Self-Reliance or Dependence? Patterns of Information Technology Use on Innovation Performance

Abstract

The association between information technology (IT) and firms' innovation performance remains underexplored within the current Operations Management literature. We attempt to address this void by exploring how patterns of IT use (exploration and exploitation) influence innovation performance. We also introduce distinct types of supply chain (SC) innovation strategies, and explore how internal, external, and ambidextrous (balanced and combined) innovation strategies moderate the relationship. Drawing upon the dynamic capability view, we consider patterns of IT use as firms' dynamic capabilities that can foster innovation performance, and regard SC innovation strategy as organizational paths that may influence the effectiveness of IT use. We empirically examine the relationship using data from 995 manufacturing firms featured in the World Bank China Enterprise Survey. We find IT exploitation and exploration positively influence innovation performance. Additionally, the internal innovation strategy can amplify the positive effect of IT exploitation, while exerting a non-significant moderating effect on IT exploration. Interestingly, the positive impacts of both IT use patterns on innovation are weakened when firms adopt external and ambidextrous innovation strategies. Our study contributes to a deeper comprehension of the relationship among IT use, SC innovation strategies, and firms' innovation performance based on a dynamic capability view.

Keywords: IT use, Innovation performance, Supply chain innovation strategy, Ambidexterity, Dynamic capability view

1. Introduction

Scholars and practitioners alike recognize the critical effect of information technology (IT) on firms' survival amidst turbulent environments (Liang et al. 2017; Wiengarten et al. 2013; Pagell, Krumwiede, and Sheu 2007) and its pervasive influence on supporting and nurturing innovation (Chau et al. 2020; Joshi et al. 2010). Consequently, the Society for Information Management's (SIM) annual surveys consistently rank IT as a top priority for executives in the past three decades (Sabherwal et al. 2019; Liang et al. 2017; Chau et al. 2020). Despite numerous investigations into IT's impact on various performance dimensions (Gerow et al. 2014), the Operations Management (OM) literature examining the relationship between IT use and innovation performance remains in its infancy. In particular, empirical studies exploring how and under which contexts patterns of IT use influence innovation performance are scarce.

In this study, we aim to fill the void and focus on how patterns of IT use can support innovation activities. Prior organizational learning research has established the distinction between exploitative and explorative patterns of organizational actions (Gu, Yang, and Huo 2021; Sanders 2008; Wu, Hitt, and Lou 2020). Exploitation entails refining existing ways for addressing problems, while exploration entails discovering novel ways. Accordingly, we categorize patterns of IT use into two constructs: IT exploitation and IT exploration, which differ in their intent in utilizing information and communication technologies. This distinction allows our study to provide a deeper comprehension of the impact of patterns of IT use on innovation.

The dynamic capability view (DCV) posits that a firm's ability to utilize, build, and reconfigure competencies enables it to maintain a competitive advantage in changing environments (Teece, Pisano, and Shuen 1997; Handfield et al. 2015; Lawson and Samson 2001). Innovation performance, as a core competitive advantage in turbulent environments and intense competition, can be achieved through firms' effective dynamic capabilities. Following

the theoretical lens of DCV, we regard IT use as a crucial dynamic capability that can integrate and reconfigure organizational IT competencies to support innovation. Moreover, the DCV suggests that achieving a competitive advantage requires the ability to leverage existing firm-specific resources and develop new ones (Teece, Pisano, and Shuen 1997). Therefore, following DCV, we contend that both patterns of IT exploitation and exploration, as firms' dynamic capabilities, are essential for achieving a competitive advantage in innovation performance. However, despite the extensive dialogue on IT use within the extant literature (e.g., Gu, Yang, and Huo 2021; Chen et al. 2021; Chen, Liu, and Chen 2022; Liang et al. 2017), there is a notable scarcity of analysis on the patterns of IT use through the lens of the DVC (Pavlou and El Sawy 2010). The neglect of IT's role in relation to DCV hinders a deeper comprehension of how distinct types of IT-related dynamic capabilities can shape innovation performance. This oversight may also lead to missed opportunities to provide more empirically rooted insights into the innovation literature. Consequently, to address this gap, we put forward our first research question:

RQ1: How do IT exploitation and IT exploration influence innovation performance?

Moreover, the DCV asserts a firm's capacity to attain competitive advantage is anchored in its organizational processes and paths (Eisenhardt and Martin 2000; Reuter et al. 2010; Teece, Pisano, and Shuen 1997; Vergne and Durand 2010). This suggests that a firm's competencies are fundamentally shaped by its path dependencies and routines, which influence the effectiveness of its capabilities. Organizational paths refer to the strategic choices that a firm can take (Teece, Pisano, and Shuen 1997). In our study, we suggest that the effectiveness of IT use on innovation performance may be influenced by firms' diverse innovation strategies, which emphasize the various ways in which a firm learns, employs resources, and acquires knowledge (Miles et al. 1978). Specifically, we concentrate on a common classification of firms' innovation strategies, encompassing internal and external innovation strategies within

their supply chain (SC) (Mata and Woerter 2013; Jiang et al. 2021; Cui et al. 2015). An internal innovation strategy involves a firm developing new products and processes in-house (Cohen and Levinthal 1990), emphasizing the need for a robust foundation of self-reliant innovation capabilities. Conversely, an external innovation strategy pertains to the approach where a firm introduces new products and processes through collaboration with its SC partners (suppliers and customers) (Cui et al. 2015), which underscores the importance of external cooperation and dependence on the innovation process. Additionally, since firms may simultaneously employ both internal and external innovation strategies, we also consider the joint moderating effects of SC innovation strategies. Specifically, we draw upon the ambidexterity perspective (He and Wong 2004; Cao, Gedajlovic, and Zhang 2009; Chandrasekaran, Linderman, and Schroeder 2012; Kortmann et al. 2014) and examine how balanced and combined SC innovation strategies moderate the IT use-innovation performance relationship.

Despite existing innovation literature having demonstrated the crucial roles of different types of innovation strategies (Cui et al. 2015; Grimpe and Kaiser 2010), we know little regarding how distinct SC innovation strategies interact with patterns of IT use to influence innovation performance. Without investigating the moderating effect of SC innovation strategies, it is challenging to determine how firms' strategic orientation and paths affect the effectiveness of IT use. Accordingly, following the theoretical lens of DCV (Eisenhardt and Martin 2000; Reuter et al. 2010; Teece, Pisano, and Shuen 1997), we consider different types of SC innovation strategies (i.e., internal, external, and ambidextrous SC innovation strategies) as important organizational innovation paths that can influence the effectiveness of IT capabilities. Thus, we have our second research question:

RQ2: How do internal, external, and ambidextrous SC innovation strategies moderate the relationship between patterns of IT use and innovation performance?

To address these questions, we empirically examine our proposed research model using data from 995 manufacturing firms featured in the World Bank China Enterprise Survey. We employ regression analysis to test our hypotheses. The results illustrate that both patterns of IT exploitation and exploration positively influence innovation performance. Furthermore, we demonstrate that internal innovation strategy can strengthen the positive impact of IT exploitation but has a non-significant moderating effect on IT exploration. Interestingly, the positive effects of both patterns of IT use are weaker for firms employing external and ambidextrous SC innovation strategies. These results remain consistent across various robustness checks and estimation approaches, such as a two-stage least squares (2SLS) approach, two-stage residual inclusion (2SRI), and the Heckman test.

Our study contributes to the existing literature in several ways. Firstly, we expand upon the literature on IT-enabled innovation by emphasizing the often overlooked yet crucial role played by patterns of IT use. While previous research has delved into IT's impact on innovation outcomes (Gómez, Salazar, and Vargas 2017; Joshi et al. 2010; Kleis et al. 2012), the specific effects of IT use patterns, such as IT exploitation and IT exploration, have remained largely unexplored. Recent studies have tended to focus on the influences of IT exploitation and IT exploration on service innovation (Chen et al. 2021), which is more closely related to outcome innovation. However, it is important to note that firms' innovation performance encompasses both process innovation and outcome innovation. Our study addresses this gap by examining the influences of IT use patterns on innovation performance based on DCV, providing a more comprehensive analysis of the relationship between IT use and innovation. Secondly, our research sheds light on how SC innovation strategies—specifically internal, external, and ambidextrous innovation strategies—moderate the relationship between IT use and innovation performance. While previous studies have explored the underlying mechanisms of the relationship between IT use and innovation (Joshi et al. 2010), studies examining the

effectiveness of IT use under different SC innovation strategies remain limited. Our study contributes to the innovation literature by analyzing the moderating roles of internal, external, and ambidextrous innovation strategies in the relationship between IT use and innovation performance, providing a deeper understanding of these dynamics. Thirdly, our study innovatively integrates patterns of IT use, SC innovation strategy, and innovation performance based on the theoretical lens of DCV. In our study, DCV aligns seamlessly with our research framework and offers a robust theoretical foundation for understanding how firms adopt various IT use patterns to bolster innovation performance. Drawing upon DCV, we conceptualize IT use patterns as the essential dynamic capabilities of firms, while view SC innovation strategies as organizational paths. Our study explains how IT exploitation and IT exploration, as core dynamic capabilities influence firms' competitive advantage of innovation performance. We also underline how SC innovation strategy (i.e., internal, external, and ambidextrous SC innovation strategies) as essential organizational paths can shape the effectiveness of IT capabilities on innovation performance. By investigating the interplay between IT use patterns and SC innovation strategy, our study not only enriches the academic discourse but also delivers nuanced insights for practitioners.

The rest of this paper is organized as follows. Section 2 introduces the concepts of patterns of IT use and SC innovation strategy and provides the theoretical background of DCV. Section 3 introduces our hypothesis development. Section 4 depicts the data, measurements, and econometric model. Section 5 depicts the related analysis and results, and Section 6 provides theoretical and practical implications.

2. Theoretical Background

2.1 Patterns of IT use

Drawing on organizational learning theory, organizational actions and the ways firms utilize capabilities can be classified into two patterns: exploitation and exploration (Sanders 2008; Gu, Yang, and Huo 2021; He and Wong 2004; Cao, Gedajlovic, and Zhang 2009). Exploitation refers to actions that refine established patterns or reuse existing knowledge, focusing on efficiency, consistency, and flexibility. In contrast, exploration involves establishing new patterns or creating new knowledge to bring value to the firm, entailing risk-taking and experimentation.

We develop exploitation versus exploration patterns to delineate patterns of IT use. Specifically, IT exploitation is defined as a firm employing information and communication technologies to leverage and refine existing products and processes. This pattern is related to a firm's capability to use and assimilate IT resources for incremental improvements in business processes and efficiency, such as enhancing production flexibility, training employees, and reducing costs. Conversely, IT exploration is defined as a firm utilizing IT resources to introduce new products and processes. This pattern is linked with a firm's capacity to leverage IT in creating new procedures and processes for gaining competitiveness, such as introducing new processes in production and operations, and developing new products and processes (Liang, Wang, and Xue 2022b).

Previous studies have explored the potential contributions of IT use on innovation. For instance, scholars have revealed the positive relationship between IT investment /IT use and innovation outcomes (e.g., Joshi et al. 2010; Kleis et al. 2012; Ravichandran, Han, and Mithas 2017) or examined the complementary roles of IT with firms' business processes to improve innovation (e.g., Gómez, Salazar, and Vargas 2017; Saldanha, Mithas, and Krishnan 2017). In the examination of empirical research on IT use patterns outlined in Appendix A, recent studies have shed light on the impacts of both IT exploitation and IT exploration on performance, such

as firm performance (Chen, Liu, and Chen 2022), supply chain performance (Gu, Yang, and Huo 2021), relationship performance (Jean, Kim, and Choi 2021), business performance (Liu, Liu, and He 2023), and organizational agility (Liang, Wang, and Xue 2022a; Zhen et al. 2021). While some scholars have delved into the effects of IT exploitation and IT exploration on service innovation (i.e., incremental and radical service innovation) (Chen et al. 2021), a comprehensive exploration of the influences of IT use patterns on innovation, guided by the DCV, is currently lacking in the existing literature. Moreover, there is a scarcity of studies delving into the moderating roles of SC innovation strategies, potentially missing the opportunity to thoroughly examine their interactions. In light of this, our study aims to fill this research gap by focusing specifically on IT exploitation and IT exploration, and scrutinizing the moderating roles of SC innovation strategies, grounded in the theoretical foundation of DCV. Concentrating on these specific patterns will contribute to a clearer understanding of IT's role in facilitating innovative business activities and provide deeper insights into the innovation literature. We posit that investigating the contingent roles of SC innovation strategies will also offer more nuanced insights into the conditions under which IT use effectively impacts innovation performance. In the subsequent subsection, we will provide a detailed overview of SC innovation strategies.

2.2 Supply chain innovation strategy

Innovation is a paradigm wherein firms utilize internal and external ideas, along with internal and external paths, to develop new products, processes, or services (Gómez, Salazar, and Vargas 2017; Jiang et al. 2021). We define SC innovation strategy as a firm's approach to employing both inbound and outbound sources and knowledge to develop new products, processes, and services in the SC context. Consequently, we classify typical SC innovation strategies into two dimensions: internal and external innovation strategies (Mata and Woerter

2013; Anzola-Román, Bayona-Sáez, and García-Marco 2018; Jiang et al. 2021; Schiele, Veldman, and Hüttinger 2012).

Specifically, an internal innovation strategy is inward-focused and entails a focal firm's approach to develop research and development (R&D) activities using internal functions and employee knowledge to achieve innovation (Anzola-Román, Bayona-Sáez, and García-Marco 2018). This strategy emphasizes the development of self-reliant innovation capabilities, helping to create firm-specific knowledge resources and generate strong integrative capabilities (Grimpe and Kaiser 2010). In contrast, an external innovation strategy is outward-focused, defined as a focal firm's approach to seek collaboration with external innovation partners so as to achieve innovation (Anzola-Román, Bayona-Sáez, and García-Marco 2018; Mata and Woerter 2013). Suppliers and customers are two crucial types of SC partners in the context of SCs (Baldwin and Von Hippel 2011; Bellamy, Ghosh, and Hora 2014).

Prior innovation literature has highlighted the benefits of both in-house and open innovation strategies (Cui et al. 2015; Grimpe and Kaiser 2010; Lawson et al. 2009). However, more recent research increasingly emphasizes the "dark side" of external innovation strategies (Gómez, Salazar, and Vargas 2017; Berchicci 2013). Firms not only benefit from the "gains" of employing an external innovation strategy but may also suffer the "pains" primarily stemming from the costs of integrating external knowledge (Grimpe and Kaiser 2010; Gómez, Salazar, and Vargas 2017). Specifically, Grimpe and Kaiser (2010) underscored the costs of integrating externally acquired knowledge from suppliers and customers with focal firms. Similarly, Berchicci (2013) found improving innovation from outbound sources increased the costs of finding, coordinating, and managing external SC partners. Moreover, Gómez, Salazar, and Vargas (2017) highlighted the costs of depending on a broad range of knowledge sources and the challenges of integrating numerous ideas. Therefore, firms employing different innovation strategies may experience distinct moderating effects.

Additionally, most firms are likely to pursue internal and external innovation strategies simultaneously in practice. However, the literature still lacks theoretical explanations and empirical evidence in terms of the ambidextrous roles of internal and external strategies. Based on the ambidexterity perspective, we propose that a firm can demonstrate ambidexterity in terms of innovation strategy in two ways: balanced innovation strategy and combined innovation strategy (Cao, Gedajlovic, and Zhang 2009; Gu, Yang, and Huo 2021; Venugopal et al. 2020). Specifically, a balanced innovation strategy represents a case in which a firm focuses on internal and external strategies to relatively similar degrees. A combined innovation strategy signifies a case in which a firm integrates both strategies to leverage and utilize the combined strength. In this study, we examine how internal, external, and ambidextrous (balanced and combined) innovation strategies differentially moderate the relationship between IT use and innovation performance.

2.3 Dynamic capability view

The DCV suggests how organizations can utilize, extend, or modify firms' capabilities to achieve competitive advantage in response to dynamic environments (Eisenhardt and Martin 2000; Teece, Pisano, and Shuen 1997; Lawson and Samson 2001). The perspective of DCV depicts specific firms' paths, routines, and competences that enable firms to generate new value-creating dynamic capabilities in response to emerging market needs (Wiengarten et al. 2022). Recently, scholars have adopted DCV to frame investigations of how IT could enable firms to cope with environmental challenges and compete successfully (e.g., Pavlou and El Sawy 2010).

DCV identifies elements that may determine the effectiveness of a firm's unique and dynamic capabilities, including organizational processes, positions, and paths (Eisenhardt and Martin 2000; Teece, Pisano, and Shuen 1997). Specifically, the essence of capabilities is

embedded in organizational procedures and is shaped significantly by the firm's processes and evolutionary path it adopts and inherits (Vergne and Durand 2010; Reuter et al. 2010; Wiengarten et al. 2022). In other words, firms' processes, asset positions, and evolution paths explain the effectiveness of a firm's capabilities to maintain competitive advantage (Wiengarten et al. 2022). In our study, we focus mainly on the role of firms' paths. Based on DCV, typical organizational paths include firms' strategic selections (Eisenhardt and Martin 2000; Teece, Pisano, and Shuen 1997). The strategic orientation of a firm affects the organization's allocation of resources and its repertoire of routines, and thus may influence the effectiveness of dynamic capabilities. Accordingly, we regard SC innovation strategy as important organizational paths that may exert moderating effects on the roles of patterns of IT use.

In this case, DCV well coincides with our research model and provides a theoretical foundation for us to comprehend how firms implement different patterns of IT use to achieve innovation performance. Based on DCV, we regard patterns of IT use as firms' core dynamics capabilities, SC innovation strategy as organizational paths, and innovation performance as firms' competitive advantage. We argue that SC innovation strategy can fundamentally shape the effectiveness of IT use to achieve firms' competitive advantage of innovation performance. We enrich the literature and provide relevant implications for managers by examining how patterns of IT use interact with SC innovation strategy to facilitate innovation from the solid theoretical perspective of DCV.

3. Hypothesis Development

Utilizing the DCV, this study posits that patterns of IT use constitute pivotal dynamic capabilities for a firm. These dynamic capabilities facilitate the seamless integration and reconfiguration of the firm's IT competencies, playing a crucial role in supporting innovation activities and sustaining competitive advantage within dynamic environments. Moreover,

according to DCV, the effectiveness of IT use in influencing innovation performance is intricately tied to organizational paths, specifically SC innovation strategies in the context of this research. The intricate relationship between a firm's patterns of IT use and SC innovation strategies highlights the complexity that ultimately molds the use of IT in attaining and sustaining a competitive advantage.

3.1 Patterns of IT use and innovation performance

Drawing on DCV, patterns of IT use enable firms to develop effective and distinct dynamic capabilities, supporting information consolidation and analysis associated with various innovation activities. Consequently, we argue that both patterns of IT use can facilitate innovation. Specifically, IT exploitation involves activities that focus on production and task efficiency, such as utilizing IT resources to reduce production costs and enhance process flexibility (Sanders 2008). These activities promote the speed, frequency, and magnitude of knowledge and information transfer across firms, ultimately strengthening and complementing the firms' knowledge base (Kleis et al. 2012; Xue, Ray, and Sambamurthy 2012). Effective IT exploitation can also accelerate firms' data processing cycles, encompassing the entire procedure from collecting data to extracting knowledge, ensuring firms can obtain innovative outcomes (Liang, Wang, and Xue 2022b). Furthermore, by using IT exploitation, firms can standardize unstructured procedures and build the infrastructure to capture and share knowledge across firms. These exploitative activities provide foundations for smooth communication and efficient coordination aimed at enhancing innovation performance.

Additionally, IT exploration promotes the creation of novel knowledge and thought based on experimentation and explorative activities (Gu, Yang, and Huo 2021). IT exploration enhances firms' innovative ability by fostering knowledge development and idea generation. Via explorative IT use, firms can uncover hidden knowledge and generate brand new ideas

(Liang, Wang, and Xue 2022b). Through various information and communication technologies, firms can efficiently exchange and integrate knowledge, leading to greater knowledge creation and recombination. Moreover, firms empowered by effective IT resources, such as social media tools, can transfer knowledge across geographical distances at lower costs and include more participants (Dahlander and Gann 2010). Frequent communication and the collision of ideas with IT support facilitate the creation of new process improvements, new product development, and new service provision in firms. Accordingly, based on DCV, we argue that both IT exploitation and IT exploration can effectively contribute to increased innovation performance, leading us to put forward:

Hypothesis 1a. IT exploitation is positively related to innovation performance.

Hypothesis 1b. IT exploration is positively related to innovation performance.

3.2 The moderating effect of supply chain innovation strategy

DCV suggests that the nature of dynamic capability in maintaining a competitive advantage is fundamentally shaped by organizational paths concerning strategic alternatives (Teece, Pisano, and Shuen 1997). In this section, we discuss how SC innovation strategies, in terms of internal, external, and ambidextrous innovation strategies, distinctly moderate the relationship between IT use and innovation performance.

According to DCV, organizational learning and knowledge acquisition tend to be localized, with opportunities for learning closely aligned with familiar paths and routines of firms (Teece, Pisano, and Shuen 1997). An internal innovation strategy emphasizes firms obtaining knowledge and conducting R&D activities among in-house employees and functions. Consequently, firms with an in-house strategic orientation will recognize, assimilate, and integrate knowledge from familiar sources and paths, thereby reducing the identification, integration, and utilization costs of knowledge (Gómez, Salazar, and Vargas 2017). As a result,

under a high level of internal innovation strategy, the costs and difficulties of leveraging IT for both exploitative and explorative innovation activities may decrease, contributing to the firm's innovation success. Specifically, with familiar routines and reduced communication costs, the effectiveness of using IT to decrease production costs and enhance flexibility may increase, thus strengthening the impact of IT exploitation. Under a high level of internal innovation strategy, firms leveraging IT to support cross-functional communication and interaction may be more frequent, which can align well with the roles of IT exploration in facilitating innovation.

Additionally, an internal innovation strategy emphasizes self-reliance and a self-dependent strategic orientation. Firms adopting such a strategy may place greater importance on developing internal IT infrastructure and R&D investments. Maintaining a strong in-house IT base creates integrative abilities that help to promote skills and routines conducive to innovation (Grimpe and Kaiser 2010; Cassiman and Veugelers 2006). Therefore, both patterns of IT use are more effective in improving innovation performance when a firm employs an internal innovation strategy. Accordingly, we hypothesize that:

Hypothesis 2a. The positive effect of IT exploitation on innovation performance is stronger for firms employing an internal innovation strategy.

Hypothesis 2b. The positive effect of IT exploration on innovation performance is stronger for firms employing an internal innovation strategy.

In contrast, we posit that firms employing an external innovation strategy may weaken the roles of IT use in innovation performance. Based on DCV, learning and innovative progress involve a procedure of trial, feedback, and evaluation (Teece, Pisano, and Shuen 1997). If too many elements of a firm's learning and innovation environment change at the same stage, the ability of firms to determine the IT use-innovation performance relationship will be disrupted and disturbed, as cognitive structures will fail to form, resulting in diminished rates of innovation (Teece, Pisano, and Shuen 1997). Firms with a high degree of external innovation

strategy, which focuses on absorbing and utilizing SC partners' knowledge to innovate, may suffer from the costs of such a strategy, potentially confounding the firms' existing IT capabilities for innovation. Although a firm can access a larger knowledge pool through an external innovation strategy (Cassiman and Veugelers 2006; Anzola-Román, Bayona-Sáez, and García-Marco 2018), an abundance of external knowledge resources may be challenging to transfer into the knowledge base of an enterprise (Grimpe and Kaiser 2010; Zahra and George 2002). In this situation, the effectiveness of both patterns of IT use may be undermined when firms employ a high level of external strategy use.

Furthermore, an external innovation strategy indicates that a firm's strategic orientation is to rely on external coordination and cooperation with SC partners to achieve innovation. Overreliance on external cooperation may dilute the firm-specific IT resource base (Grimpe and Kaiser 2010; Kesidou et al. 2022). This impediment may prevent firms from focusing on developing and maintaining their internal IT infrastructures, thus undermining firms' IT capabilities for both exploitative and explorative innovation activities (Cui et al. 2015). Therefore, we believe that employing an external strategy by firms may hinder the effectiveness of patterns of IT use on innovation performance (Mata and Woerter 2013; Grimpe and Kaiser 2010). In summary, we propose that:

Hypothesis 3a. The positive effect of IT exploitation on innovation performance is weaker for firms employing an external innovation strategy.

Hypothesis 3b. The positive effect of IT exploration on innovation performance is weaker for firms employing an external innovation strategy.

As most firms are likely to employ inbound and outbound strategies simultaneously in practice, we focus on the ambidexterity perspective in terms of balanced and combined innovation strategy. Although most previous organizational studies have found that firms can benefit from ambidexterity (i.e., Salvador, Chandrasekaran, and Sohail 2014; Kortmann et al.

2014; Gu, Yang, and Huo 2021), we argue that the use of an ambidextrous innovation strategy may weaken the positive relationship between patterns of IT use and innovation performance.

Specifically, a balanced innovation strategy indicates that a firm allocates similar levels of resources and attention to both inbound and outbound innovation strategies. Allocating resources equally to internal and external innovation strategies does not guarantee equivalent returns (Grimpe and Kaiser 2010). A balanced strategy may confuse firms concerning strategic positioning and resource allocation priorities because of the so-called "attention allocation problem" (Kesidou et al. 2022). An internal innovation strategy, emphasizing inward R&D development, is prone to increase firms' self-reliant innovation capabilities (Zahra and George 2002; Roberts et al. 2012). However, firms that rely on SC partners to innovate may not invest sufficient effort into developing their own IT capabilities. In this case, the benefits derived from an internal innovation strategy may be counteracted by an external innovation strategy. Therefore, the effectiveness of patterns of IT use may be reduced when a firm employs a balanced innovation strategy.

Furthermore, we believe that a combined innovation strategy may impede the effectiveness of IT use in achieving innovation as well. A combined innovation strategy means that a firm's total level of internal innovation strategy multiplied by external innovation strategy is high. In this situation, although the use of an internal innovation strategy could facilitate the effectiveness of IT use for innovative activities, the drawbacks of external innovation strategies may also be exacerbated (Patel, Terjesen, and Li 2012). The high level of resource dilution and deterioration of IT capabilities resulting from external innovation strategies may undermine the normal mechanism of patterns of IT use in improving innovation performance (Grimpe and Kaiser 2010). Additionally, not all firms are capable of adopting a high degree of combined strategy (Mehrabi, Coviello, and Ranaweera 2019; Benner and Tushman 2015). According to the DCV, firms are resource-limited (Mehrabi, Coviello, and

Ranaweera 2019; Benner and Tushman 2015), and internal and external strategies are underlying incompatible strategies that compete for rare resources. If firms develop a high level of external strategy use, they may not have the resources and capability to focus on building internal R&D development. Therefore, firms with a high degree of combined innovation strategy are less likely to promote the effective mechanisms of patterns of IT use in achieving innovation performance. To sum up, we propose the following hypotheses. We show our research model in Figure 1.

Hypothesis 4a. The positive effect of IT exploitation on innovation performance is weaker for firms employing an ambidextrous (balanced and combined) innovation strategy.

Hypothesis 4b. The positive effect of IT exploration on innovation performance is weaker for firms employing an ambidextrous (balanced and combined) innovation strategy.

======== Figure 1 about here ========

4. Methodology

4.1 Data

We used data from the World Bank's Enterprise Survey conducted in China from December 2011 to February 2013, primarily referring to fiscal year 2011 (FY2011). Firms were re-interviewed for updated responses if they were interviewed prior to FY2011's end. The dataset included 2,700 privately-owned and 148 state-owned firms, selected via stratified random sampling based on industry, size, and region. Industry stratification included 11 manufacturing and 7 service industries, with 150 interviews targeted for each manufacturing industry. Size stratification classified firms into small (5-19 employees), medium (20-99 employees), and large (over 99 employees). Regional stratification covered 25 metro areas, chosen according to the number of establishments, employment contribution, and value added. The survey implementation entailed a two-stage process: an initial phone-administered

screener questionnaire to determine eligibility and schedule appointments, followed by face-to-face interviews with each establishment's managers, owners, or directors. Several studies have employed this survey data (Iriyama, Kishore, and Talukdar 2016; McCann and Bahl 2017; Storz, ten Brink, and Zou 2022). The data spans innovation activities across industry, size, and region, mitigating the bias that innovation activities predominantly involve larger firms (Storz, ten Brink, and Zou 2022). We limited our sample data to the manufacturing industry. After excluding firms with missing values, our sample consisted of 995 firms across 25 cities and 19 industries. Table B1 in Appendix B provides an outline of the selected firms' locations and industries.

4.2 Variables

Dependent variable

Innovation Performance: Innovation in manufacturing firms is expressed through both product and process innovation (Prajogo 2016). We evaluated innovation performance by measuring the proportion of production volume linked to new or improved products and processes, including non-patented innovations integrated into production.

Independent variable

IT exploitation, our independent variable, measured the extent of information technology utilization for four exploitative innovation activities: (a) technology training for staff, (b) adding new features to existing products or services, (c) reducing production costs, and (d) improving production flexibility. Managers' responses were assigned values of 1 (no use), 2 (some use), or 3 (heavy use). A confirmatory factor analysis (CFA) was used to assess content validity for IT exploitation, with factor loadings exceeding the minimum acceptable threshold (Hair et al. 1998). We use Cronbach's α to test internal reliability and the construct's Cronbach's α is 0.8707.

IT exploration, another independent variable, assessed the degree of information and communication technology usage in supporting four explorative innovation activities: (a) introducing new technology and equipment for product or process improvements, (b) implementing new quality control procedures, (c) introducing new managerial/administrative processes, and (d) introducing new products or services. Managers' responses were assigned values of 1 (no use), 2 (some use), or 3 (heavy use). The results of CFA for IT exploration have shown that the factor loadings of the construct are much higher than the lowest acceptable threshold and the Cronbach's α is 0.8838.

Moderators

We measured internal and external innovation, balanced innovation, and combined innovation using adapted questionnaires from prior studies (Mata and Woerter 2013; Chi et al. 2017; Luger, Raisch, and Schimmer 2018).

Internal Innovation was assessed using four questions regarding in-house product or service development and implementation with ideas from internal R&D. We assigned a value of 1 for affirmative responses and 0 otherwise. Our data only captured firms' engagement in internal or external innovation, not the invested amounts or proportions. The CFA results of internal innovation are shown in Table B2 in Appendix B. The factor loadings of the internal innovation are all higher than 0.8 and the Cronbach's α value is 0.8589.

External Innovation was measured using four questions related to product or service development and process improvement in cooperation with suppliers or client firms. We assigned a value of 1 for affirmative responses and 0 otherwise. Table B2 shows the CFA analysis results of external innovation. Cronbach's α value is 0.8516.

Balanced Innovation, representing equilibrium between internal and external innovation, was operationalized by reversing the absolute difference between internal and external

innovation (5 - |internal innovation - external innovation|), with a greater value demonstrating a greater level of the balanced innovation.

Combined Innovation, reflecting the combined magnitude of internal and external innovation, was calculated by multiplying internal and external innovation (internal innovation × external innovation), with internal and external scales mean-centered to mitigate multicollinearity.

Control variables

We accounted for potential confounding variables in our analysis. First, we considered firm age and size, as they relate to a firm's internal innovation capability and external interactions (Wang et al. 2015). Years since founding was used to measure firm age, and the number of full-time employees was used to determine firm size. Second, we controlled for IT expenditures and R&D investments, which influence firms' IT and innovation capabilities, respectively (Wang et al. 2015). R&D investment was determined by the sum of internal and contracted R&D activities, while IT expenditures included spending on various information processing equipment and software. Third, we incorporated manager experience, as it provides human and social capital, enabling firms to exploit resources for competitive advantage and improved innovation performance (Hmieleski, Carr, and Baron 2015). Manager experience was measured by the top manager's tenure at the firm. Fourth, we controlled for computer use, which enhances work efficiency, communication, and integration, essential for innovation (Ben-Daya, Hassini, and Bahroun 2017). Computer use was determined by the percentage of employees regularly using computers in their jobs. Fifth, we accounted for affiliation, as firms connected to larger organizations can access resources for innovation activities (Kim, Hoskisson, and Lee 2014). We set the value equal to 1 if the firm was affiliated with a larger firm, and 0 otherwise. Sixth, we controlled for capacity utilization and skilled labor, as they impact innovation outcomes and productivity (Enkel et al. 2017). Capacity utilization was

determined by the firm's amount of maximum possible productivity, and skilled labor was determined by the number of skilled full-time production workers. Seventh, we accounted for business city, as the environment and policies influence resource exchange and integration, promoting innovation (Prajogo 2016). A value of 1 was assigned if the firm was in a business city, and 0 otherwise. Lastly, we controlled for female leadership, which offers advantages in team cohesion, cooperative learning, and participative communication for innovation activities (Post 2015). We set the value equal to 1 if the firm's top leader is female, and 0 otherwise. The descriptive statistics and correlation analysis are shown in Table 1. We summarize all variable measures in Table B3 in Appendix B.

======== Table 1 about here ========

4.3 Econometric model

We employed the following specification to analyze the primary effects of a firm's IT exploitation and IT exploration on its innovation performance.

$$\text{Performance}_i = \beta_0 + \beta_1 exploitation_i + \beta_2 exploration_i + + \gamma X_i + \varepsilon_i \quad (1)$$

where performance_i represents the ith firm's innovation performance, while $exploitation_i$ and $exploration_i$ denote the ith firm's IT exploitation and exploration, respectively. X_i is a vector of control variables. ε_i is the error term. In accordance with H1 and H2, we anticipate β_1 and β_2 to be positive. Subsequently, we employed the following specifications to investigate the moderating roles of internal innovation, external innovation, combined innovation, and balanced innovation on the relationship between IT exploitation (or IT exploration) and innovation performance.

$$\text{Performance}_i = \beta_0 + \beta_1 exploitation_i + \beta_2 exploration_i + \beta_3 exploitation_i \times internal_i + \beta_4 exploitation_i \times external_i + \beta_5 exploitation_i \times balanced_i + \beta_6 exploitation_i \times combined_i + \beta_7 exploration_i \times internal_i + \beta_8 exploration_i \times$$

$$external_i + \beta_9 exploration_i \times balanced_i + \beta_{10} exploration_i \times combined_i +$$

$$\beta_{11} internal_i + \beta_{12} external_i + \beta_{13} balanced_i + \beta_{14} combined_i + \gamma X_i + \varepsilon_i \quad (2)$$

where $internal_i$ represents the ith firm's internal innovation, $external_i$ denotes the ith firm's external innovation, $balanced_i$ indicates the ith firm's balanced innovation, and $combined_i$ is the ith firm's combined innovation. We expect β_3 and β_7 to be positive, while β_4, β_5, β_6, β_8, β_9 and β_{10} to be negative.

5. Analysis and Results

5.1 Regression analysis

We utilize fractional logit regression to test the hypothesized framework. Model 1 of Table 2 reveals that both IT exploitation and IT exploration have positive and highly significant coefficients (exploitation: b = 0.156, p < 0.01; exploration: b = 0.246, p < 0.01), signifying their significantly positive impact on innovation performance, thus supporting H1a and H1b.

Concerning H2a, Model 2 in Table 2 demonstrates a significantly positive interaction between IT exploitation and internal innovation (b = 0.076, p < 0.10), suggesting that internal innovation amplifies the positive effects of IT exploitation on innovation performance. However, Model 6 shows a nonsignificant interaction between IT exploration and internal innovation (b = -0.011, p > 0.10). The positive moderating influence of internal innovation on the relationship between IT exploitation and innovation performance is shown in Figure 2(a).

Notably, a negative and significant interaction exists between IT exploitation and external innovation (b = -0.132, p < 0.01), indicating that external innovation negatively moderates the relationship between IT exploitation and innovation performance. Model 7 in Table 2 also exhibits a negative and significant interaction between IT exploration and external innovation (b = -0.142, p < 0.01). Figure 2(b) demonstrates the impact of IT exploitation and IT

exploration on innovation performance at different levels of external innovation. Consequently, H3a and H3b are supported.

Regarding ambidextrous innovation strategy, the interaction coefficients of balanced innovation and IT exploitation are -0.138 ($p < 0.05$) in Model 4 of Table 2. Model 5 shows a negative and significant interaction between IT exploitation and combined innovation ($b = -0.115$, $p < 0.01$), supporting H4a. Similarly, Model 8 presents negative and significant interaction coefficients of balanced innovation and IT exploration ($b = -0.147$, $p < 0.05$). The interaction between IT exploration and combined innovation is also significantly negative ($b = -0.084$, $p < 0.05$), thereby supporting H4b. Figure 2(c) shows the interactions, highlighting a negative moderating effect as balanced innovation ranges from low to high levels, further substantiating H4a and H4b.

======== Table 2 and Figures 2 about here ========

5.2 Endogeneity analysis

Endogeneity, resulting from omitted variables or reverse causality, may pose concerns in this study. Omitted variables could impact innovation performance, potentially leading to incorrect conclusions. Reverse causality is also problematic; managers may alter a firm's innovation strategy to address low innovation performance, which implies that the causality between dependent and independent variables could be reversed. In line with recommendations by Ho et al. (2017) and Lu et al. (2018), we applied the generated instrument method to address the endogeneity problems .

A convincing instrumental variable should meet the relevance and exclusion restriction assumptions (Wooldridge 2002). Specifically, this variable should be uncorrelated with innovation performance and correlated with IT exploitation and IT exploration. In essence, the instrument should explain the dependent variable solely through the endogenous variable.

We employed the average values of IT exploitation and IT exploration in a firm's city-industry as two instrumental variables for the respective independent variables (Müller, Fay, and vom Brocke 2018). Firms situated in the same city, operating within the same business environment, have similar probabilities of using IT for exploitative and explorative activities. Consequently, a firm's IT exploitation and IT exploration are likely to correlate with firms in the same city, satisfying the instrumental variable's relevance condition. Moreover, a firm's innovation performance is probably and directly influenced by IT exploitation and IT exploration at the industry level, thus satisfying the exclusion condition. We employed 2SLS and 2SRI as estimation methods to address endogeneity issues, with Tables 3 and 4 presenting the regression results.

Table 3 displays the 2SLS results. In the first stage, we regressed IT exploitation and IT exploration on the instrumental variables and control variables and the results are shown in Models 1 and 2. We find positive and significant coefficients of the two instrumental variables (IV_exploitative: $b = 0.451$, $p < 0.01$; IV_explorative: $b = 0.459$, $p < 0.01$). In the second stage (Model 3), we found that IT exploitation and IT exploration positively impact innovation performance (exploitation: $b = 0.055$, $p < 0.01$; exploration: $b = 0.048$, $p < 0.01$). The selected instrumental variables passed the underidentification and weak identification tests. Specifically, the result of the Kleibergen–Paap rk LM statistic of the underidentification test was 224.007 ($p < 0.01$), indicating that the model was not underidentified. Furthermore, the result of the Wald F statistic for the Cragg-Donald weak identification test was 294.084, and the Wald F statistic of the Kleibergen–Paap rk weak identification test was 407.580, also indicating that the instruments are not weak. The 2SLS estimation results were consistent with the main findings in Table 2.

In the 2SRI estimation approach, we incorporated the residuals of the first-stage as additional variable to reveal the error term correlated with the endogenous explanatory

variables (Menon, Mishra, and Ye 2020). The 2SRI method, exhibiting greater consistency than other two-stage methods (e.g., 2SLS and two-stage predictor substitution (2SPS)) (Menon, Mishra, and Ye 2020; Sevcenko and Ethiraj 2018), particularly for nonlinear models, has been utilized in operations management (Li, Netessine, and Koulayev 2018; Menon, Mishra, and Ye 2020; Setia, Bayus, and Rajagopalan 2020).

Applying the 2SRI approach, we included predicted residuals from first-stage models as additional explanatory variables in second-stage models, assessing the effects of IT exploitation and exploration on innovation performance. The first stage employed a linear model, and the second stage used a logit model. Table 4's Model 1 reveals significantly positive effects of IT exploitation and exploration on innovation performance (exploitation: $b = 0.370$, $p < 0.01$; exploration: $b = 0.276$, $p < 0.01$). Model 2 demonstrates that the positive influence of IT exploitation on innovation performance is more pronounced for firms adopting an internal strategy ($b = 0.073$, $p < 0.05$). Model 3 exhibits a negative interaction between external innovation and IT exploitation ($b = -0.125$, $p < 0.01$), while Model 4 displays a negative coefficient of the interaction between balanced innovation and IT exploitation ($b = -0.129$, $p < 0.05$). Model 5 reports a negative coefficient of the interaction between IT exploitation and combined innovation ($b = -0.111$, $p < 0.01$). Table 4's Model 7 indicates that the positive impact of IT exploration on innovation performance is weaker for an external strategy ($b = -0.135$, $p < 0.01$). Model 8 presents a negative and significant coefficient for the interaction between balanced innovation and IT exploration ($b = -0.140$, $p < 0.05$). The interaction coefficient of IT exploration and combined innovation in Model 8 is also negative ($b = -0.083$, $p < 0.05$). The 2SRI models' results reveal that including residuals does not alter the statistical significance of the main results.

======== Table 3 and 4 about here ========

5.3 Addressing selection bias

One potential issue encountered in this study was sample selection bias. A firm's IT exploitation and exploration are dictated by its IT strategies, with some firms leveraging IT for other operational activities. To mitigate potential selection bias, we employed Heckman (1979) two-step method.

In the first step, managers who reported using IT for exploitation and exploration were coded as 1, while those who did not respond to this question were coded as 0. We then regress the control variables by using a probit model. The outcomes of the initial step revealed disparities between our sample and other firms excluded from our analysis. We estimated the "inverse Mills ratio" (IMR) in the first step and incorporated it in the second step. Table 5 reports the findings of the Heckman two-step method.

In the Model 1 of Table 5, we find that after adjusting for sample selection error, the impacts of IT exploitation and IT exploration on innovation performance are significantly positive (exploitation: $b = 0.152$, $p < 0.01$; exploration: $b = 0.245$, $p < 0.01$). As shown in Model 2, the interaction coefficients of IT exploitation and internal innovation remain positive and significant following sample selection error correction ($b = 0.073$, $p < 0.10$). Furthermore, after accounting for sample selection error, the interaction coefficient of IT exploitation and external innovation is negative ($b = -0.134$, $p < 0.01$). The interaction coefficient of IT exploitation and balanced innovation is -0.137 ($p < 0.05$). In Model 5, the interaction coefficients of IT exploitation and combined innovation are negative ($b = -0.116$, $p < 0.01$). As illustrated in Model 7, after correcting for sample selection error, the interaction coefficient of IT exploration and external innovation is negative ($b = -0.143$, $p < 0.01$). The interaction coefficient of IT exploration and balanced innovation is -0.146 ($p < 0.05$). Model 9 shows that after accounting for sample selection error, the interaction coefficient of IT exploration and combined innovation is negative ($b = -0.085$, $p < 0.05$).

In prior analyses, we employed multiple items to gauge IT exploitation, IT exploration, internal innovation, and external innovation through principal component analysis. For robustness evaluation, we utilized the average value of items for each construct to conduct analogous analyses. The outcomes of the 2SLS, 2SRI, and Heckman analyses are presented in Appendix C (Table C1-4), substantiating the robustness of our findings.

======== Table 5 about here ========

6. Discussion and Conclusion

In this study, we investigated the roles of IT use patterns (i.e., IT exploitation and IT exploration) on innovation performance, drawing upon the dynamic capabilities view. In addition, we examined how the moderating role of internal, external, and ambidextrous innovation strategies as organizational paths influence this relationship. Utilizing data from 995 Chinese manufacturers in the World Bank China Enterprise Survey, our empirical findings underscore the positive association between both IT use patterns and innovation performance. Moderating results reveal that an internal innovation strategy strengthens the positive impact of IT exploitation yet has an insignificant effect on IT exploration. Intriguingly, the positive impacts of both IT use patterns on innovation are weakened when firms adopt external and ambidextrous innovation strategies. Our findings emphasize the crucial role of IT use patterns and SC innovation strategies in shaping innovation performance, offering valuable insights for both academia and practice.

6.1 Theoretical implications

Our study contributes significantly to the literature in three main ways. First, we address a knowledge gap in the innovation literature by examining the impact of IT use patterns on innovation performance. While existing research has explored IT's role in innovation outcomes (Gómez, Salazar, and Vargas 2017; Joshi et al. 2010; Kleis et al. 2012), the specific effects of

IT use patterns, namely IT exploitation and IT exploration, have not been received adequate attention. Previous studies have predominantly focused on the influence of IT use patterns on SC resilience and cooperation (Sanders 2008; Gu, Yang, and Huo 2021), with limited attention to their impact on innovation performance. A recent study has explored the relationship between IT use patterns and service innovation performance (Chen et al. 2021). Innovation performance contains outcome innovation and process innovation, which is a more general performance. Further analysis is needed to explore the influence of IT use patterns on innovations. Our research builds upon this by conducting a comprehensive analysis of the connection between IT use patterns and innovation performance, thereby contributing to the innovation literature based on DCV. We reveal the positive and significant role of both IT exploitation and IT exploration in enhancing innovation performance, emphasizing the importance of distinct IT use modalities, and providing deeper insights into the conditions and consequences of IT use on innovation performance. Additionally, we contribute to the existing literature by providing a more nuanced understanding of IT use complexity and its implications for innovation performance.

Second, our study offers detailed insights into the moderating effects of SC innovation strategies on the relationship between IT use patterns and innovation performance. While previous studies have explored the mechanisms underlying the influence of IT use patterns on innovation performance (Joshi et al. 2010), our research advances this by investigating the specific SC innovation strategies that may shape the effectiveness of IT use patterns on innovation performance. We focus on internal and external innovation strategies within the SC context, also distinguishing between their ambidextrous effects. Our findings highlight that an internal innovation strategy positively moderates the relationship between IT exploitation and innovation performance. This suggests a path-dependent trajectory where the utility of exploitative IT practices is contingent upon internal routines, as posited by previous studies

(Gu, Yang, and Huo 2021; Vergne and Durand 2010). In contrast, explorative IT use, aimed at creating new products and services, is less influenced by internal innovation strategy. Notably, our study indicates that external and ambidextrous innovation strategies, on the other hand, exert negative moderation on the relationship between both IT use patterns and innovation performance.

These findings suggest that an overreliance on external partners and collaborations may hinder the potential benefits derived from of IT use in enhancing innovation performance. Our results underscore the importance of self-reliance over dependence on external partners for innovation and accentuate the significance of fostering an internal innovation competency. This notion is increasingly important in the context of the current global environment, which is characterized by heightened uncertainty (Akkermans and Van Wassenhove 2018; Mata and Woerter 2013). In times of uncertainty, the agility and responsiveness afforded by self-reliance of internal innovation strategy become invaluable. Firms that implementing internal innovation strategy can cultivate robust internal innovation processes and more swiftly adapt to changing market dynamics and technological disruptions (Akkermans and Van Wassenhove 2018; Grimpe and Kaiser 2010). Moreover, internal innovation efforts often lead to the development of unique resources and capabilities that can serve as a source of facilitating IT capabilities. Conversely, an over-dependence on external partners for innovation can introduce additional layers of risk and complexity. While collaborations with external entities can provide access to new knowledge (Berchicci 2013), they can also lead to increased coordination costs, potential misalignment of objectives, and ignorance of developing firms' own innovation resources and capabilities. Consequently, our study contributes to the extant literature by delineating the conditions under which IT exploitation and exploration are differentially effective, thereby offering a more granular understanding of how firms can utilize IT capability and innovation strategy to drive innovation performance.

Lastly, our research contributes to the field by innovatively integrating the concepts of IT use patterns, SC innovation strategy, and innovation performance through the theoretical lens of DCV. Prior studies have mainly applied organization learning theory to explore the relationship between IT use and firm performance (Chen, Liu, and Chen 2022; Zhen et al. 2021), but few studies apply DCV to frame the relationship between IT use and innovation performance. DCV offers a unique framework for understanding how organizations can leverage their IT resources and innovation strategies to achieve superior innovation performance. Following the theoretical lens of DCV, we recognize patterns of IT use as a critical dynamic capability that can integrate and reconfigure organizational IT competencies to support innovation. Based on DCV, we also underline how SC innovation strategy (i.e., internal, external and ambidextrous SC innovation strategies) as essential organizational paths can shape the effectiveness of IT capabilities. By doing so, we provide a theoretical extension of DCV, and offer a new perspective for analyzing the interplay between IT use patterns and SC innovation strategy on innovation performance through the lens of DCV.

6.2 Practical implications

Our study provides valuable practical implications for firms. Firstly, our findings provide insights into leveraging distinct IT capabilities, specifically IT exploitation and exploration, to enhance innovation performance. We demonstrate the positive effects of both exploitative and explorative IT use on innovation outcomes. These results suggest firms increase investment in information and communication technologies so as to strengthen IT capabilities. From a top management or board perspective, allocating resources and governance attention to both exploitation and exploration IT investments is crucial, as they influence firms' innovation performance, especially in the current highly competitive environment. Our study offers

practical guidance for firms seeking to effectively utilize IT for both exploitative and explorative innovation activities.

Secondly, our findings emphasize the differing roles of SC innovation strategies—internal, external, and ambidextrous-in shaping the effectiveness of firms' IT use for achieving innovation performance. We found that an internal innovation strategy strengthens the effect of IT exploitation but has a non-significant moderating effect on IT exploration. Thus, we recommend firms adopt an internal innovation strategy focused on developing in-house R&D capabilities when leveraging IT, particularly for exploitation. Furthermore, the negative moderating effects of both external and ambidextrous innovation strategies suggest firms should be cautious of the potential drawbacks and costs of external innovation. Overreliance on suppliers and customers for innovation may undermine firms' IT capabilities and offset the benefits of internal innovation strategies. Consequently, we advise firms to prioritize internal innovation strategies over collaborative innovation with SC partners when using IT to support innovation.

Our nuanced moderating results also offer insights into firms operating in the post-epidemic context. Given the increasing likelihood of "black swan" events (e.g., COVID-19) (Akkermans and Van Wassenhove 2018), external SCs are fragile and unstable, necessitating the development of innovation capabilities within organizations. In this context, an internal innovation strategy plays an essential role in facilitating the effectiveness of IT use patterns. The key takeaway for firms leveraging IT use patterns is to focus on building self-reliant innovation capabilities rather than depending on SC partners to attain a competitive advantage in achieving innovation.

6.3 Limitations and future research directions

Our study does face some limitations that can be addressed in future research. First, we focus exclusively on two distinct IT use patterns—IT exploitation and IT exploration—within the context of their impact on performance, specifically innovation performance. This deliberate choice leaves room for subsequent investigations to delve into additional IT use patterns concerning various performance metrics. For example, future studies may explore the connections between internal and external IT use concerning operational performance, as well as the interplay between customer and supplier IT use and its effects on supply chain performance (Gu, Yang, and Huo 2021). Second, our study examines this relationship based on data concerning Chinese manufacturers. Although China, as the "world's factory", plays a key role in the global market (Liu, Luo, and Liu 2009; Zhang, Jin, and Yang 2020), the generalizability of this study remains limited. We thus recommend that future research should investigate different countries or conduct comparison studies in different cultural settings to determine whether the results differ. Third, our study considers contextual factors only with respect to SC innovation strategies. We suggest that future research should produce a more explicit account of the various innovation modes, integrating not only internal and external strategies but also R&D outsourcing or the in-licensing of technology (Grimpe and Kaiser 2010). Other contingent factors, such as environmental uncertainty (Xue, Ray, and Sambamurthy 2012) and IT governance (Chau et al. 2020), may also influence the IT use-innovation performance relationship. Thus, we encourage future studies to make context-sensitive extensions and recognize contextual differences.

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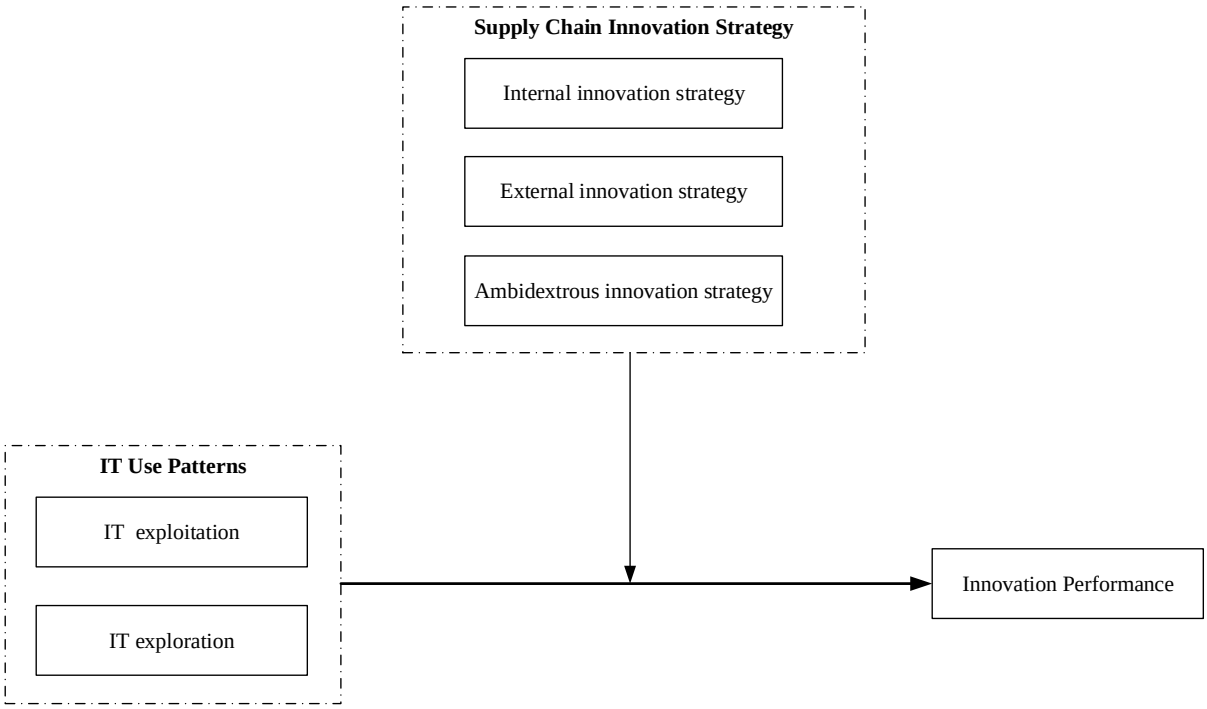


Figure 1. Research model

Figure 1 Alt Text: The relationship between IT use patterns (i.e., IT exploitation and IT exploration) and innovation performance is moderated by the supply chain innovation strategy (i.e., internal, external, and ambidextrous innovation strategy).

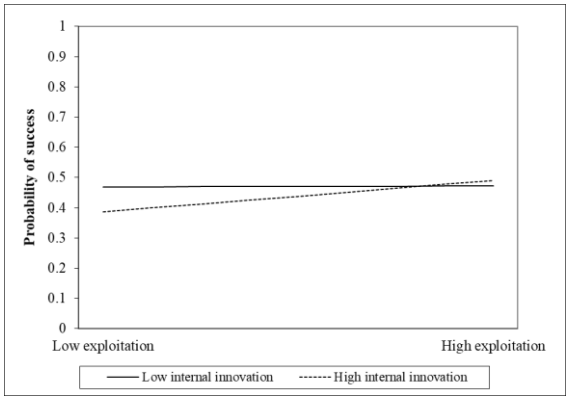
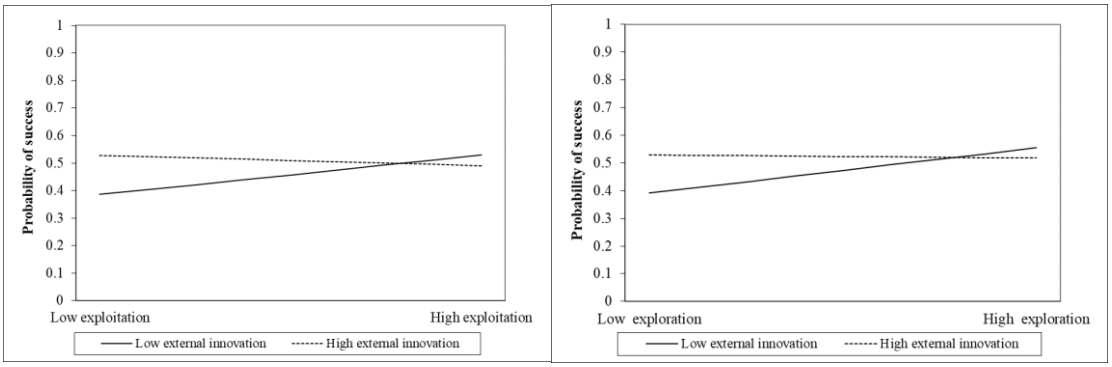


Figure 2(a) The moderating role of internal innovation

Figure 2(a) Alt Text: The positive relationship between IT exploitation and innovation exhibits a steeper slope when the internal innovation strategy is high, compared to when the internal innovation strategy is low.



(1) (2)

Figure 2(b) The moderating role of external innovation

Figure 2(b) Alt Text: The positive relationship between IT exploitation (IT exploration) and innovation demonstrates a steeper slope when the external innovation strategy is low, compared to when the external innovation strategy is high.

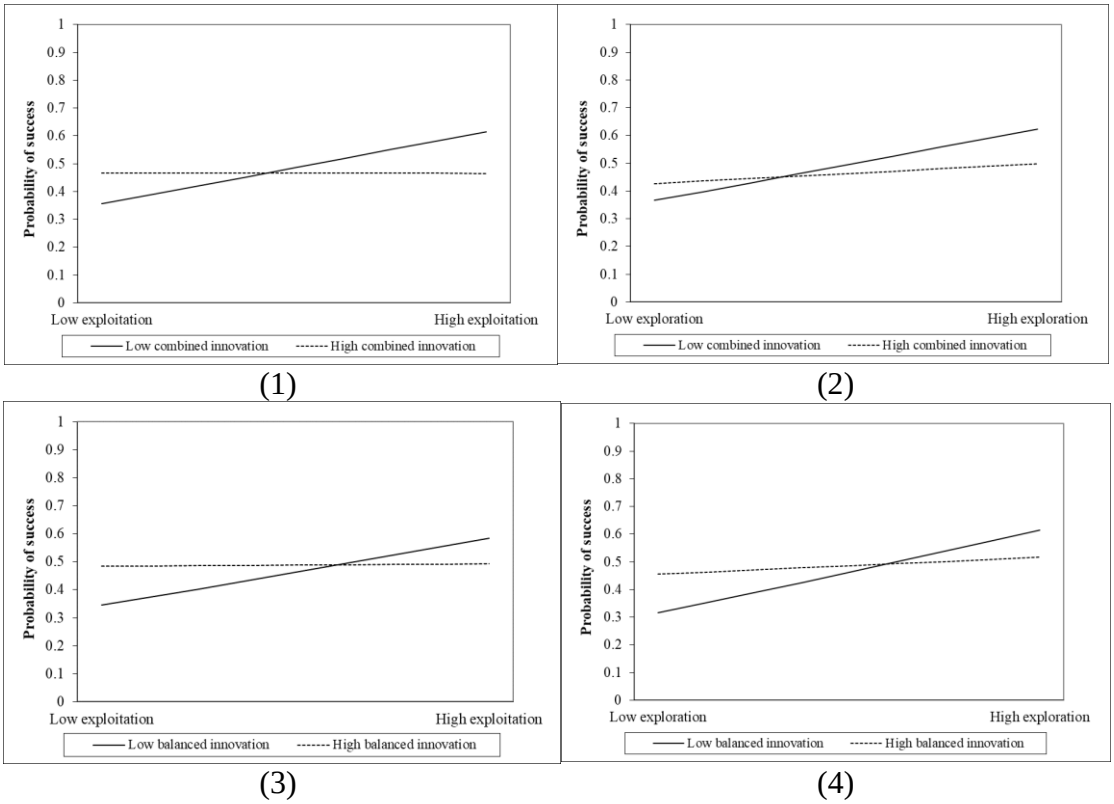


Figure 2(c) The moderating role of ambidextrous innovation strategy

Figure 2(c) Alt Text: The positive relationship between IT exploitation (IT exploration) and innovation demonstrates a steeper slope when the combined innovation strategy is low, compared to when the combined innovation strategy is high. Similarly, the positive relationship between IT exploitation (IT exploration) and innovation exhibits a steeper slope when the balanced innovation strategy is low, compared to when the balanced innovation strategy is high.

Figure 2 Plots of moderating effects of SC innovation strategy

Figure 2 Alt Text: Depict the relationship between IT use patterns and innovation across various supply chain innovation strategies.

Table 1. Descriptive Statistics and Correlation Analysis

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Innovation performance	1.000											
(2) IT exploitation	0.295***	1.000										
(3) IT exploration	0.312***	0.799***	1.000									
(4) Internal strategy	0.017	0.179***	0.219***	1.000								
(5) External strategy	0.099***	0.230***	0.311***	0.243***	1.000							
(6) Combined strategy	0.056*	0.110***	0.154***	-0.178***	0.334***	1.000						
(7) Balanced strategy	0.003	0.017	0.072**	0.047	0.046	0.630***	1.000					
(8) Firm age	-0.022	0.036	0.037	0.048	-0.032	-0.007	0.003	1.000				
(9) Manager experience	0.031	0.037	0.057*	0.005	-0.009	-0.007	0.017	0.358***	1.000			
(10) IT Expenditures	-0.012	-0.055*	-0.035	0.024	-0.030	-0.035	-0.034	-0.038	-0.030	1.000		
(11) Computer use	0.022	-0.035	-0.015	0.001	0.024	0.035	0.002	-0.046	-0.124***	-0.009	1.000	
(12) Affiliation	0.096***	0.125***	0.150***	0.069**	0.092***	0.033	-0.008	-0.048	0.055*	0.083***	0.083***	1.000
(13) R&D	0.128***	0.044	0.090***	0.066**	-0.007	-0.042	-0.023	0.026	0.057*	0.000	0.030	0.124***
(14) Labor	0.043	0.027	0.071**	0.065**	0.013	-0.019	-0.008	0.049	0.043	0.647***	0.015	0.187***
(15) Capacity utilization	-0.109***	0.090***	0.114***	0.089***	-0.013	-0.048	-0.029	0.033	0.014	-0.019	-0.125***	0.026
(16) Skilled labor	-0.030	0.041	0.055*	0.053*	0.019	-0.020	0.007	0.087***	0.059*	0.303***	0.042	0.154***
(17) Business city	-0.106***	-0.002	0.065**	0.131***	0.155***	0.038	0.081**	0.038	-0.093***	0.013	0.151***	0.063**
(18) Female leader	0.044	0.037	0.044	-0.002	0.041	0.005	-0.042	-0.073**	-0.086***	-0.011	0.047	0.018
Mean	0.201	0.021	0.017	0.106	0.006	0.232	3.963	0.011	0.022	0.013	-0.08	-0.01
SD	0.182	0.998	0.986	0.947	0.989	0.874	0.597	1.002	1.013	1.204	0.878	0.989

Variables	(13)	(14)	(15)	(16)	(17)	(18)
(13) R&D	1.000					
(14) Labor	0.421***	1.000				
(15) Capacity utilization	0.043	-0.002	1.000			
(16) Skilled labor	0.266***	0.783***	-0.023	1.000		
(17) Business city	0.029	0.037	0.114***	0.031	1.000	
(18) Female leader	-0.019	-0.023	-0.068**	-0.027	0.009	1.000
Mean	0.053	0.021	86.327	0.017	0.881	0.091
SD	1.293	1.098	10.975	1.05	0.323	0.288

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 2. Regression Results of the Influences of IT Use Patterns on Innovation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
exploitative	**0.156*****	**0.150*****	**0.162*****	**0.691*****	**0.171*****	**0.158*****	**0.171*****	**0.146****	**0.157*****
	[0.059]	[0.058]	[0.059]	[0.227]	[0.058]	[0.059]	[0.059]	[0.059]	[0.059]
explorative	**0.246*****	**0.243*****	**0.243*****	**0.255*****	**0.266*****	**0.246*****	**0.229*****	**0.841*****	**0.271*****
	[0.062]	[0.061]	[0.061]	[0.063]	[0.063]	[0.062]	[0.062]	[0.250]	[0.063]
exploitative×internal		**0.076***							
		[0.039]							
exploitative×external			**-0.132*****						
			[0.035]						
exploitative×balanced				**-0.138****					
				[0.057]					
exploitative×combined					**-0.115*****				
					[0.042]				
explorative×internal						**-0.011**			
						[0.034]			
explorative×external							**-0.142*****		
							[0.038]		
explorative×balanced								**-0.147****	
								[0.060]	
explorative×combined									**-0.084****
									[0.040]
internal	-0.050	-0.050	-0.041	-0.054	-0.043	-0.050	-0.029	-0.054	-0.042
	[0.040]	[0.040]	[0.040]	[0.040]	[0.041]	[0.040]	[0.041]	[0.040]	[0.040]
external	0.035	0.033	0.079*	0.042	0.058	0.036	0.076*	0.046	0.058
	[0.041]	[0.041]	[0.042]	[0.041]	[0.041]	[0.041]	[0.042]	[0.041]	[0.042]
combined	-0.035	-0.051	0.007	-0.031	-0.014	-0.032	0.030	-0.039	-0.026
	[0.061]	[0.061]	[0.060]	[0.061]	[0.061]	[0.061]	[0.061]	[0.061]	[0.061]
balanced	0.019	0.039	-0.002	0.033	0.020	0.017	-0.013	0.030	0.015
	[0.079]	[0.079]	[0.079]	[0.079]	[0.079]	[0.079]	[0.079]	[0.078]	[0.079]
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	995	995	995	995	995	995	995	995	995
adj. R^2	0.0363	0.0369	0.0387	0.0371	0.0376	0.0363	0.0387	0.0372	0.0370

Standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3. Results of 2SLS

	exploitative	explorative	innovation
	(1)	(2)	(3)
IV_exploitative	**0.451*****		
	[0.028]		
IV_explorative		**0.459*****	
		[0.029]	
exploitative		0.662***	**0.055*****
		[0.018]	[0.015]
explorative	0.672***		**0.048*****
	[0.019]		[0.015]
Industry	Yes	Yes	Yes
Controls	Yes	Yes	Yes
N	1404	1404	995
adj. R^2	0.718	0.724	0.112

Standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4. Results of 2SRI

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
exploitative	**0.370*****	**0.353*****	**0.365*****	**0.873*****	**0.377*****	**0.373*****	**0.389*****	**0.359*****	**0.368*****
	[0.093]	[0.094]	[0.093]	[0.228]	[0.091]	[0.094]	[0.093]	[0.092]	[0.093]
explorative	**0.276*****	**0.284*****	**0.276*****	**0.278*****	**0.299*****	**0.275*****	**0.245*****	**0.840*****	**0.304*****
	[0.092]	[0.092]	[0.092]	[0.091]	[0.093]	[0.092]	[0.092]	[0.248]	[0.094]
exploitative×internal		**0.073****							
		[0.037]							
exploitative×external			**-0.125*****						
			[0.035]						
exploitative×balanced				**-0.129****					
				[0.055]					
exploitative×combined					**-0.111*****				
					[0.040]				
explorative×internal						**-0.013**			
						[0.034]			
explorative×external							**-0.135*****		
							[0.038]		
explorative×balanced								**-0.140****	
								[0.057]	
explorative×combined									**-0.083****
									[0.039]
internal	-0.043	-0.044	-0.035	-0.047	-0.036	-0.043	-0.024	-0.048	-0.035
	[0.040]	[0.040]	[0.040]	[0.040]	[0.040]	[0.040]	[0.041]	[0.040]	[0.040]
external	0.025	0.023	0.066	0.032	0.048	0.026	0.064	0.036	0.048
	[0.041]	[0.041]	[0.042]	[0.041]	[0.040]	[0.041]	[0.042]	[0.041]	[0.041]
combined	-0.025	-0.041	0.015	-0.021	-0.005	-0.021	0.036	-0.029	-0.016
	[0.061]	[0.061]	[0.060]	[0.061]	[0.061]	[0.061]	[0.061]	[0.060]	[0.060]
balanced	0.025	0.045	0.006	0.037	0.027	0.023	-0.005	0.034	0.021
	[0.078]	[0.078]	[0.078]	[0.078]	[0.078]	[0.078]	[0.078]	[0.078]	[0.078]
Xuhat_exploitative	-0.317***	-0.300**	-0.302**	-0.321***	-0.307**	-0.319***	-0.325***	-0.314***	-0.313***
	[0.121]	[0.121]	[0.121]	[0.120]	[0.120]	[0.121]	[0.119]	[0.120]	[0.121]
Xuhat_explorative	-0.047	-0.064	-0.051	-0.037	-0.053	-0.046	-0.025	-0.046	-0.051
	[0.114]	[0.115]	[0.114]	[0.114]	[0.115]	[0.114]	[0.112]	[0.114]	[0.115]
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	995	995	995	995	995	995	995	995	995
adj. R^2	0.0403	0.0409	0.0425	0.0411	0.0416	0.0403	0.0425	0.0411	0.0410

Standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5. Results of Heckman

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
exploitative	**0.152*****	**0.147****	**0.158*****	**0.683*****	**0.167*****	**0.154*****	**0.167*****	**0.142****	**0.153*****
	[0.059]	[0.058]	[0.059]	[0.225]	[0.058]	[0.059]	[0.059]	[0.059]	[0.059]
explorative	**0.245*****	**0.243*****	**0.242*****	**0.254*****	**0.265*****	**0.245*****	**0.228*****	**0.836*****	**0.270*****
	[0.061]	[0.061]	[0.061]	[0.062]	[0.063]	[0.061]	[0.061]	[0.249]	[0.063]
exploitative×internal		**0.073***							
		[0.039]							
exploitative×external			**-0.134*****						
			[0.035]						
exploitative×balanced				**-0.137****					
				[0.057]					
exploitative×combined					**-0.116*****				
					[0.041]				
explorative×internal						**-0.014**			
						[0.034]			
explorative×external							**-0.143*****		
							[0.037]		
explorative×balanced								**-0.146****	
								[0.059]	
explorative×combined									**-0.085****
									[0.040]
internal	-0.062	-0.062	-0.054	-0.066	-0.055	-0.063	-0.042	-0.067	-0.054
	[0.041]	[0.041]	[0.041]	[0.041]	[0.042]	[0.041]	[0.042]	[0.041]	[0.041]
external	0.033	0.031	0.077*	0.040	0.056	0.034	0.074*	0.044	0.056
	[0.041]	[0.041]	[0.042]	[0.041]	[0.041]	[0.041]	[0.042]	[0.041]	[0.041]
combined	-0.032	-0.048	0.012	-0.028	-0.011	-0.028	0.034	-0.036	-0.023
	[0.061]	[0.061]	[0.060]	[0.061]	[0.061]	[0.061]	[0.061]	[0.061]	[0.061]
balanced	0.018	0.037	-0.004	0.031	0.019	0.015	-0.015	0.028	0.013
	[0.079]	[0.078]	[0.079]	[0.078]	[0.079]	[0.079]	[0.079]	[0.078]	[0.079]
imr	-1.341	-1.232	-1.457	-1.315	-1.377	-1.359	-1.421	-1.316	-1.345
	[1.112]	[1.109]	[1.130]	[1.118]	[1.117]	[1.111]	[1.118]	[1.117]	[1.109]
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	995	995	995	995	995	995	995	995	995
adj. R^2	0.0366	0.0372	0.0391	0.0374	0.0380	0.0366	0.0391	0.0375	0.0373

Standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Supplementary Appendix

Appendix A

Table A1. Summary of Empirical Studies on IT Exploitation and Exploration

Study	Independent variable	Dependent variable	Mediator/moderator	Theory	Finding
Subramani (2004)	IT use for exploitation and IT use for exploration	First-Order benefits: operational benefits and strategic benefits; Second-Order benefits: competitive performance	Mediators: business-process specificity and domain-knowledge specificity	Organizational theories of learning and action and transaction cost theory	Two patterns of Supply Chain Management System (SCMS) use by suppliers—exploitation and exploration—establish environments conducive to suppliers making relationship-specific investments in business processes and domain knowledge. Subsequently, these investments empower suppliers to generate value and retain a share of the value derived from employing these systems in interfirm relationships.
Sanders (2008)	IT use for exploitation and IT use for exploration	Operational benefits and strategic benefits	Mediators: operational coordination and strategic coordination	Organizational theories of learning	While both coordination activities are essential for attaining strategic and operational benefits, we observe that each coordination activity is distinctly promoted by a specific pattern of IT use. IT use for exploitation is identified as a precursor to operational coordination, while IT use for exploration is identified as a precursor to strategic coordination.
Liu, McKone-Sweet, and Shah (2009)	IT use for exploitation and IT use for exploration	Operational performance	Mediator: supply chain planning capability	Resource-based view	Leveraging IT to exploit existing opportunities directly and indirectly affects operational performance, with the indirect impact mediated through supply chain planning capabilities. However, utilizing IT to explore new opportunities does not have either a direct or an indirect effect on operational performance.
Huang and Chou (2013)	External technology acquisition (ETA) and external technology exploitation (ETE)	Firm performance	Moderators: internal R&D and environmental turbulence (technological turbulence and market turbulence)		ETA positively affects firm performance, whereas ETE does not. ETA strengthens the relationship between ETE and firm performance. Both ETA and ETE are positively related to firm performance under high internal R&D investment and market turbulence. Technological turbulence only positively affects the relationship between ETA, but not ETE, and firm performance.

Mao and Quan (2015)	IT exploration capability and IT exploitation capability	Organizational agility			IT exploration and exploitation capabilities have positive effects on customer, operational and partner agilities. IT exploitation capability mediates the relationship between IT exploration capability and organizational agility.
Morimura and Sakagawa (2018)	IT use for exploitation and IT use for exploration	Standardization of pricing and promotion strategies			IT use for exploitation has a positive effect on the standardization of promotion strategies, whereas IT use for exploration has a positive impact on the standardization of pricing strategies.
Jiang, Han, and Huo (2020)	IT use for exploitation and IT use for exploration	Environmental performance and economic performance	Mediators: green strategy alignment and green process coordination		IT use for both exploitation and exploration demonstrates a positive association with green strategy alignment and green process coordination. However, the connection between IT use for exploration and green strategy alignment is comparatively weaker. While green strategy alignment marginally contributes to positive economic performance, its impact on environmental performance is not statistically significant. On the other hand, green process coordination positively influences environmental performance, but its effect on economic performance lacks statistical significance.
Chen et al. (2021)	IT exploration and IT exploitation	Service innovation	Moderator: cross-functional integration (CFI)	Knowledge-based view	IT exploration exhibits positive associations with both radical and incremental service innovations, while IT exploitation is only positively linked to radical service innovation. CFI positively moderates the relationship between IT exploitation and service innovation.
Gu, Yang, and Huo (2021)	Exploitative use of IT and explorative use of IT	Supply chain performance	Mediators: supplier and customer resilience	Information processing theory	Only explorative engagement with IT involving suppliers and customers contributes to the enhancement of supplier and customer resilience, while exploitative IT use yields no significant effects. The ambidextrous use of IT with suppliers does not enhance supplier resilience; however, such ambidextrous patterns on the customer side demonstrate effectiveness. Improved resilience of both suppliers and customers positively influences supply chain performance, especially in highly volatile environments.
Jean, Kim, and Choi (2021)	IT exploration and IT exploitation	Relationship performance	Mediator: relationship learning; Moderators: technological uncertainty and cultural distance	Resource based view	The exploratory aspect of IT use significantly influences relationship learning and establishes a positive relationship between relationship learning and performance. Additionally, the impact of IT exploration

					on relationship learning is positively moderated by technological uncertainty but negatively moderated by cultural distance. In contrast, the effect of IT exploitation on relationship learning is negatively moderated by technological uncertainty but positively moderated by cultural distance.
Zhen et al. (2021)	IT exploration and IT exploitation	Organizational agility		Organizational inertia theory	Organizational agility is positively associated with both IT exploration and exploitation, with IT exploitation exerting a predominant influence.
Liang, Wang, and Xue (2022a)	IT exploitation; IT exploration	Organizational agility	Moderator: environmental dynamism		IT exploitation and exploration both demonstrate significant enhancements to organizational agility. The synergy between IT exploration and exploitation particularly amplifies agility, especially in dynamic environments. Achieving a simultaneous perfect balance in the levels of IT exploitation and exploration is not a requisite for enhancing organizational agility.
Chen, Liu, and Chen (2022)	IT exploitation and IT exploration	Firm performance	Mediators: novelty-centered business model design (NBMD); efficiency-centered business model design (EBMD)	Organizational learning theory	IT exploration exhibits positive correlations with both NBMD and EBMD, while IT exploitation is positively linked only to EBMD. Both NBMD and EBMD show significant associations with firm performance. The relationship between NBMD and EBMD initially experiences a decline followed by an ascent as the balance between IT exploration and exploitation increases. In cases of imbalance between IT exploration and exploitation, NBMD decreases, but EBMD rises.
Liu, Liu, and He (2023)	DT (digital transformation) exploitation, DT exploration, and DT ambidexterity	Business performance			DT exploitation, DT exploration, and DT ambidexterity exhibit positive effects on business performance, albeit with heterogeneity.
Our study	IT exploitation and IT exploration	Innovation performance	Moderators: internal, external, and ambidextrous SC innovation strategies	Dynamic capabilities view	IT exploitation and exploration exert positive influences on innovation performance. The internal innovation strategy enhances the positive impact of IT exploitation but exhibits a non-significant moderating effect on IT exploration. However, the favorable impacts of both IT use patterns on innovation diminish when firms adopt external and ambidextrous innovation strategies.

Appendix B

Table B1. Demographic Profile of the Sample (N =995)

Industry	Frequency	%	City	Frequency	%
Food	111	11.16	Hefei	70	7.04
Textiles	83	8.34	Beijing	22	2.21
Garments	82	8.24	Guangzhou	52	5.23
Leather	6	0.6	Shenzhen	58	5.83
Wood	3	0.3	Foshan	81	8.14
Paper	11	1.11	Dongguan	27	2.71
Recorded media	11	1.11	Shijiazhuang	47	4.72
Refined petroleum product	3	0.3	Tangshan	43	4.32
Chemicals	89	8.94	Zhengzhou	47	4.72
Plastics & rubber	92	9.25	Luoyang	42	4.22
Nonmetallic mineral products	97	9.75	Wuhan	37	3.72
Basic metals	52	5.23	Nanjing	33	3.32
Fabricated metal products	98	9.85	Wuxi	48	4.82
Machinery and equipment	66	6.63	Suzhou	30	3.02
Electronics (31 & 32)	104	10.45	Nantong	38	3.82
Precision instruments	10	1.01	Shenyang	42	4.22
Transport machines (34&35)	66	6.63	Dalian	41	4.12
Furniture	8	0.8	Jinan	46	4.62
Recycling	3	0.3	Qingdao	65	6.53
			Yantai	32	3.22
			Shanghai	8	0.80
			Chengdu	25	2.51
			Hangzhou	20	2.01
			Ningbo	24	2.41
			Wenzhou	17	1.71

Table B2. Convergent Validity and Reliability Analysis

Constructs	Factor loadings	Cronbach α
IT use for exploitation (KMO = 0.7864, $\chi^2(6) = 3046.91$, p = 0.000)		
Provide technology training for staff	0.7882	0.8707
Add new features to existing products or services	0.8430	
Take measures to reduce production costs	0.8817	
Take actions to improve production flexibility	0.8865	
IT use for exploration (KMO = 0.8187, $\chi^2(6) = 3130.73$, p = 0.000)		
Introduce new technology and equipment(s) for product or process improvements	0.8842	0.8838
Introduce new quality control procedure in production or operations	0.8935	
Introduce new managerial/administrative processes	0.8310	
Introduce a new product or new service	0.8378	
Internal innovation (KMO = 0.6730, χ^2 (6) = 3361.29, p = 0.000)		
Developed or adapted in house	0.8599	0.8589
Implemented idea from internal R&D	0.8443	
Developed or adapted in house	0.8336	
Implemented idea from internal R&D	0.8167	
External innovation (KMO = 0.6678, χ^2 (6) = 3423.70, p = 0.000)		
Developed in cooperation with suppliers	0.8446	0.8516
Developed in cooperation with client firms	0.8401	
Developed in cooperation with suppliers	0.8118	
Developed in cooperation with client firms	0.8323	

Table B3. Measurements

Variable	Measurements
IT exploitation	To what extent are information and communication technologies (computers, internet, and software) used to support each innovation activity in the following list? CNo15d. Provide technology training for staff. CNo15f. Add new features to existing products or services. CNo15g. Take measures to reduce production costs. CNo15h. Take actions to improve production flexibility.
IT exploration	To what extent are information and communication technologies (computers, internet, and software) used to support each innovation activity in the following list? CNo15a. Introduce new technology and equipment(s) for product or process improvements. CNo15b. Introduce new quality control procedures in production or operations. CNo15c. Introduce new managerial/administrative processes. CNo15e. Introduce a new product or new service.
Internal innovation	In what ways has this establishment introduced new products or services? CNo17a. Developed or adapted in house. CNo17e. Implemented idea from internal R&D. In what ways has this establishment introduced new or improved processes? CNo17g. Developed or adapted in house. CNo17k. Implemented idea from internal R&D.
External innovation	In what ways has this establishment introduced new products or services? CNo17b. Developed in cooperation with suppliers. CNo17c. Developed in cooperation with client firms.

	In what ways has this establishment introduced new or improved processes? CNo17h. Developed in cooperation with suppliers. CNo17i. Developed in cooperation with client firms.
Innovation	CNo16.Percentage of production volume associated with new/improved new products and processes.
Firm age	B5. In what year did this establishment begin operations?
IT expenditure	CNo7a. Over the last three years, how much did this establishment spend in the following categories on average annually? Computers and other information processing equipment (including printers, terminals, optical and magnetic reader, RFID, operating systems, and software).
Manager experience	B7. How many years of experience working in this sector does the Top Manager have?
R&D investment	CNo4. Over the last three years, how much did this establishment spend on research and development activities performed within this establishment on average annually? CNo6. Over the last three years, how much did this establishment spend on research and development activities contracted with other companies on average annually?
Computer use	CNO8.Currently, what percent of this establishment's workforce regularly use computers in their jobs?
Affiliation	A7.Establishment is part of a larger firm.
Labor	L1: At the end of fiscal year 2011, how many permanent, full-time individuals worked in this establishment? Please include all employees and managers.
Capacity utilization	F1. In fiscal year 2011, what was this establishment's output produced as a proportion of the maximum output possible if using all the resources available (capacity utilization)?
Skilled labor	L4. At the end of fiscal year 2011, how many permanent, full-time individuals working in this establishment were: Skilled production workers?
Business city	A3c.Is this city the main business city?
Female leader	B7a. Is the Top Manager female?

Appendix C

Table C1. Regression Results of the Influences of IT Use Patterns on Innovation (alternative measure)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
exploitative	**0.246****	**0.018**	**0.435*****	**3.345*****	**0.272*****	**0.250*****	**0.271*****	**0.226****	**0.248*****
	[0.096]	[0.165]	[0.111]	[1.098]	[0.094]	[0.097]	[0.096]	[0.096]	[0.096]
explorative	**0.382*****	**0.379*****	**0.378*****	**0.397*****	**0.411*****	**0.420*****	**0.539*****	**3.338*****	**0.422*****
	[0.095]	[0.094]	[0.095]	[0.097]	[0.097]	[0.131]	[0.104]	[1.070]	[0.098]
exploitative×internal		**0.308***							
		[0.164]							
exploitative×external			**-0.538*****						
			[0.145]						
exploitative×balanced				**-0.678*****					
				[0.240]					
exploitative×combined					**-1.237*****				
					[0.445]				
explorative×internal						**-0.055**			
						[0.137]			
explorative×external							**-0.546*****		
							[0.147]		
explorative×balanced								**-0.638*****	
								[0.229]	
explorative×combined									**-0.866****
									[0.406]
internal	-0.110	-0.718**	-0.087	-0.128	-0.092	-0.006	-0.056	-0.128	-0.090
	[0.104]	[0.334]	[0.104]	[0.105]	[0.105]	[0.273]	[0.106]	[0.105]	[0.104]
external	0.048	0.044	1.214***	0.073	0.111	0.051	1.176***	0.082	0.108
	[0.106]	[0.106]	[0.333]	[0.105]	[0.105]	[0.106]	[0.318]	[0.106]	[0.108]
combined	-0.112	-0.222	0.179	-0.111	2.455**	-0.088	0.320	-0.170	1.579*
	[0.401]	[0.401]	[0.396]	[0.400]	[1.018]	[0.401]	[0.401]	[0.399]	[0.872]
balanced	-0.003	0.049	-0.062	1.383***	-0.005	-0.010	-0.089	1.241**	-0.018
	[0.197]	[0.196]	[0.197]	[0.509]	[0.196]	[0.197]	[0.196]	[0.484]	[0.197]
Firm age	-0.030	-0.029	-0.032	-0.038	-0.032	-0.030	-0.030	-0.035	-0.029
	[0.044]	[0.044]	[0.044]	[0.044]	[0.044]	[0.044]	[0.044]	[0.044]	[0.044]
Manager experience	0.021	0.016	0.022	0.023	0.015	0.022	0.024	0.023	0.015
	[0.034]	[0.035]	[0.034]	[0.034]	[0.034]	[0.034]	[0.033]	[0.034]	[0.034]
IT Expenditures	-0.030	-0.027	-0.027	-0.027	-0.032	-0.030	-0.031	-0.028	-0.031

	[0.032]	[0.032]	[0.029]	[0.032]	[0.031]	[0.032]	[0.031]	[0.033]	[0.031]
Computer use	0.016	0.019	0.019	0.013	0.018	0.015	0.014	0.012	0.016
	[0.041]	[0.041]	[0.042]	[0.041]	[0.041]	[0.041]	[0.042]	[0.041]	[0.041]
Affiliation	0.053	0.055	0.053	0.048	0.051	0.052	0.052	0.049	0.054
	[0.035]	[0.035]	[0.034]	[0.035]	[0.035]	[0.035]	[0.034]	[0.035]	[0.035]
R&D	0.080***	0.079***	0.081***	0.081***	0.076***	0.081***	0.077**	0.081**	0.076**
	[0.030]	[0.028]	[0.030]	[0.030]	[0.029]	[0.030]	[0.032]	[0.033]	[0.030]
Labor	0.133*	0.128*	0.141**	0.129*	0.144*	0.134*	0.144*	0.126	0.137*
	[0.078]	[0.077]	[0.070]	[0.077]	[0.074]	[0.077]	[0.073]	[0.079]	[0.075]
Capacity utilization	-0.013***	-0.014***	-0.013***	-0.013***	-0.014***	-0.013***	-0.013***	-0.013***	-0.013***
	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]
Skilled labor	-0.190**	-0.184**	-0.194**	-0.175*	-0.191**	-0.191**	-0.193**	-0.175*	-0.188**
	[0.092]	[0.092]	[0.086]	[0.092]	[0.090]	[0.092]	[0.086]	[0.094]	[0.090]
Business city	-0.360***	-0.360***	-0.366***	-0.362***	-0.371***	-0.361***	-0.370***	-0.359***	-0.369***
	[0.107]	[0.107]	[0.108]	[0.108]	[0.109]	[0.107]	[0.108]	[0.107]	[0.108]
Female leader	0.092	0.070	0.074	0.093	0.063	0.095	0.094	0.093	0.074
	[0.119]	[0.120]	[0.118]	[0.120]	[0.120]	[0.119]	[0.119]	[0.120]	[0.119]
_cons	-1.207	-0.974	-1.384	-7.575***	-1.299	-1.252	-1.245	-6.945***	-1.232
	[0.907]	[0.927]	[0.910]	[2.361]	[0.903]	[0.921]	[0.905]	[2.247]	[0.909]
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	995	995	995	995	995	995	995	995	995
adj. R^2	0.0361	0.0367	0.0385	0.0373	0.0375	0.0362	0.0385	0.0372	0.0369

Standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C2. Results of 2SLS (alternative measure)

	(1) exploitative	(2) explorative	(3) innovation
IV1_exploitative	0.470***		
	[0.032]		
IV1_explorative		0.457***	
		[0.034]	
exploitative		0.685***	0.092***
		[0.022]	[0.022]
explorative	0.626***		0.065***
	[0.021]		[0.022]
Firm age	0.001	-0.002	-0.005
	[0.011]	[0.012]	[0.007]
Manager experience	-0.000	0.020*	0.002
	[0.011]	[0.011]	[0.006]
IT Expenditures	0.011	-0.016**	-0.004
	[0.018]	[0.007]	[0.008]
Computer use	0.003	0.020	0.005
	[0.013]	[0.013]	[0.007]
Affiliation	0.013	0.023*	0.004
	[0.012]	[0.012]	[0.006]
R&D	-0.012	0.010	0.013***
	[0.010]	[0.008]	[0.005]
Labor	-0.041	0.050***	0.022
	[0.039]	[0.016]	[0.018]
Capacity utilization	0.000	0.001	-0.003***
	[0.001]	[0.001]	[0.001]
Skilled labor	0.026	-0.022	-0.030**
	[0.023]	[0.017]	[0.012]
Business city	-0.086***	0.047	-0.061***
	[0.033]	[0.037]	[0.019]
Female leader	-0.025	0.022	0.008
	[0.034]	[0.039]	[0.021]
_cons	-0.060	-0.477***	0.158***
	[0.096]	[0.100]	[0.057]
Industry	Yes	Yes	Yes
N	995	995	995
adj. R^2	0.717	0.717	0.115

Standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C3. Results of 2SRI (alternative measure)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
exploitative	**0.617*****	**0.398***	**0.804*****	**3.573*****	**0.641*****	**0.623*****	**0.662*****	**0.591*****	**0.615*****
	[0.145]	[0.205]	[0.155]	[1.079]	[0.143]	[0.146]	[0.145]	[0.144]	[0.145]
explorative	**0.391*****	**0.396*****	**0.387*****	**0.395*****	**0.423*****	**0.437*****	**0.517*****	**3.072*****	**0.435*****
	[0.138]	[0.138]	[0.138]	[0.137]	[0.139]	[0.160]	[0.142]	[1.049]	[0.141]
exploitative×internal		**0.282***							
		[0.158]							
exploitative×external			**-0.536*****						
			[0.143]						
exploitative×balanced				**-0.646*****					
				[0.235]					
exploitative×combined					**-1.256*****				
					[0.434]				
explorative×internal						**-0.069**			
						[0.136]			
explorative×external							**-0.539*****		
							[0.147]		
explorative×balanced								**-0.578*****	
								[0.224]	
explorative×combined									**-0.869****
									[0.405]
internal	-0.096	-0.652**	-0.072	-0.113	-0.077	0.033	-0.044	-0.113	-0.075
	[0.104]	[0.324]	[0.104]	[0.105]	[0.105]	[0.274]	[0.106]	[0.104]	[0.104]
external	0.018	0.015	1.178***	0.044	0.084	0.022	1.133***	0.051	0.080
	[0.105]	[0.105]	[0.324]	[0.105]	[0.104]	[0.105]	[0.317]	[0.105]	[0.106]
balanced	-0.002	0.047	-0.059	1.315***	-0.004	-0.011	-0.086	1.123**	-0.017
	[0.195]	[0.194]	[0.195]	[0.498]	[0.195]	[0.195]	[0.195]	[0.474]	[0.195]
combined	-0.066	-0.168	0.231	-0.064	2.542**	-0.036	0.367	-0.121	1.629*
	[0.399]	[0.399]	[0.395]	[0.397]	[0.993]	[0.398]	[0.400]	[0.396]	[0.875]
Firm age	-0.042	-0.042	-0.044	-0.050	-0.044	-0.042	-0.042	-0.046	-0.042
	[0.043]	[0.043]	[0.043]	[0.043]	[0.043]	[0.043]	[0.043]	[0.043]	[0.043]
Manager experience	0.022	0.018	0.024	0.025	0.016	0.024	0.026	0.024	0.017
	[0.035]	[0.035]	[0.034]	[0.035]	[0.034]	[0.035]	[0.034]	[0.034]	[0.035]
IT Expenditures	-0.005	-0.002	-0.002	-0.003	-0.006	-0.005	-0.007	-0.003	-0.006
	[0.029]	[0.029]	[0.027]	[0.029]	[0.028]	[0.029]	[0.029]	[0.030]	[0.028]
Computer use	0.024	0.026	0.026	0.021	0.025	0.022	0.022	0.020	0.024
	[0.042]	[0.042]	[0.042]	[0.042]	[0.042]	[0.042]	[0.042]	[0.042]	[0.042]
Affiliation	0.028	0.030	0.027	0.024	0.026	0.027	0.028	0.025	0.028

	[0.036]	[0.036]	[0.036]	[0.036]	[0.036]	[0.036]	[0.036]	[0.036]	[0.036]
R&D	0.079***	0.078***	0.080***	0.080***	0.075***	0.080***	0.076***	0.079***	0.075***
	[0.023]	[0.022]	[0.022]	[0.023]	[0.021]	[0.023]	[0.023]	[0.025]	[0.022]
Labor	0.102	0.098	0.109*	0.099	0.113*	0.103	0.113*	0.097	0.106
	[0.069]	[0.069]	[0.064]	[0.069]	[0.067]	[0.069]	[0.067]	[0.071]	[0.067]
Capacity utilization	-0.015***	-0.015***	-0.014***	-0.015***	-0.015***	-0.015***	-0.014***	-0.015***	-0.015***
	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]
Skilled labor	-0.173*	-0.168*	-0.175**	-0.159*	-0.173*	-0.174*	-0.175**	-0.160*	-0.171*
	[0.091]	[0.091]	[0.086]	[0.091]	[0.089]	[0.091]	[0.085]	[0.092]	[0.090]
Business city	-0.349***	-0.351***	-0.355***	-0.351***	-0.361***	-0.350***	-0.356***	-0.348***	-0.358***
	[0.106]	[0.105]	[0.106]	[0.106]	[0.107]	[0.106]	[0.107]	[0.106]	[0.107]
Female leader	0.042	0.022	0.022	0.044	0.013	0.045	0.045	0.044	0.023
	[0.121]	[0.121]	[0.120]	[0.122]	[0.121]	[0.121]	[0.120]	[0.121]	[0.120]
Xuhat_exploitative	-0.603***	-0.586***	-0.600***	-0.608***	-0.601***	-0.605***	-0.637***	-0.589***	-0.599***
	[0.195]	[0.194]	[0.194]	[0.193]	[0.193]	[0.195]	[0.193]	[0.194]	[0.195]
Xuhat_explorative	-0.007	-0.020	-0.008	0.007	-0.012	-0.006	0.040	-0.010	-0.013
	[0.178]	[0.178]	[0.177]	[0.178]	[0.179]	[0.178]	[0.176]	[0.178]	[0.179]
_cons	-1.806*	-1.590*	-1.994**	-7.849***	-1.898**	-1.861**	-1.844**	-6.984***	-1.831**
	[0.928]	[0.950]	[0.932]	[2.298]	[0.926]	[0.944]	[0.929]	[2.200]	[0.931]
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	995	995	995	995	995	995	995	995	995
adj. R^2	0.0410	0.0415	0.0433	0.0420	0.0423	0.0410	0.0433	0.0419	0.0417

Standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C4. Results of Heckman (alternative measure)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
exploitative	**0.240****	**0.022**	**0.431*****	**3.308*****	**0.266*****	**0.244****	**0.264*****	**0.220****	**0.241****
	[0.096]	[0.164]	[0.111]	[1.091]	[0.094]	[0.097]	[0.096]	[0.096]	[0.096]
explorative	**0.381*****	**0.378*****	**0.377*****	**0.395*****	**0.410*****	**0.427*****	**0.540*****	**3.309*****	**0.421*****
	[0.095]	[0.094]	[0.095]	[0.097]	[0.097]	[0.130]	[0.104]	[1.066]	[0.097]
exploitative×internal		**0.295***							
		[0.163]							
exploitative×external			**-0.546*****						
			[0.144]						
exploitative×balanced				**-0.671*****					
				[0.238]					
exploitative×combined					**-1.243*****				
					[0.443]				
explorative×internal						**-0.067**			
						[0.136]			
explorative×external							**-0.552*****		
							[0.146]		
explorative×balanced								**-0.632*****	
								[0.228]	
explorative×combined									**-0.867****
									[0.404]
internal	-0.144	-0.724**	-0.123	-0.160	-0.126	-0.020	-0.091	-0.160	-0.123
	[0.107]	[0.333]	[0.107]	[0.108]	[0.108]	[0.273]	[0.109]	[0.107]	[0.107]
external	0.042	0.039	1.225***	0.067	0.105	0.045	1.182***	0.076	0.102
	[0.105]	[0.105]	[0.331]	[0.105]	[0.105]	[0.105]	[0.317]	[0.105]	[0.107]
combined	-0.090	-0.197	0.210	-0.088	2.490**	-0.060	0.350	-0.147	1.603*
	[0.399]	[0.398]	[0.392]	[0.398]	[1.015]	[0.398]	[0.398]	[0.397]	[0.870]
balanced	-0.008	0.042	-0.069	1.364***	-0.010	-0.017	-0.095	1.224**	-0.023
	[0.196]	[0.195]	[0.196]	[0.505]	[0.195]	[0.196]	[0.195]	[0.482]	[0.196]
Firm age	-0.036	-0.035	-0.038	-0.044	-0.038	-0.036	-0.036	-0.041	-0.035
	[0.044]	[0.044]	[0.044]	[0.044]	[0.044]	[0.044]	[0.044]	[0.044]	[0.044]
Manager experience	0.027	0.022	0.029	0.029	0.021	0.029	0.030	0.029	0.021
	[0.034]	[0.035]	[0.034]	[0.034]	[0.034]	[0.034]	[0.033]	[0.034]	[0.034]
IT Expenditures	-0.055	-0.050	-0.054	-0.051	-0.057	-0.055	-0.058	-0.051	-0.056
	[0.043]	[0.043]	[0.041]	[0.043]	[0.042]	[0.043]	[0.042]	[0.043]	[0.042]
Computer use	0.074	0.072	0.083	0.069	0.077	0.073	0.076	0.068	0.074
	[0.065]	[0.065]	[0.065]	[0.065]	[0.065]	[0.065]	[0.064]	[0.065]	[0.065]

Affiliation	0.055	0.057	0.055	0.051	0.054	0.054	0.055	0.052	0.056
	[0.035]	[0.035]	[0.035]	[0.035]	[0.035]	[0.035]	[0.034]	[0.035]	[0.035]
R&D	0.058*	0.059**	0.057*	0.060*	0.053*	0.059*	0.053*	0.060*	0.054*
	[0.031]	[0.030]	[0.030]	[0.031]	[0.030]	[0.031]	[0.032]	[0.033]	[0.031]
Labor	0.186*	0.177*	0.199**	0.180*	0.198**	0.187*	0.200**	0.178*	0.190*
	[0.101]	[0.100]	[0.095]	[0.101]	[0.098]	[0.101]	[0.098]	[0.102]	[0.098]
Capacity utilization	-0.012***	-0.013***	-0.012***	-0.012***	-0.013***	-0.012***	-0.012***	-0.012***	-0.012***
	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]
Skilled labor	-0.221**	-0.213**	-0.228**	-0.205**	-0.222**	-0.222**	-0.226**	-0.205**	-0.219**
	[0.101]	[0.101]	[0.095]	[0.101]	[0.099]	[0.101]	[0.095]	[0.102]	[0.099]
Business city	-0.383***	-0.381***	-0.391***	-0.384***	-0.394***	-0.384***	-0.395***	-0.381***	-0.391***
	[0.110]	[0.110]	[0.111]	[0.111]	[0.112]	[0.110]	[0.112]	[0.110]	[0.112]
Female leader	0.075	0.055	0.056	0.077	0.046	0.079	0.077	0.077	0.057
	[0.117]	[0.118]	[0.116]	[0.118]	[0.118]	[0.117]	[0.117]	[0.118]	[0.117]
imr	-1.362	-1.255	-1.494	-1.317	-1.387	-1.384	-1.455	-1.323	-1.364
	[1.110]	[1.108]	[1.129]	[1.116]	[1.115]	[1.110]	[1.118]	[1.116]	[1.108]
_cons	-1.140	-0.922	-1.313	-7.447***	-1.233	-1.192	-1.173	-6.827***	-1.166
	[0.906]	[0.926]	[0.909]	[2.346]	[0.903]	[0.920]	[0.904]	[2.243]	[0.908]
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	995	995	995	995	995	995	995	995	995
adj. R^2	0.0365	0.0370	0.0389	0.0376	0.0378	0.0365	0.0389	0.0375	0.0372

Standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.