusion of OSIOS

Because OSIOS are deployed to support a wide spectrum of internal supply chain functions and cross-boundary processes, it is important to consider internal assimilation and external diffusion at the same time to provide a complete delineation of its permeation process. After a technology is adopted and adapted, it will progressively be integrated into supply chain processes to support activities and knowledge transfers within and beyond organizational boundaries (Ranganathan *et al.*, 2004). While internal assimilation concerns the intensity and scale of OSIOS assimilation, external diffusion concerns the diversity and scope of OSIOS diffusion (Zhang *et al.*, 2016). These concepts can provide valuable insights about the post-adoption stages (Fichman, 2000), which have seldom been studied in current literature, as a majority of studies have focused on the single adoption stage, which essentially treated innovation diffusion process as a one-shot behavior (Zhu *et al.*, 2006b).

Internal assimilation refers to the extent to which the use of OSIOS permeates organizational processes and becomes routinized in the relevant activities (Chatterjee *et al.*, 2002; Ranganathan *et al.*, 2004). External diffusion refers to the extent to which OSIOS are used across organizational boundaries to integrate various trading partners (Ranganathan *et al.*, 2004; Wu and Chang, 2012). By aligning IT assets with internal and external resources, internal assimilation and external diffusion of OSIOS can fully leverage the technological value and improve and develop a firm's capabilities (Nevo and Wade, 2010). However, the full value of OSIOS can only be leveraged when it is appropriately deployed to support internal and external processes (Zhang *et al.*, 2016), which entails the importance to understand the risks and challenges involved in assimilation and diffusion processes to gain a more complete picture of the value creation mechanisms of OSIOS.

Although internal assimilation is the key to exploit the full business value of a technology (Liang *et al.*, 2007), very often practitioners may encounter difficulties in assimilating new technologies into their business processes, a phenomenon which is referred to as the "assimilation gap" (Fichman and Kemerer, 1999). To routinize a new technology within a firm after the initial adoption stage, a company needs to develop sufficient knowledge to leverage and adapt the technology to align it with relevant processes (Zhu *et al.*, 2006b). To bridge the assimilation gap for OSIOS will require a considerable amount of investment in the form of hardware, software, and personnel training. Moreover, relevant cross-boundary processes should be redesigned to satisfy the requirements of the new technical standards (Sodero *et al.*, 2013). Weighing the business value and the substantial investment, the performance implication of internal assimilation of OSIOS remains undetermined.

By diffusing OSIOS to connect with supply chain partners, the focal firm can exploit network effects (Sodero *et al.*, 2013) with enhanced information processing capability and a larger knowledge base (Church and Gandal, 1992; Venkatesh and Bala, 2012). However, the diffusion process is complex, dynamic, and contingent on various technological and contextual factors, which entails a long time-lag before the full attainment of the benefits (Wu and Chang, 2012). Moreover, the widespread diffusion of technology might create inconsistency across different adopters regarding technical documents and managerial procedures due to discrepancies in understanding. Therefore, it remains challenging to conclude the influence of external diffusion of OSIOS.

Past studies investigating the outcomes of OSIOS deployment generally assume a linear relationship between them as one where increased assimilation and diffusion of OSIOS will indefinitely enhance the postulated benefits. For example, Venkatesh and Bala (2012) found that there is a negative linear relationship between OSIOS assimilation and cycle time; the study of Malhotra *et al.* (2007) suggested a positive association between OSIOS deployment and mutual adaptation. Although these studies expanded our knowledge frontier in understanding the performance outcomes of OSIOS adoption, they might have used an oversimplified lens by assuming an invariant, linear impact on a firm's capabilities and performance. This ignores the possibility of negative effects when OSIOS are assimilated or diffused to a certain level. Scholars also doubted this positive linear effect by claiming that the use of IT might hurt supply chain performance (e.g., ineffective decision-making) when a company collaborates too closely with its partners (Crosno and Dahlstrom, 2008; Villena *et al.*, 2011). Accordingly, our study proposes that to maximize the benefits enabled by OSIOS, there should be an appropriate level of OSIOS assimilation and diffusion such that an inflection point will be achieved where the users can benefit the most. Developing and testing non-linear models to study technology adoption and use has been suggested to be an important contribution to

fill the research gap in current literature where over-simplified linear models have been essentially used to understand the phenomenon (Venkatesh and Goyal, 2010).

2.3 The Relational Mechanisms of OSIOS

The relational view of the firm, employing an inter-organizational theoretical lens, explains how relational resources and capabilities can form the foundation of strategic advantages (Kanter, 1994; Dyer and Singh, 1998). It is contended that a firm's critical resources will span across organizational boundaries and can be generated from inter-organizational processes and routines (Dyer and Singh, 1998). Therefore, this theoretical view extends beyond the resource-based view (RBV) which based only on a single firm's view, asserts that competitive advantages fully originate from the resources housed internally (Wernerfelt, 1984; Barney, 1991). With the evolution of inter-firm relationships from arm-length short-term transactions to collaborative partnerships over the last few decades (Corsten and Felde, 2005), increasingly, inter-organizational information systems (IOS) including OSIOS, are being used to create, sustain and develop inter-organizational relationships (Hagel and Brown, 2005). OSIOS could be the major source of competitive advantage as it is embedded in inter-organizational processes and routines to develop relational capabilities (Powell and Dent-Micallef, 1997; Bharadwaj, 2000). Therefore, following the logic of relational view, OSIOS, through promoting information sharing and inter-firm communication, can serve as an important embedding mechanism to generate relational rents that promote long-term success in supply chains (Paulraj *et al.*, 2008).

Relational rents are conceptualized as the economic rents generated from inter-organizational linkages when companies uniquely configure and combine the complementary relation-specific resources emerging from external partnerships (Dyer and Singh, 1998; Saraf *et al.*, 2007). The framework of Dyer and Singh (1998) identifies a wide range of determinants of relational rents (drivers of organizational performance), which provides the theoretical generalizability to study various inter-organizational relationships such as scientific alliances, marketing alliances, and supply chain collaborations (Malhotra *et al.*, 2005). In our study, some of the strategic determinants of relational rents such as complementary capabilities, effective governance mechanisms, partner scarcity, and institutional environment, however, are excluded because they are more relevant with joint ventures and R&D collaborations which are out of the scope of this study. In the context of digital supply chain relationships, this study will focus on relation-specific assets, knowledge exchange and joint learning, and interfirm assets interconnectedness identified by Dyer and Singh (1998) as the key sources of relational rents (Saraf *et al.*, 2007; Wang *et al.*, 2014). As a firm's core infrastructure to communicate and transact with supply chain partners, OSIOS can perform as a platform enabling the combination of these resources and to produce relational rents (Bensaou and Venkatraman, 1996; Bala and Venkatesh, 2007).

It is suggested that OSIOS could have a significant impact on an organization's process adaptability by transforming and shaping interfirm connectedness and knowledge exchanges (Malhotra *et al.*, 2007). Process adaptability connotes a firm's ability to accommodate new functions and reduce the costs associated with reconfiguring resources to support the emerging requirements to adapt supply chain activities and operational processes in inter-organizational relationships (Young-Ybarra and Wiersema, 1999; Gosain *et al.*, 2004; Rai and Tang, 2010), which can be enabled by OSIOS by developing flexible and responsive IT assets and processes. Based on modular interdependent processes, structured data connectivity and standardized interfaces (Gosain *et al.*, 2004), OSIOS allow a firm to quickly and

economically adapt its IT assets to both the evolutionary and revolutionary changes in business requirements and processes (Kumar, 2004; Langdon, 2006). Users of OSIOS explicitly or implicitly agree on the common specifications at both syntactic and semantic levels, which not only improves multilateral information processing capability and knowledge exchange, but also resolves the interpretive differences in the information transmitted (Malhotra *et al.*, 2007). Supply chain partners thus can learn and adapt to the needs of each other better without the extensive coordination efforts in clarifying and conveying the uncertainty and ambiguity in the messages they send or receive (Gosain *et al.*, 2003). At the same time, the modular architecture of OSIOS allows for the disaggregation and reconfiguration of systems to accommodate new functions, which enables adaptation at system level (Rai and Tang, 2010). Therefore, the common templates and standardized interfaces of OSIOS will not constrain information diversity as the users are allowed to customize parameters to flexibly adapt to the requirements of partner-specific process (Malhotra *et al.*, 2007).

However, process adaptability *per se* does not create direct performance gains (Saraf *et al.*, 2007). Companies must develop process alignment that integrates, coordinates and jointly optimizes interfirm activities with partners (Rai and Tang, 2010). A major source of process alignment is suggested to be asset interconnectedness, which is created when supply chain partners closely link their business processes, and thereby increase relationship specificity (Dyer and Singh, 1998). Through process alignment, a focal firm can coordinate and interweave the interdependent supply chain activities with its business partners, which can ensure that business processes spanning across the supply chain network are operationally integrated (Saraf *et al.*, 2007; Rai and Tang, 2010). A company can achieve process alignment by deploying their IT assets to work as a “functional whole” with that of its partners (Saraf *et al.*, 2007, p. 324), which requires supply chain partners to resolve their differences at both the syntactic and semantic boundaries (Malhotra *et al.*, 2007). With the standardized interfaces of OSIOS, companies can quickly respond to the idiosyncrasies in the interfirm processes of their partners (Saraf *et al.*, 2007), enabling information sharing, activity coordination and process alignment (Grover and Saeed, 2007). In doing so, OSIOS provide firms with valuable bonding mechanisms that allow firms to transform from traditional weakly connected supply chains to closely aligned collaborative networks for joint success (Whipple and Russell, 2007).

3 Hypothesis Development

3.1 Curvilinear Relationships between OSIOS and Process Adaptability

Internal assimilation and external diffusion are the two underlying building blocks for the strategies to deploy OSIOS (Zhang and Dhaliwal, 2009). Internal assimilation of OSIOS provides companies with the ability to coordinate and synchronize interfirm processes (Bala and Venkatesh, 2007). When OSIOS are deployed to digitalize more supply chain processes, companies can standardize more information exchange, which can reduce the time and effort spent in interpreting and completing supply chain activities. By assimilating OSIOS with internal processes, the clarity of exchanged information is improved, which prevents information distortion and errors during information transfer (Venkatesh and Bala, 2012). This increased operational efficiency and information visibility will enhance a company’s flexibility to adapt its business operations to external environments (Stevenson and Spring, 2007).

However, excessive internal assimilation of OSIOS may restrict the level of adaptability OSIOS can enable. To internally assimilate OSIOS, a company needs to spend a large amount of resources and make substantial

adjustments to its supply chain processes (Venkatesh and Bala, 2012). Therefore, over-assimilation of OSIOS may present a major disruption in a company's existing processes that are already embedded in its operational routines (Porter, 2001), which will increase the difficulty to control interfirm processes, reducing a firm's ability to reconfigure current supply chain activities and adapt to the external environment. In addition, OSIOS may not be compatible with a firm's existing IT infrastructure, which requires specialized IT investment and personnel to support the operations of OSIOS (Gosain *et al.*, 2003). When OSIOS are deployed to complement too many supply chain activities, it will become increasingly challenging for a company to develop an adequate IT capability to maintain the systems and to adapt the systems and functions to the changing requirements. The discussion leads to the following hypothesis:

H1: An inverted U-shaped relationship exists between OSIOS internal assimilation and the level of process adaptability enabled by OSIOS, such that internal assimilation improves process adaptability at first and impedes process adaptability after reaching a certain level.

When OSIOS are externally diffused to connect more partners, the users can exploit network effects that may expand the scope and range of information exchanged (Zhu *et al.*, 2006a). The more the partners are connected in the OSIOS network, the more diverse the knowledge a company can access and integrate, through which a company can absorb knowledge to enhance adaptability (Malhotra *et al.*, 2005). To adapt to the changes in the external environment, a company should develop knowledge of the environment, understand and improve their existing capabilities and skills, and restructure relevant business processes to build new capabilities. External diffusion of OSIOS generates a rich knowledge base by accessing diverse external knowledge sources, which enables companies to receive and respond to signals in the market, and adapt to the changes in the business environment by precisely capturing and fulfilling market needs (Malhotra *et al.*, 2005).

When OSIOS are excessively diffused and connected with too many external partners, the problem of information overload will be created (Hiltz and Turoff, 1985; Gulati *et al.*, 2012), which reduces a firm's ability to organize the information in the supply chain and also create obstacles for interfirm collaboration. The information flow might have a curvilinear relationship with the level of adaptability enabled by OSIOS, because there can be an inflection point at which it becomes overwhelming for an organization to deal with more information or coordinate with more partners (Huber, 1991). In the meantime, the information shared in the OSIOS network will become increasingly homogenous, as the number of partners increases, which diminishes the informational value accessed from OSIOS because the knowledge circulated among the partners will become increasingly redundant. This declined value of external knowledge might induce rigidity to deal with market changes (Gulati *et al.*, 2012). In addition, as the number of participants increases, free-riding behaviors and unexpected spillover effects are highly possible due to the misuse of proprietary information and resources (Wu, 2008). To deal with this threat, additional efforts of security control and institutional mechanisms should be implemented to manage OSIOS, which further complicates business processes and impedes the level of adaptability a company can attain from OSIOS (Lee and Lim, 2003; Valdés-Llaneza and García-Canal, 2006). Based on our discussion, we propose the following hypothesis:

H2: An inverted U-shaped relationship exists between OSIOS external diffusion and the level of process adaptability enabled by OSIOS, such that external diffusion improves process adaptability at first and impedes process adaptability after reaching a certain level.

3.2 Process Adaptability and Process Alignment

To effectively manage supply chain relationships and leverage external resources, alignment and adaptability are highly correlated together (Bharadwaj, 2000; Langdon, 2006). However, researchers argue that there exists a trade-off between these two capabilities. To exploit benefits of alignment, a firm must forgo most of the benefits of adaptability (Kambil *et al.*, 1999; Saeed *et al.*, 2005). Therefore, it has been challenging for companies to maintain both process alignment and adaptability. This intuition is rooted in the context of traditional EDI where a firm must make chunky infrastructure investments, develop rigid and complex X12 formats, and create highly relation-specific EDI connections, which will result in a minimal level of flexibility to adjust and reconfigure IT assets (Hart and Estrin, 1991; Gosain *et al.*, 2004). Based on recent developments in open standards, modular design and extensible markups, OSIOS can resolve the contradictory requirements between alignment and adaptability (Zhu *et al.*, 2006a; Malhotra *et al.*, 2007; Saraf *et al.*, 2007). There is going to be a higher degree of IOS flexibility after the implementation of OSIOS, which in turn can enhance supply chain integration (Hagel and Brown, 2005).

Allowing firms to flexibly adjust their IT infrastructures and extend IT functionalities, OSIOS enable supply chain partners to rapidly respond to the changing needs in business processes and adapt to inter-organizational activities and plans (Rai and Tang, 2010), which can facilitate the dynamic alignment of processes with supply chain partners (Gosain *et al.*, 2004). Although in a stable environment, a firm can only choose to create highly partner-specific connections and invest in process-specific IT assets that forgo flexibility and adaptability, in a more dynamic environment a company must establish linkages and develop IT infrastructures that are more robust and reconfigurable. Otherwise, the company may develop sticky patterns with entrenched partners over time, resulting in resistance to change (Van Den Bosch *et al.*, 1999). Through obtaining process adaptability from OSIOS, firms can bridge the information gaps in markets and quickly respond to the changes in external environments using various strategies and actions (Gosain *et al.*, 2004), which can reduce of risk of the aforementioned “rigidity traps” and in the long-term, can promote the restructuring of supply chain processes and lead to greater process alignment (Bharadwaj, 2000). Therefore, we formulate the following hypothesis:

H3: OSIOS enabled process adaptability is positively associated with OSIOS enabled process alignment.

The overarching research model of this study is depicted in Figure 1.

<Figure 1 around here>

4 Methodology

To test the hypotheses, this study collected data from manufacturing companies operating in China using a self-report survey instrument which was carefully developed following existing guidelines and exemplars (Sethi and King, 1994). China is considered as an ideal environment to study IOS and supply chain management because of several reasons. Firstly, China is currently one of the foremost global manufacturing centers and is an attractive place for companies throughout the world to set up a manufacturing base (Flynn *et al.*, 2010). Secondly, the Chinese government has made significant efforts in the drive towards achieving Industry 4.0, with many resources being invested into areas such as smart and intelligent manufacturing (Zhong *et al.*, 2017). Lastly, the Chinese government also places great emphasis

on their efforts to achieve the “Made in China 2025” project and as a result, there is growing efforts devoted by Chinese companies in deploying IOS to integrate partners within their global supply chains (Huo *et al.*, 2014; Liu *et al.*, 2016). To collect data from the existing adopters of OSIOS, the respondents were asked to identify the type of IOS their companies are implementing before they were provided with the questionnaire to fill in.

4.1 Measurement Development

The survey instrument employed in this study was designed based on a comprehensive review of the literature on inter-organizational information systems, inter-organizational relationship management and supply chain management. Whenever possible, existing measurements in the literature were adapted from past studies to safeguard the content validity of the constructs and their fit in the research context, and to ensure that the overlap among the constructs was minimal (Cronbach, 1971).

The key variables in this study were operationalized as multi-item reflective and formative constructs. To decide whether a construct should be modeled as formative or reflective, four major criteria should be examined: (1) the direction of causality between constructs and their indicators, (2) the interchangeability of indicators, (3) the covariation among indicators, and (4) the nomological net of constructs (Jarvis *et al.*, 2003). A latent variable should be constructed as formative when the direction of causality is from the indicators to the constructs (i.e., the indicators create the constructs), the indicators are not inter-changeable and do not necessarily covary, and the nomological net of the indicators can differ (Chin, 1998). In contrast, reflective constructs should be created when the opposite conditions hold. Suggested by the decision rules, OSIOS enabled process alignment and internal assimilation, which were modeled as formative constructs; OSIOS enabled process adaptability and external diffusion, which were modeled as reflective constructs. The response formats and specific items for all measures are shown in Table 3.

Internal Assimilation measures the extent to which OSIOS have been used to support internal supply chain operation practices (Zhang *et al.*, 2016). Following Zhu *et al.* (2006b), Zhang and Dhaliwal (2009) and Zhang *et al.* (2016), a three-item formatively measured construct was adapted to assess the degree of OSIOS usage in different key up-stream supply chain activities: supplier selection, purchase-order processing, procurement from suppliers, and invoicing and payment processing.

External diffusion refers to the degree to which OSIOS have been used to facilitate inter-organizational activities with supply chain partners. Three reflective items were adapted from Premkumar *et al.* (1994), Premkumar and Ramamurthy (1995), Zhang *et al.* (2016), and Zhang and Dhaliwal (2009) to measure the breadth and volume of the transactions that a firm has conducted through OSIOS (Zhu and Kraemer, 2002; Zhang and Dhaliwal, 2009; Zhang *et al.*, 2016), which includes the number of partners a firm has been interacting with, the volume of transactions with partners, and the overall interactions with partners that have been handled via OSIOS.

OSIOS enabled process alignment measures the extent to which OSIOS enables the coordination and joint optimization of activities between a firm and its supply chain partners, and was measured with four formative items adopted from Tang and Rai (2012) and Rai and Tang (2010). The four items assessed the capabilities of OSIOS to enhance bonding among supply chain partners through coordinating

interdependency, improving process visibility, optimizing supply chain processes, and handling operational exceptions and errors efficiently.

OSIOS enabled process adaptability was assessed with three reflective items adapted from Gibson and Birkinshaw (2004) and Im and Rai (2008), which measured the extent to which OSIOS promotes organizational responsiveness to adapt to the variations in the external environment through reconfiguring and adjusting supply chain relationships and activities.

4.2 Control Variables

To control for unobserved heterogeneity caused by industry effects in value creation analysis, following China's industrial classification guide (National Bureau of Statistics, 2017), eight industry dummies were created to represent the industries of the following: (1) automobiles and components, (2) electrical goods and electronics, (3) materials and chemicals, (4) energy, (5) healthcare and healthcare machinery, (6) machinery and equipment, (7) consumer durables and apparel, and (8) others. Ownership was also controlled by creating dummy variables to indicate whether a firm was state-owned, privately owned, or foreign-controlled. In addition, performance was also controlled for the influence of firm size by measuring the yearly turnover and the number of employees of a firm. Larger firms tend to enjoy more abundant resources to deploy OSIOS compared with smaller firms. We also controlled for the number of years a firm has been operating because the older a firm is, the more likely it has invested legacy systems that might not be compatible with OSIOS. In addition, we measured IT department size as the number of technical personnel hired to control for the IT capability of a firm. Two additional control variables – relationship duration and number of suppliers – were also accounted for the possible effects of supplier portfolio characteristics (Tang and Rai, 2012). Relationship duration measured the average relationship length (in years) between a firm and its major suppliers, which is consistent with Im and Rai (2008). Number of suppliers measures the number of major suppliers a firm has been routinely interacting with.

We further controlled for the effects of market and technological turbulence. Market turbulence describes the heterogeneity and the rapid variations in a firm's customer portfolio and the preferences of its customers (Kandemir *et al.*, 2006), which was assessed by three reflective items adapted from Calantone *et al.* (2003), Kandemir *et al.* (2006) and Trkman and McCormack (2009). Technology turbulence refers to the speed of changes in technology over time in the principal industry that a firm operates in and the consequences these changes induce to the industry (Chatterjee, 2004). Three reflective items adapted from Kandemir *et al.* (2006), Koo *et al.* (2006) and Trkman and McCormack (2009) were employed to measure technology turbulence.

4.3 Data Collection

To facilitate the data collection process, a survey research company specialized in helping researchers distribute survey in China was hired to collect data. The role of the data collection firm was to help distribute the survey as well as following up by phoning the companies and conversing with them in Chinese to remind them to fill in the questionnaire if they were willing to participate in our research. Employing data collection to distribute surveys has grown substantially in recent years across a variety of academic disciplines, but specific examples in supply chain operations and management research include Autry *et al.* (2010), Cai *et al.* (2010) and Schoenherr *et al.* (2015). Previous researchers have addressed the concerns

with regards to the quality of data collected from survey research firms by confirming that the responses do not differ from those collected via random mail samples as long as the target population is knowledgeable regarding the subject matter (Autry *et al.*, 2010; Schoenherr *et al.*, 2015). It is argued that despite the potential challenges faced by survey research firm recruitment, employing them for data collection can provide a viable alternative to traditional self-administered surveys (Schoenherr *et al.*, 2015). In order to avoid potential bias in our data collection process, one of the co-authors of the research presented at the survey research company when the follow up phone calls were made to the respondents. We also followed the guidelines recommended by Schoenherr *et al.* (2015) to avoid potential bias in our data such as having clear procedures with the survey research company to ensure only qualified respondents took part in the survey, as well as having screening questions to provide assurance of reliability and validity of responses. In this study, the list of manufacturing firms with the Chinese Industrial Classification (CIC) codes 1311 – 4290 (National Bureau of Statistics, 2017) was decided to be the sampling frame to ensure the sample could span a comprehensive spectrum of manufacturing industries. Following Cai *et al.* (2010), the target companies were randomly selected based on the stratified probability proportional to sizes (PPS) method, which could ensure good representation of the sample in terms of industry, firm size and ownership. A list of 3,400 firms was selected as the target samples.

The surveys were conducted through computer-aided phone interviews by the employees of the professional research company. Based on standard practice (Flynn *et al.*, 2010; Zhou *et al.*, 2014; Liu *et al.*, 2016), our survey collected data from senior executives holding titles such as the chief executive officer, chief technology officer, and senior operations managers. These individuals were identified to be the key informants because they confirmed their involvement with supply chain technology as part of their job role, and they have strong knowledge about their companies' overall operational and IT capabilities. The data collection professionals first identified whether a firm has adopted OSIOS or not before administering the questionnaire to the respondents. We screened our data by following the procedure by Schoenherr *et al.* (2015). We were able to monitor the time respondents took to complete the survey. Surveys that were answered in less than 15 minutes were eliminated. This 15-minute benchmark was the average completion time incurred by the authors when carefully reading and thoughtfully answering the survey. Following Schoenherr *et al.* (2015), we deemed these “speeders” as unreliable respondents. After discarding the responses with missing data, the final sample consisted of 308 valid responses from OSIOS current adopters. The sample demographic and respondent profile are shown in Table 1 respectively.

<Table 1 around here>

5 Data Analysis and Results

5.1 Measurement Validation

Confirmatory factor analysis was conducted to validate the measurement. Because reflectively measured constructs and formatively measured constructs are based on different concepts, they must be distinguished when evaluating the measurement models by using different assessment measures (Ringle *et al.*, 2009). Reflective constructs were assessed regarding their internal consistency reliability and construct validity following Hair *et al.* (2014), whereas formative constructs were evaluated following guidelines suggested by and Petter *et al.* (2007).

The internal consistency reliability of the reflective constructs was established by assessing composite reliabilities. The results in Table 2 showed that the composite reliabilities of all constructs were greater than the recommended benchmark of 0,70, suggesting satisfactory internal consistency of the reflective measurement model (Barclay *et al.*, 1995).

<Table 2 around here>

Construct validity assesses whether the items can actually capture the concepts that the constructs intend to measure (Bagozzi, 1980), which is evaluated by convergent and discriminant validity respectively. As shown in Table 2, the reflective measurement models exhibit sufficient indicator reliability because the standardized factors loadings ranged from 0.681 to 0.983 (Flynn *et al.*, 2010). Meanwhile, the average variance extracted (AVE) ranged from 0.577 to 0.949, greater than the suggested 0.50 threshold (Koufteros, 1999). These results thus provided strong evidence of convergent validity. To establish discriminant validity of the reflective measurements, the Fornell-Larcker criterion and cross-loadings were used as two measures. The Fornell-Larcker criterion (Fornell and Larcker, 1981) proposes that a construct should share more variance with its indicators than the variance shared with other constructs in the same model, which is statistically expressed as the rule suggesting that the square root of a construct's AVE should exceed the highest correlation it has with any other construct. As shown in Table 3, the square roots of the AVEs (figures on the diagonal) were all greater than the correlations among the constructs (figures off the diagonal), providing evidence for discriminant validity. In addition, the results in Table 4 demonstrate that no indicators loaded higher on other constructs than on their assigned constructs (Petter *et al.*, 2007), which further lends support for discriminant validity.

<Table 3 around here>

<Table 4 around here>

For OSIOS enabled process alignment and internal assimilation, which are formative measures, the statistical assessment criteria for reflective measurements such as composite reliability and AVE are not applicable. Content validity of formative measures, which ensures that all the formative indicators capture all, or at least a major part of, the facets of the construct domain (Nunnally, 1978), must be established before data collection and estimation. Because all of the measures for formative constructs were adapted directly from previous literature in prestigious IS and OM journals, the theoretical grounding of the indicators are well supported. In addition, as described in the data collection section, the questionnaire items were reviewed cautiously by a panel of eight academics and five practitioners to ensure the content validity of the formative indicators.

Similar to reflective measurements, cross-loadings of formative indicators are employed to evaluate their discriminant validity (Petter *et al.*, 2007). As shown in Table 4, no formative indicators loaded greater on the constructs they are not intended to measure, which provides support for discriminant validity of the formatively measured constructs.

5.2 Hypothesis Testing

Conventional analytical methods such as ordinary least squares (OLS) and general least squares (GLS) might not be appropriate for this study because the endogenous variables – OSIOS enabled process adaptability – is also specified as an explanatory variable in another equation in the system of equations (Hamilton and Nickerson, 2003). In addition, problems arising from correlated error terms due to the possible omission of variables that are correlated with the dependent variable and any of the independent variables in the model may arise (Zaefarian *et al.*, 2017). Correlation among error terms could also arise because each case is based on data obtained from a single respondent (Kuruzovich *et al.*, 2008). Therefore, the three-stage least squares (3SLS) estimation, which combines the features of two-stage least squares (2SLS) and seemingly unrelated regression estimation (SURE), was employed to analyze the data to simultaneously address the problems of dependent regressors and correlation of error terms (Kuruzovich *et al.*, 2008). In addition, 3SLS is recommended to be a more efficient approach (compared with OLS and GLS) to solve triangular structural models (Lahiri and Schmidt, 1978), just as the research model proposed in this study. When estimating models involving latent variables, 3SLS also has the advantage of being more robust to model specification errors, e.g., omitted paths or incorrect structures, compared with the commonly used maximum likelihood based structural equation modeling (SEM) method (Bollen *et al.*, 2007). Furthermore, because our research model involves quadratic effects, using 3SLS can cater for interacting variables more easily compared with SEM. The following system of equations was developed to test the proposed hypotheses:

$$\begin{aligned} \text{Process Adaptability}_i = & \beta_0 + \beta_1 \text{ExternalDiffusion}_i + \beta_2 \text{InternalAssimilation}_i + \\ & + \beta_3 \text{ExternalDiffusion}_i^2 + \beta_4 \text{InternalAssimilation}_i^2 + \beta_5 \text{Market Turbulence}_i + \\ & + \beta_6 \text{TechnologicalTurbulence} + \beta_7 \text{Turnover} + \beta_8 \text{Employee} + \beta_9 \text{IT Department} + \\ & + \beta_{10} \text{OperationYears} + \beta_{11-12} \text{OwnershipDummies} + \beta_{13-19} \text{IndustryDummies} + e_i \end{aligned} \quad (1)$$

$$\begin{aligned} \text{Process Alignment}_i = & \gamma_0 + \gamma_1 \text{Process Adaptability}_i + \gamma_2 \text{No. of Suppliers}_i + \\ & + \gamma_3 \text{RelationshipDuration}_i + \gamma_4 \text{Market Turbulence}_i + \gamma_5 \text{TechnologicalTurbulence} + \\ & + \gamma_6 \text{Turnover} + \gamma_7 \text{Employee} + \gamma_8 \text{IT Department} + \gamma_9 \text{OperationYears} + \\ & + \gamma_{10-11} \text{OwnershipDummies} + \gamma_{12-18} \text{IndustryDummies} + v_i \end{aligned} \quad (2)$$

As specified in the equations, we controlled the effects market and technological turbulence on process adaptability. In addition, relationship duration and number of suppliers, as two network properties, were included as control variables for process alignment in the model.

5.3 Results

Table 5 details the main estimation result of the system of equations, wherein, Models (1), (2) and (3) list estimate for the various specifications of Equation (1) while Models (4) and (5) detail the result for Equation (2). Among the control variables, it was found that the effect of number of suppliers was negative on process alignment, which reflects the difficulty in managing a wide variety of inter-organizational relationships. A company is constrained to attained high levels of process alignment when there are many partnerships to cater for (Madhok, 2002). Relationship duration, on the other hand, was positively associated with process

alignment, which lends support to the notion that tie strength can facilitate supply chain integration (Tang and Rai, 2012).

<Table 5 around here>

In Model (1), the main linear effects of both OSIOS deployment constructs were entered. Consistent with our earlier discussion that OSIOS can provide relational mechanism to enable process adaptability, results showed that external diffusion ($\beta_1 = 0.265$, $p < .01$) and internal assimilation ($\beta_2 = 0.241$, $p < .01$) were predictive for the creation of process adaptability. In Model (2), quadratic terms of the two OSIOS deployment constructs were entered. Only the nonlinear term of internal assimilation was significant predictive for process adaptability ($\beta_3 = -0.075$, $p < .01$), which lent support for Hypothesis 1. However, Hypothesis 2 was not supported as the nonlinear effect of external diffusion was not significant ($\beta_4 = -0.06$, ns). External diffusion thus only had positive linear effect on OSIOS enabled process adaptability. To corroborate the nonlinear effect in the case of internal assimilation, Figures 2 illustrates the graph of the quadratic relation. Hypothesis 3 posits that OSIOS enabled process adaptability positively affects OSIOS enabled process alignment. Model (3) represents the corresponding result: the positive effect of process adaptability was statistically significant ($\gamma_1 = 0.501$, $p < .01$), offering support to Hypothesis 3.

<Figure 2 around here>

Although not explicitly suggested in the hypotheses, the research model implies a mediation effect of process adaptability on the relationship between OSIOS deployment and process alignment. Because external diffusion was shown to have no significant relationship with process adaptability, we only tested the mediating role of process adaptability. Due to the involvement of nonlinear effect, we performed a bootstrapping test ($n = 5000$) following the procedure of Hayes and Preacher's (2010) to calculate the instantaneous indirect effects of internal assimilation on process alignment through process adaptability at different values of internal assimilation (i.e., mean and mean \pm SD). The instantaneous indirect effect was significant at low internal assimilation ($\theta_{x=-1.04} = 0.288$, bias-corrected bootstrap 95% CI = [0.167, 0.397], not including zero), mean ($\theta_{x=-0.11} = 0.227$, bias-corrected bootstrap 95% CI = [0.145, 0.307], not including zero), and higher ($\theta_{x=0.82} = 0.167$, bias-corrected bootstrap 95% CI = [0.085, 0.259], not including zero). The result provides evidence that increasing internal assimilation can enable more process alignment through the effect on OSIOS enabled process adaptability. However, the return from internal assimilation is diminishing as its marginal effect on process alignment is larger for companies low in internal assimilation compared with those have moderate or high levels of internal assimilation.

As OSIOS internal assimilation and external diffusion could be endogenously affected by the level of process adaptability, the results might be biased and inconsistent (Guide and Ketokivi, 2015). We conducted a two-stage least squares (2SLS) regression with instrumental variables and a Durbin–Wu–Hausman postestimation test of endogeneity (Davidson and MacKinnon, 1993) to deal with the potential endogeneity concern (Liu *et al.*, 2016). The results (see Appendix I, Table A1) showed that the findings in our original model were unlikely to be unduly influenced by endogeneity.

Several additional tests were conducted to check the robustness of our results. We tested our hypotheses using Structural Equation Modeling with FIML estimation to estimate simultaneously the effect of OSIOS adoption on process adaptability and process alignment. The model leads to the same statistical conclusions as 3SLS (see Appendix II, Table A2). Additionally, a 2SLS analysis with LIML estimation was performed, which also showed consistent results with 3SLS (see Appendix II, Table A3). 2SLS recommended for system of equations where there might be endogeneity due to potential reverse causality between the

independent and dependent variable (Baron and Kenny, 1986). The consistent results from 2SLS thus minimize concerns about endogeneity.

6 Discussion and Implications

OSIOS technology is an important fundamental IT artifact to help achieve Industry 4.0. It has the potential to provide the standards for business processes and data exchanges that can create an autonomous, decentralized supply chain network, thus helping firms to achieve better supply chain integration. As found in Flynn *et al.* (2010), supply chain integrations can be described in three dimensions, namely internal, customer and supplier integration. OSIOS technology is important in helping firms improve their supply chain integration (Chong and Ooi, 2008). However, OSIOS implementation is still in its infancy stage given that the technology is still elusive to most manufacturers. Most manufacturers understand the potential values of OSIOS, but at the same time they are taking a cautious approach in investing in OSIOS. Our research advances contemporary knowledge of the values brought by the assimilation and diffusion of OSIOS. Drawing on the theoretical lens of the relational view of the firm, we examined how manufacturers can achieve process adaptability and alignment by implementing OSIOS. Through collecting surveys from a large group of manufacturers, we were able to examine the non-linear impact of OSIOS assimilation and diffusion on process adaptability and alignment, and shed light on how manufacturers should optimize their implementation of OSIOS to achieve the best outcomes. As such, our research bears significant implications for both theory and practice.

6.1 Implications for Theory

By conducting an empirical examination on the research model proposed, this research contributes to extant literature on three fronts.

Firstly, our study extends previous studies conducted by scholars such as Gosain *et al.* (2004) and Malhotra *et al.* (2007) which have examined the role of OSIOS in improving flexibility and adaptability. One of the key contributions of the paper is to extend the linear models in their studies, and examine the curvilinear effects of OSIOS internal assimilation and external diffusion on enabling process adaptability. Existing studies have mainly focused on the linear relationship between IS implementations and organizational performance, e.g., Malhotra *et al.* (2007), Chang and Shaw (2009) and Venkatesh and Bala (2012), which might oversimplify the complex phenomenon of technology adoption and deployment (Venkatesh and Goyal, 2010). Our study found that relationship between internal assimilation and OSIOS enabled process adaptability followed an inverted U-shaped pattern. The findings ascertain that by deploying OSIOS to support key supply chain activities, the utility of OSIOS to enhance process adaptability will drop after a certain degree. This could be because that as more functions and processes are integrated in OSIOS, the whole system will become complicated to use and difficult to learn, which reduces the flexibility of the system and thus constrain the level of process adaptability OSIOS can enable. External diffusion only showed a positive linear relationship with process adaptability, which confirms with the network externalities of OSIOS, where once there are more supply chain partners using OSIOS, the value of OSIOS increases (Zhu *et al.*, 2006a). This supports why OSIOS such as RosettaNet Standards need manufacturers in the industry to buy in into the technology and co-adopt it in order to maximize the values that OSIOS can offer.

Secondly, by conceptualizing OSIOS implementation into internal assimilation and external diffusion, we enhanced the knowledge about the post-adoption stage of OSIOS. The innovation diffusion literature has developed a multi-stage diffusion model to generalize the full process as innovation pervades organizational practices – from initial evaluation at the pre-adoption stage, to formal adoption, and to general deployment or routinization at the post-adoption stage (Fichman, 2001). Past studies have mainly focused on the single adoption stage and treat innovation diffusion as a one-shot organizational behavior (Zhu *et al.*, 2006b), while little is known about the post-adoption stages although they are suggested to be a valuable research focus (Fichman, 2000). Our study focuses specifically on the post-adoption stages and recognizes that after a technology is adopted and adapted, it will progressively be integrated into supply chain processes to support activities and knowledge transfers within and beyond organizational boundaries (Ranganathan *et al.*, 2004). The findings showed differential impact mechanisms between internal assimilation and external diffusion, which provides valuable insights to understand how IT can create value when deployed to support different functions.

Lastly, although many studies in the past have been focused on the role of existing information systems such as EDI or ERP on organization performances (e.g., Sodero *et al.*, 2013; Liu *et al.*, 2016), research investigating the specific outcomes related to IT-enabled supply chain capabilities remains to be scarce. This is of particular interest and importance to achieve Industry 4.0 given that OSIOS have the ability to examine and address the potential tradeoffs between IOS integration and flexibility (Saraf *et al.*, 2007; Rai and Tang, 2010). Our study also showed that through enabling process adaptability, OSIOS can indirectly generate process alignment to integrate interfirm supply chain processes and activities. Without process adaptability, even though a company achieves process alignment, it will not be able to reconfigure its supply chain activities to adapt to the changing environments. The company thus will face risks of rigidity such that the existing business processes that were once aligned will become obsolete or misaligned when relevant supply chain activities or relationships change. This rigidity has been pertinent to the use of EDI because its inflexibility and costs have restrained its ability to transform inter-organizational relationships (Hart and Estrin, 1991). OSIOS overcomes the disadvantages of EDI by affording companies with the flexibility to tune the parameters related to business processes, allowing them to adapt to the emerging alignment requirement (Malhotra *et al.*, 2007; Saraf *et al.*, 2007). Therefore, our research empirically confirmed that OSIOS can enable companies to enjoy close coordination and inter-firm integration and to pursue higher-order performance by developing adaptability to continually restructure supply chain processes and respond to external changes.

Arguably, from the discussions above, it is evident that our research can be heralded as a modest effort to bring clarity to the current state of progress for OSIOS and its implications for further theory development along the lines of the values delivered from OSIOS assimilation and diffusion.

6.2 Implications for Practice

Our research informs practice in two ways. Firstly, even though Industry 4.0 provides numerous opportunities for many countries to digitalize manufacturing industries, contemporary applications of Industry 4.0 technologies still exist at an experimental stage. This study offers an overview of how OSIOS can be deployed to help create value to supply chain processes. Furthermore, we separate deployment of OSIOS into internal assimilation and external diffusion, thus offering a richer understanding of how applying OSIOS within a firm's business process and its integration with its partners can help create values

to a manufacturer. In this sense, our study informs practitioners who are planning or in the process of implementing OSIOS, to gain a comprehensive view of the value offered by OSIOS.

Secondly, given that organizations may have limited resources to invest in OSIOS, our study provides valuable insights into how to deploy IT assets internally and externally to maximize the relational outcomes from OSIOS. In particular, we showed that manufacturers should not blindly increase assimilation of OSIOS into their business processes, as more does not necessarily mean better in our U-shaped result. Manufacturers should instead focus on key business processes to implement OSIOS, while other business processes internally can function using existing systems. On the other hand, within the supply chain network, manufacturers should ensure that the business processes that have assimilated OSIOS should be fully integrated with their supply chain partners, as this is shown to increase the process adaptability of manufacturers.

7 Limitations and Future Research

Despite the contributions of this study in both theory and practice, there are several limitations. Firstly, this study could not show the value creation of OSIOS over time. Future studies can consider the dynamism of time when evaluating the relationship between OSIOS and relational capabilities. This study used cross-sectional data, which might be subject to the risk that the influence of OSIOS on organizational outcomes is only temporal. The quasi-open attribute of OSIOS makes imitation easy, which will reduce the uniqueness of OSIOS and erode a firm's competitive advantage overtime. It is important to ensure that performance gains from OSIOS can be sustained in the long-term. Future study can conduct longitudinal research to understand whether and how OSIOS deployment can promote long-term advantages. The use of cross-sectional data also restricts us from exploring whether the capabilities developed from OSIOS implementation, in the long run, will in turn affect the extent to which OSIOS are deployed. With improved adaptability and alignment, a firm might be more capable of assimilating and diffusing OSIOS to support interfirm activities.

Although our research model in terms of OSIOS enabled process adaptability and alignment has the advantage of parsimony, the explanatory breath and richness can be improved. Future study thus can include other outcomes of OSIOS such as relationship flexibility (Rai and Tang, 2010), or even first order value such as operational and financial performance that could potentially yield from OSIOS implementation. In addition, the moderation effects of inter-organizational relationships e.g., trust and information sharing can be explored in the future. In addition, we also acknowledge the limitation of measuring internal assimilation as the extent to which OSIOS are deployed to support internal activities. Due to the differences in downstream and upstream supply chain activities, assimilation of IT to integrate customers and suppliers should be measured as separate variables (Frohlich, 2002). Future research can investigate internal assimilation of OSIOS in downstream activities to provide more insights into the phenomenon.

Furthermore, the data was collected from China where there is a collectivist cultural environment and therefore the respondents may have a tendency to agree regardless of the content of the questions (Liu *et al.*, 2010). Thus there might be a slight chance of acquiescence bias in our data. Despite these limitations, we believe that this study provides compelling evidence showing that OSIOS can be leveraged as importance value creation mechanisms to lead to the roadmap of Industry 4.0.

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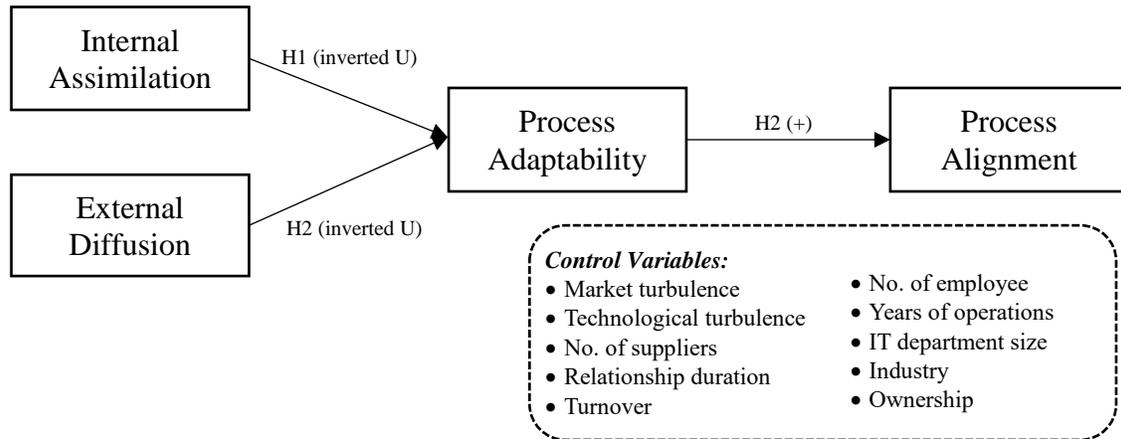


Figure 1. Research Model

Table 1. Sample Demographics and Respondent Profile (N = 308)

| Sample Demographics | | | | | |
|---|------------------|-------------------|--------------------------------|------------------|-------------------|
| | Frequency | Percentage | | Frequency | Percentage |
| Industry | | | Turnover | | |
| Automobiles & Components | 21 | 6.82% | < 25 Million | 32 | 10.39% |
| Electronical & Electronics | 71 | 23.05% | 25–100 Million | 72 | 23.38% |
| Materials/Metals/Chemicals | 93 | 30.19% | 100-300 Million | 63 | 20.45% |
| Energy | 13 | 4.22% | > 300 Million | 141 | 45.78% |
| Health Care | 28 | 9.09% | Employee | | |
| Equipment & Machinery | 46 | 14.94% | <160 | 34 | 11.04% |
| Consumer Durables & Apparel | 22 | 7.14% | 160-1000 | 161 | 52.27% |
| Others | 14 | 4.55% | > 1000 | 113 | 36.69% |
| Years of Operation | | | Operation Scope | | |
| ≅ 5 Years | 15 | 4.87% | Multinational Organization | 94 | 43.12% |
| 6-10 Years | 127 | 41.23% | Non-multinational Organization | 214 | 98.17% |
| ≅ 10 Years | 166 | 53.90% | | | |
| Organization Type (Ownership) | | | Size of IT Department | | |
| State-owned (fully/partly owned) | 36 | 11.69% | ≅ 5 | 58 | 18.83% |
| Privately-owned | 145 | 47.08% | 6 – 10 | 90 | 29.22% |
| Foreign Controlled | 127 | 41.23% | 11– 15 | 93 | 30.19% |
| | | | ≅ 16 | 67 | 21.75% |
| Respondent Profile | | | | | |
| | Frequency | Percentage | | Frequency | Percentage |
| Position | | | Years of Working | | |
| CEO/President | 3 | 0.97% | ≅ 5 Years | 89 | 28.90% |
| Senior executive/Vice President | 122 | 39.61% | 6-10 Years | 210 | 68.18% |
| IT Manager/CIO/CTO | 72 | 23.38% | ≅ 11 Years | 9 | 2.92% |
| Supply Chain/Operations Manager/ COO | 111 | 36.04% | | | |

Table 2. Questionnaire Items and Confirmatory Factor Analysis

| Construct and items | Standardized loadings | Composite Reliability | AVE |
|---|-----------------------|-----------------------|-------|
| OSIOS Enabled Process Alignment (ALM)* <i>Adapted from Tang and Rai (2012) and Rai and Tang (2010)</i> | | | |
| <i>Through implementing OSIOS...</i> | | | |
| ALM1 we can closely coordinate interdependent processes with specific partners. | 0.851 | | |
| ALM2 we can make interdependent operating procedures and routines (e.g., manufacturing, bar coding, packaging, shipping, etc.) to be highly visible among specific partners and us. | 0.688 | - | - |
| ALM3 we can jointly optimize related operating processes with specific partners. ALM4 | 0.714 | | |
| ALM1 we can closely coordinate interdependent processes with specific partners. | 0.866 | | |
| OSIOS Enabled Process Adaptability (ADP) <i>Adapted from Gibson and Birkinshaw (2004) and Im and Rai (2008)</i> | | | |
| <i>Through implementing OSIOS...</i> | | | |
| ADP1 we can adapt current supply chain relationships to respond quickly to changes in our markets. | 0.838 | | |
| ADP2 we can adapt existing business processes rapidly to respond to shifts in our business priorities. | 0.821 | 0.868 | 0.686 |
| ADP3 we can facilitate reconfiguration of activities to respond to changes in the external environments. | 0.827 | | |
| Internal Assimilation (INT)* <i>Adapted from Zhu et al. (2006b), Zhang and Dhaliwal (2009) and Zhang et al. (2016)</i> | | | |
| <i>Please rate the extent to which your firm has been using OSIOS to conduct the following supply chain activities...</i> | | | |
| INT1 Supplier selection (getting quotes, bid etc.) | 0.928 | | |
| INT2 Purchase order processing | 0.907 | - | - |
| INT3 Procurement from suppliers (distribution, warehouse, shipping, logistics etc.) | 0.944 | | |
| External Diffusion (EXT) <i>Adapted from Premkumar et al. (1994), Premkumar and Ramamurthy (1995), Zhang et al. (2016), and Zhang and Dhaliwal (2009)</i> | | | |
| <i>Please indicate the percentage of total transactions or inter-firm interactions that your firm has performed through OSIOS...</i> | | | |
| EXT1 Percent of total supply chain partners who interact with your organization through the system | 0.968 | | |
| EXT2 Percent of total supply chain partner transactions done through the system | 0.983 | 0.983 | 0.949 |
| EXT3 Percent of overall interactions with supply chain partners carried out through the system | 0.973 | | |
| Market Turbulence (MT) <i>Adapted from Calantone et al. (2003), Kandemir et al. (2006) and Trkman and McCormack (2009)</i> | | | |
| <i>Please indicate the extent to which you agree with the following statements regarding the principal market your company is operating in...</i> | | | |
| MT1 We continuously cater too many new customers. | 0.804 | | |
| MT2 Our customers tend to look for new products all the time. | 0.681 | 0.803 | 0.577 |
| MT3 New customers tend to have product-related needs that differ from our existing customers. | 0.788 | | |
| Technological Turbulence (TT) <i>Adapted from Kandemir et al. (2006), Koo et al. (2006) and Trkman and McCormack (2009)</i> | | | |
| <i>Please indicate the extent to which you agree with the following statements regarding the principal market your company is operating in...</i> | | | |
| TT1 It is very difficult to forecast where the technology in our industry will be in the next 2–3 years. | 0.883 | | |
| TT2 In our principal industry the modes of production and service often change. | 0.887 | 0.876 | 0.704 |
| TT3 The rate of product/service obsolescence in our industry is very high. | 0.737 | | |

*Formative Constructs

Table 3. Discriminant Validity, Means, Standard Deviations, and Correlations

| | Mean | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-----------------------------|---------|---------|---------|--------------|---------|--------------|--------------|--------------|----------|----------|---------|--------|
| 1. Process Alignment | 4.698 | 0.780 | - | | | | | | | | | |
| 2. Process Adaptability | 4.925 | 0.758 | 0.695** | 0.828 | | | | | | | | |
| 3. Internal Assimilation | 3.961 | 0.980 | 0.577** | 0.532** | - | | | | | | | |
| 4. External Diffusion | 4.518 | 1.800 | 0.638** | 0.532** | 0.691** | 0.974 | | | | | | |
| 5. Market Turbulence | 5.190 | 0.645 | 0.439** | 0.303** | 0.363** | 0.453** | 0.760 | | | | | |
| 6. Technological Turbulence | 5.447 | 0.647 | 0.407** | 0.281** | 0.322** | 0.486** | 0.711** | 0.839 | | | | |
| 7. Number of Suppliers | 119.344 | 119.350 | 0.062 | 0.034 | 0.161** | 0.217** | -0.118* | -0.092 | - | | | |
| 8. Relationship Duration | 6.107 | 2.653 | 0.258** | 0.208** | 0.271** | 0.289** | -0.017 | 0.005 | 0.342** | - | | |
| 9. Turnover | NA | NA | 0.388** | 0.287** | 0.375** | 0.454** | 0.077 | 0.008 | 0.376** | 0.423** | - | |
| 10. Ownership | NA | NA | 0.105 | 0.096 | 0.191** | 0.285** | 0.113* | 0.045 | -0.201** | -0.003 | 0.042 | - |
| 11. Industry | NA | NA | -0.056 | -0.060 | -0.100 | -0.145* | -0.006 | -0.033 | -0.094 | -0.190** | -0.146* | -0.001 |

* $p < 0.05$, ** $p < 0.01$

Note: The square roots of the AVEs were shown as figures on the diagonal

Table 4. Cross Loadings

| | ADP | ALM | EXT | INT | TT | MT |
|------|--------------|--------------|--------------|--------------|--------------|--------------|
| ADP1 | 0.838 | 0.578 | 0.487 | 0.456 | 0.331 | 0.388 |
| ADP2 | 0.821 | 0.561 | 0.394 | 0.465 | 0.199 | 0.327 |
| ADP3 | 0.827 | 0.556 | 0.442 | 0.403 | 0.086 | 0.252 |
| ALM1 | 0.621 | 0.851 | 0.602 | 0.497 | 0.361 | 0.502 |
| ALM2 | 0.593 | 0.688 | 0.457 | 0.549 | 0.120 | 0.324 |
| ALM3 | 0.482 | 0.714 | 0.478 | 0.452 | 0.246 | 0.480 |
| ALM4 | 0.538 | 0.866 | 0.516 | 0.365 | 0.442 | 0.613 |
| EXT1 | 0.483 | 0.575 | 0.968 | 0.660 | 0.414 | 0.507 |
| EXT2 | 0.540 | 0.653 | 0.983 | 0.670 | 0.424 | 0.535 |
| EXT3 | 0.532 | 0.663 | 0.973 | 0.664 | 0.392 | 0.548 |
| INT1 | 0.495 | 0.522 | 0.706 | 0.928 | 0.238 | 0.423 |
| INT2 | 0.484 | 0.483 | 0.631 | 0.907 | 0.286 | 0.435 |
| INT3 | 0.503 | 0.479 | 0.577 | 0.944 | 0.199 | 0.397 |
| TT1 | 0.199 | 0.390 | 0.451 | 0.294 | 0.883 | 0.577 |
| TT2 | 0.263 | 0.438 | 0.360 | 0.232 | 0.887 | 0.510 |
| TT3 | 0.138 | 0.187 | 0.174 | 0.012 | 0.737 | 0.271 |
| MT1 | 0.380 | 0.600 | 0.459 | 0.395 | 0.237 | 0.804 |
| MT2 | 0.254 | 0.360 | 0.324 | 0.284 | 0.679 | 0.681 |
| MT3 | 0.235 | 0.469 | 0.438 | 0.323 | 0.517 | 0.788 |

Table 5. Results of Hypothesis Testing

| | Process Adaptability | | | Process Alignment | |
|------------------------------------|----------------------|----------------------------|----------------------------|----------------------------------|----------------------------------|
| | (1) | (2) | (3) | (4) | (5) |
| Market Turbulence | 0.033 (0.62) | 0.046 (0.88) | 0.066 (1.25) | 0.201** (4.69) | 0.168** (4.17) |
| Technological Turbulence | 0.036 (0.65) | 0.054 (0.96) | -0.012 (-0.21) | 0.019 (0.44) | 0.070 (1.70) |
| Internal Assimilation | 0.265** (5.11) | 0.236** (4.44) | 0.317** (5.25) | | |
| External Diffusion | 0.241** (5.06) | 0.248** (5.14) | 0.215** (4.17) | | |
| Internal Assimilation ² | | -0.079** (-3.00) | -0.076** (-2.79) | | |
| External Diffusion ² | | -0.006 (-0.12) | -0.013 (-0.26) | | |
| Process Adaptability | | | | 0.574** (18.17) | 0.501** (16.29) |
| No. of Suppliers | | | -0.126** (-2.68) | | -0.048 (-1.36) |
| Relationship Duration | | | 0.0333 (0.71) | | 0.098** (2.75) |
| Turnover | | | -0.0619 (-1.06) | | 0.148** (3.39) |
| No. of Employee | | | 0.0320 (0.52) | | -0.120* (-2.51) |
| IT Department Size | | | 0.0419 (0.71) | | 0.0729 (1.59) |
| Years of Operation | | | 0.028 (0.69) | | 0.005 (0.16) |
| Ownership (State) | | | 0.0529 (0.42) | | 0.119 (1.24) |
| Ownership (Private) | | | 0.212* (2.49) | | 0.011 (0.19) |
| IND1 ^c | | | 0.327 (1.71) | | -0.188 (-1.26) |
| IND2 | | | 0.055 (0.75) | | -0.008 (-0.14) |
| IND3 | | | 0.031 (0.64) | | -0.00141 (-0.04) |
| IND4 | | | 0.011 (0.21) | | -0.091* (-2.18) |
| IND5 | | | 0.056 (1.32) | | 0.0231 (0.71) |
| IND6 | | | -0.017 (-0.57) | | 0.024 (1.09) |
| IND7 | | | 0.0122 (0.54) | | -0.0267 (-1.53) |
| Constant | 4.981** (140.01) | 5.054** (84.21) | 4.845** (34.35) | 4.707** (161.11) | 4.740** (46.43) |
| R ² | 0.333 | 0.340 | 0.380 | 0.557 | 0.640 |
| F | 43.72** | 31.69** | 9.83** | 168.5** | 35.86** |

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$

^b For ownership dummies, foreign-controlled firms served as the base group relative to the effects other dummies.

^c IND1 = automobiles and components industry; IND2 = electrical and electronics industry; IND3 = materials and chemicals industry; IND4 = energy industry, IND5 = healthcare and healthcare machinery industry; IND6 = machinery and equipment industry, IND7 = consumer durables and apparel industry. Others served as the base group relative to the effects other industry dummies.

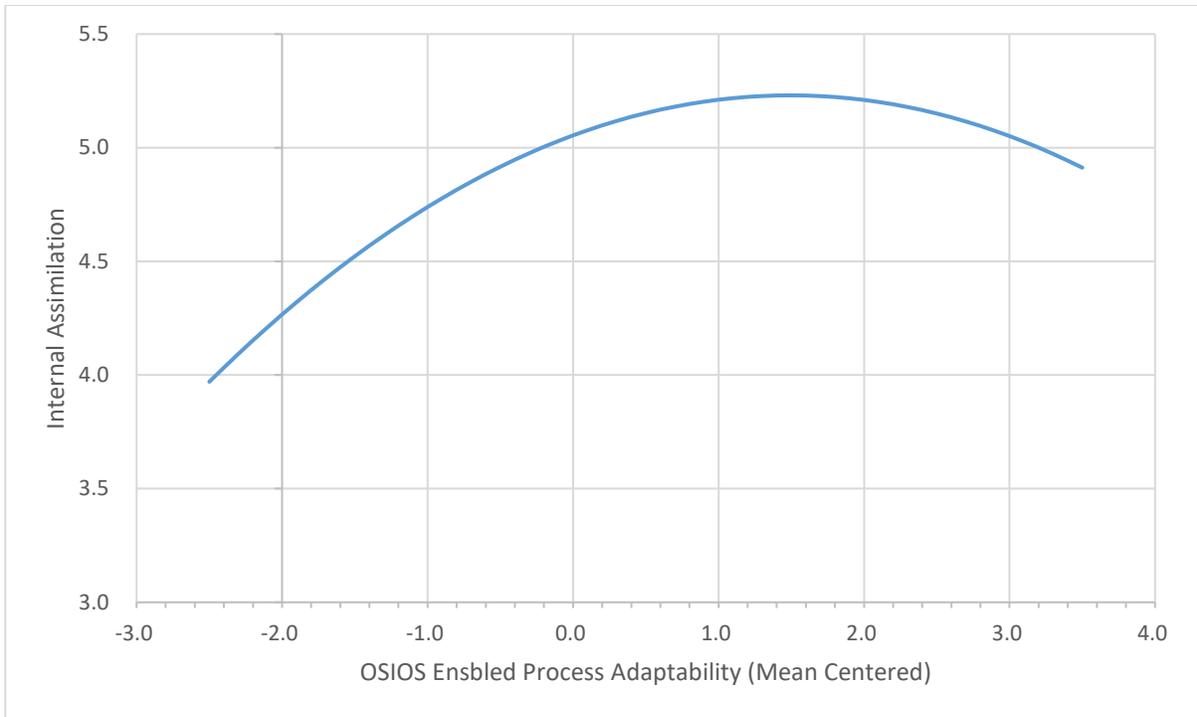


Figure 2. Curvilinear Relationship Between Internal Assimilation and Process Adaptability