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Unleashing the power of supply chain learning: an empirical investigation

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Unleashing the power of supply chain learning: an empirical investigation

Abstract

Purpose – Organisational learning plays a critical role for firms to keep abreast of a supply chain environment filled with volatility, uncertainty, complexity, and ambiguity (VUCA). This study investigates the extent to which supply chain learning (SCL) affects operational resilience under such circumstances.

Design/methodology/approach – This study developed a research framework and underlying hypotheses based on SCL and information processing theory (IPT). An empirical test was carried out using secondary data derived from the ‘Supply Chain Policy’ launched by the Chinese government and two large related conferences.

Findings – SCL positively relates to operational resilience, and several moderators influence the relationship between them. We argue that digital-technological diversity could weaken the role of SCL in operational resilience, whereas customer concentration, and participating in a pilot programme could enhance the effect of SCL.

Practical implications – Firms should embrace the power of SCL in building resilience in the VUCA era. Meanwhile, they should be cautious of a digital-technological diversification strategy, appraise the customer base profile, and proactively engage in pilot programmes.

Originality/value – This research develops the SCL construct further in the context of China and empirically measures its power on operational resilience using a unique dataset. This contributes to the theorisation of SCL.

Keywords Supply chain learning, Operational resilience, Information processing theory, Supply chain management

1. Introduction

Organisational learning plays a critical role in a firm's success. By leveraging learning, organisations can better adapt to a dynamic business environment and increase their competitiveness, productivity, and innovation (Dodgson, 1993). In China, organisational learning is significant for firms' business and operations as well, largely because the business environment is fast-changing with high volatility, uncertainty, complexity, and ambiguity (VUCA). Under such circumstances, novel phenomena and new issues emerge constantly, yet no firms have prior experiences to refer to. Therefore, to seize potential opportunities and attain a competitive edge under fierce competition, firms should sometimes 'learn-by-doing', as expressed by a Chinese metaphor - '*crossing the river by touching the stones*'. In the supply chain context, organisational learning is even more important. This is the challenge posed by the harsh business environment and transition of competitive patterns, that is, the scenario where competition has been shifted from firms to supply chains (Christopher, 1992).

Moreover, the most challenging aspect is that the development of supply chain management (SCM) strategies and practices in China is still evolving (Liu and McKinnon, 2019). The supply chain environment has become more complicated and dynamic due to the development of newer forms of disruptive technology, supply shortages caused by the pandemic, and the unstable political environment (e.g. trade wars) (Alexander *et al.*, 2022; Sarkis, 2021). Therefore, to overcome these supply chain challenges, top managers are keen to absorb supply chain knowledge from their business partners. In other words, they are enthusiastic about reaping the rewards by leveraging supply chain learning (SCL).

Conceptually, SCL is derived from inter-organisational learning (Bessant *et al.*, 2003). According to Flint *et al.* (2008, p. 274), SCL occurs when '*multiple supply chain partners engaged in interaction where learning occurs and is focused on supply chain issues and solutions*'. Essentially, SCL goes beyond inter-organisational learning, which focuses on dyadic learning at an inter-firm level (Jia and Lamming, 2013), where supply chain members jointly learn to perform new activities, build new capabilities, and innovate (Silvestre, 2015). SCL is receiving increasing academic attention, with extant studies falling chiefly into three categories. The first, and largest, category focuses on the benefits of SCL, such as innovation diffusion (Flint *et al.*, 2005; Li *et al.*, 2018; Ojha *et al.*, 2016), performance improvement (Gosling *et al.*, 2016; Haq, 2021; Huo *et al.*, 2020; Spekman *et al.*, 2002), and dynamic supply chain capability cultivation (Aslam *et al.*, 2020). The second category concentrates on the triggers of SCL. For example, by investigating supply chain competency, Spekman *et al.*

(2002) found that multiple factors such as trust, communications, integrative mechanisms, decision-making style, and culture trigger SCL. Ojha *et al.* (2018) identified transformational leadership as a contributor to SCL in their exploration of supply chain ambidexterity. To study the factors enabling SCL, Huo *et al.* (2020) and Huo *et al.* (2021) identified IT applications and information sharing, respectively. Finally, the third category shows their interest in the conceptualised framework of the SCL process (Bessant *et al.*, 2003; Gong *et al.*, 2018; Silvestre, 2015; Silvestre *et al.*, 2020). Overall, SCL research is thriving, especially in recent years.

As SCM is evolving, many SCM phenomena have not been identified as of yet (Min *et al.*, 2019). This draws scholars' attention to the value of SCL, particularly in an era characterised by VUCA. To what extent is SCL valuable to supply chain managers for solving issues and problems and improving supply chain performance? The present study intends to explore the influence of SCL on operational resilience, an emerging performance indicator that is drawing the attention of academics and practitioners (DesJardine *et al.*, 2019; Li *et al.*, 2022b).

Operational resilience depicts the ability of a firm's operations to absorb and recover from disruptions (Essuman *et al.*, 2020). It is a crucial factor for firms to compete while countering difficult situations. It is known that operationally resilient firms can come up with alternate operational solutions when facing adversities. For example, during the COVID-19 outbreak, many manufacturers faced a severe disruption of upstream and downstream supply chains. Since disruptions happen regularly for firms and their supply chains in the VUCA context (Alexander *et al.*, 2022), resilience-building has become a major task for managers. Additionally, acquiring operational resilience is essential because a firm's operations act as a unique subsystem of the organisation, a principal value-creation function that produces revenues, and is also the immediately affected system under a disruption (Essuman *et al.*, 2020). Given that in emerging economies, supply chain disruption is a major vulnerability (Aman and Seuring, 2021), probing into the power of SCL on operational resilience in China is meaningful.

However, some circumstances could diminish or reinforce the effect of SCL on operational resilience. In a VUCA era filled with digital transformation and social-political changes, three scenarios - digital power, market trends, and institutional arrangements - which exert substantial influences on business and operations, cannot be ignored. Exploratorily, with the advent of digital economy, digital technology is rapidly transforming the business landscape,

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3 leading to greater efficiency and quality (Westerman and Bonnet, 2015). Accordingly, the
4 market is witnessing new trends, as customers are demanding increasingly sophisticated
5 requirements in their service experiences (Min *et al.*, 2019). Further, to meet the many new
6 challenges, institutional support is becoming critical, especially in emerging economies (Wei
7 *et al.*, 2020). In this sense, this study is intended to investigate the extent to which these
8 emerging circumstances may impact the relationship between SCL and operational resilience
9 in China. Specifically, this study concentrates on three factors related to these scenarios:
10 digital-technological diversity, customer concentration, and pilot programme. Digital-
11 technological diversity points to the application of diverse digital technologies, a factor that
12 enables firms to move towards a more productive and sustainable business (Chauhan *et al.*,
13 2022). Customer concentration reflects the concentration of the firm's customer base as an
14 important element that improves firms' operations (Patatoukas, 2012). Pilot programmes are
15 an institutional arrangement related to government policy that encourages firms to initiate
16 business in an uncertain environment. Building upon these considerations, this study seeks to
17 answer the following two research questions:

- 18 • RQ1: To what extent does SCL contribute to operational resilience?
- 19 • RQ2: How does the influence of SCL on operational resilience vary under different
20 moderators (i.e. digital-technological diversity, customer concentration, and a pilot
21 programme)?

22 To better explain the phenomenon of SCL observed in the China's supply chain
23 environment, we adopt the theoretical lens of information processing theory (IPT). IPT posits
24 how firms can effectively utilise information to perform well, especially when facing a high
25 level of uncertainty (Galbraith, 1974). As Huber (1991) stated, an organisation learns through
26 its processing of information. Several studies have applied IPT to explain organisational
27 learning. For instance, Xie *et al.* (2022) verified that organisational learning could help firms
28 improve their organisational resilience capacity. Wei *et al.* (2011) claimed that intra-
29 organisational learning could promote a firm's exploratory innovation. Likewise, Ignatius *et*
30 *al.* (2012) revealed the positive influence of intra-firm technological learning on project
31 success in new product development. In the context of SCM, some authors adopted IPT to
32 explain supply chain phenomena, such as sustainable SCM (Busse *et al.*, 2017), supply chain
33 integration (Flynn *et al.*, 2016), supply chain disruptions (Bode *et al.*, 2011), and so on. The
34 tenet for such use, as Busse *et al.* (2017) ascertained, comes from the close tie between IPT
35 and the very essence of SCM. In this case, IPT has the potential to predict SCL phenomenon.

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3 Apart from the theoretical conjecture, an empirical investigation was carried out from
4 the announcement of the first ‘Supply Chain Policy’ in China and the two resulting large-
5 scale conferences, to answer the research questions posed above. In October 2017, the
6 Chinese government introduced a policy, ‘*the Guideline on Promoting Supply Chain*
7 *Innovation and Application*’ (SCIA), to promote SCM development in China (General Office
8 of the State Council, 2017). Given that this was the first national document on the Chinese
9 supply chains, this policy is recognised as a milestone in Chinese SCM. The measurement of
10 SCL was therefore performed via a unique conference dataset closely related to the SCIA
11 policy.
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19 The present study makes contributions to the research in the following ways: First, we
20 further develop the SCL construct in the contextualised setting of China. We argue that the
21 content of SCL in China is not confined to the knowledge of supply chains only. The
22 indigenous knowledge specific to supply chain policies should be incorporated, given the
23 critical role the Chinese government played in promoting SCM. Further, we develop a novel
24 SCL measurement using a unique secondary dataset. The methods adopted by prior empirical
25 studies are case- or/and survey-based. The former may have limited generalizability, and the
26 latter, especially those with single-source respondents, face potential common method bias.
27 However, secondary data can address these concerns by utilising longitudinal and multi-
28 source datasets. Second, this study includes operational resilience as a valuable component
29 influenced by SCL, which the extant literature has not focused on. Moreover, to better
30 understand SCL, three factors are taken to examine the interaction between them (intrinsic or
31 extrinsic) as well as their relationship. Third, this study is the first attempt to use the
32 theoretical lens of IPT to interpret the SCL phenomenon. This offers a new lens to explain
33 SCL.
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45 The remainder of this paper is structured as follows. The following section offers a
46 literature review of SCL and IPT. Section 3 develops research hypotheses, including the
47 effect of SCL on operational resilience and the moderating role of three factors. Section 4
48 describes the research design. Section 5 presents empirical results and robustness tests, and
49 Section 6 discusses the implications and limitations of this study, and future directions of
50 research.
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2. Literature review and theoretical underpinning

2.1 Supply chain learning (SCL)

SCL posits multiple supply chain members engaged in learning, where the supply chain is a 'vehicle' for gathering knowledge and learning (Spekman *et al.*, 2002, p.42). SCL is about both knowledge diffusion (Biotto *et al.*, 2012) and knowledge creation (Lambrechts *et al.*, 2012). Knowledge diffusion is the process through which knowledge is disseminated and used by other organisations (Lane *et al.*, 2021). Knowledge creation concerns 'knowledge addition and/or the correction of existing knowledge' (Shin *et al.*, 2001, p.340). Nonaka (1994) argued that knowledge creation could occur within an organisation or through inter-organisational interaction. The process of SCL, as Bessant *et al.* (2003) proposed, could consist of three stages: setting-up, operating, and sustaining. Specifically, setting-up converges learning drivers to establish a learning environment, operating allows processes to address the learning agenda, and sustaining establishes benchmarking and measurements to maintain continuous learning.

SCL may have a positive impact on business performance. Flint *et al.* (2008) found that SCL could positively affect a firm's innovation, and hence its performance. Lisi *et al.* (2020) examined SCL in sustainable development and identified a positive relationship between green SCL and green innovation. In addition, some authors (e.g. Haq, 2021; Huo *et al.*, 2020; Huo *et al.*, 2021) have considered supplier learning, customer learning, and internal learning as dimensions of SCL and discovered that the latter two types were pertinent to operational performance, service performance, and flexibility performance, though supplier learning was not. Moreover, Haq (2021) reported that SCL could affect a firm's financial performance via other factors, such as the mediating role of operational performance. Nevertheless, a close examination of the extant literature yields no evidence on the influence of SCL on operational resilience. This gap suggests the need for an exploratory study in this area.

2.2 Information processing theory (IPT)

As Galbraith (1974) indicated, IPT identifies how an organisation can deal with uncertainty through information processing. The key elements of IPT can be identified as information processing needs, information processing capacity, and the congruence between needs and capacity (Tushman and Nadler, 1978). Processing needs are the information required by an organisation's strategy or environment (Egelhoff, 1991; Tushman and Nadler, 1978). As Galbraith (1974) noted, uncertainty creates information processing needs. Processing

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3 capacity refers to organisations' capability to utilise and structure information to efficiently
4 support decision-making (Cegielski *et al.*, 2012).
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6 According to IPT, an organisation may cope with increased uncertainty by either reducing
7 the amount of information it needs or strengthening its capacity to process information
8 (Galbraith, 1974). Normally, at the organisational level, uncertainty arises mainly from three
9 aspects: task characteristics, interfirm relationships, and external environment (Bensaou and
10 Venkatraman, 1995; Premkumar *et al.*, 2005). The interdependent nature of firms' tasks, as
11 Cegielski *et al.* (2012) stated, could contribute to the degree of uncertainty firms face. This
12 kind of uncertainty is also called as task uncertainty. Such uncertainty may arise from the
13 complexity of a task, where higher complexity would create a higher level of uncertainty
14 (Tushman and Nadler, 1978). Inter-organisational relationships are concerned with the
15 connection between firms and their business partners (Bensaou and Venkatraman, 1995). In a
16 supply chain, many factors influence the relationship between supply chain actors. To
17 maintain a tight relationship, significant information is needed for processing (Premkumar *et*
18 *al.*, 2005). The firm's external environment may also expose the firm to uncertainty
19 (Cegielski *et al.*, 2012), arising from natural disasters, wars, political crises, market
20 turbulence, technology advancement, and so on. The greater these uncertainties, the more
21 information processing is required.
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34 Another important implication of IPT is the fit between information processing needs and
35 capacity. A better fit increases the likelihood of the best performance, where a poor fit could
36 hinder performance (Egelhoff, 1991; Galbraith, 1974). This is because the misfit between
37 information processing needs and capacity could result in schedule and budget overruns, as
38 insufficient capacity cannot support decision-making; conversely, too much capacity incurs
39 excess unnecessary costs (Galbraith, 1974; Tushman and Nadler, 1978). Empirical studies
40 supported the rationale behind 'fit'. For example, Premkumar *et al.* (2005) identified a
41 positive influence of matched information processing needs and capacity on procurement
42 performance. Concerning IPT, Cheng and Krumwiede (2018) found that when knowledge
43 processing capacity can handle the amount of knowledge required, firms obtain greater new
44 product development gains. Likewise, Stock *et al.* (2021) confirmed a positive effect of the
45 fit between knowledge processing needs and capacity by observing the knowledge-sharing
46 requirements and knowledge-sharing quantity.
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3. Hypothesis development

3.1 SCL and operational resilience

In IPT, the idea of ‘fit’ indicates that the performance of firms will suffer from the misalignment of information processing needs and capacity (Galbraith, 1974; Tushman and Nadler, 1978). Hence, to cope with uncertainty, firms can choose to either increase their processing capacity or decrease their processing needs (Galbraith, 1974). Supply chain actors engaging in SCL can be viewed as choosing a path to increase their knowledge processing capacity because SCL can provide firms with access to valuable knowledge from upstream suppliers, downstream customers, and third-party knowledge providers. Thus, through SCL, firms can enhance their capacity to utilise and structure current know-how and absorb and exploit new knowledge to advance supply chain operations, which fits well with Cegielski *et al.*'s (2012) interpretation of processing capacity.

We argue that SCL could enable firms to make a timely adjustment to operate stably and effectively in a highly uncertain business environment. First, given that SCL is characterised as boundary-spanning learning, firms can acquire operational experience and knowledge generated by other supply chain members. They can integrate them with their knowledge base. This may open gateways to new technical and administrative know-how that departs from extant organisational memory, increasing the opportunities for innovation and enhanced flexibility (Bao *et al.*, 2012). As SCL stimulates the combination of existing and newly learnt knowledge, firms incurring marginal time, effort, cost, or performance penalties are at an advantage to innovate (Zhu *et al.*, 2018a). The enhanced innovation further augments a firm's ability to develop alternative solutions geared toward resisting external uncertainty, significantly improving its operational resilience. Based on Ngai *et al.* (2011), we inferred that SCL could consistently provide supply chain members with the most cutting-edge knowledge on systems, procedures, technology, and benchmarking, enabling them to respond to task uncertainty quickly and efficiently.

Second, SCL can yield useful insights. Specifically, processing valuable knowledge from external stakeholders helps firms become more sensitive to upstream, downstream, and market changes (Tse *et al.*, 2016; Wang *et al.*, 2019). For example, learning from upstream suppliers indicates that firms are more likely to gain insights associated with supply market dynamics, which ultimately enable firms to respond effectively to supply uncertainty via adjusting production plans (Huo *et al.*, 2021). Meanwhile, learning from customers can help firms to know more about the market, which could assist them in reorganising their resources

and capabilities (Huo *et al.*, 2021; Wang *et al.*, 2019). Additionally, through learning from third-party knowledge providers (e.g. industrial associations, third-party service providers, and competitors), firms are more likely to coordinate operational activities to reduce risk, contributing to their sustainable operations and stability in the face of external change.

Finally, and most importantly, SCL can help firms use best practices in which supply chain partners have successfully coped with the change and proactively responded to market changes, such as applying disruptive technologies to facilitate operations to withstand adversity (Modgil *et al.*, 2022). As Burnard *et al.* (2018) indicated, learning about the experiences of threats and disruptions from others could facilitate the development of resilience. According to the above arguments, we conjecture that:

H1. SCL positively impacts a firm's operational resilience.

3.2 Moderating factors

As postulated above, SCL may affect operational resilience; however, a better understanding of when and how SCL can improve such resilience is useful. **Therefore, the moderating role of three factors - digital-technological diversity, customer concentration, and the pilot programme - as noted at the outset, are to be examined below.**

3.2.1 Digital-technological diversity

Digital technologies are a combination of 'information, computing, communication and connectivity technologies' (Bharadwaj *et al.*, 2013, p. 471). **Emerging digital technologies such as cloud computing, big data, artificial intelligence, and 3D printing have profoundly influenced business operations (Nambisan, 2017; Liu *et al.*, 2022a) and are closely linked to improving firms' resilience (Remko, 2020).** Digital-technological diversity signifies the breadth of a firm's digital-technological portfolio.

Diversified digital technologies hold the promise to advance operations and enable intelligent and autonomous operational tasks (Choi *et al.*, 2022; Fatorachian and Kazemi, 2018), thus reducing task complexity. Tushman and Nadler (1978) assumed that complex tasks could create difficulty in predictability, and therefore incur greater information processing needs. This suggests that digital-technological diversity is likely to decrease the knowledge processing needs and weaken the role of learning in building resilience accordingly. In addition, the uncertainty caused by rapid technological advances could be mitigated by the broader digital technology portfolio of firms with more advantages in seizing emerging technological opportunities from scientific breakthroughs (Bolli *et al.*, 2020;

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3 Subramanian *et al.*, 2018). In such cases, on the one hand, a diversified technical base could
4 hinder interfirm knowledge transfer in SCL. Han *et al.* (2018) pointed out that the strongly
5 increased overlapped knowledge reduces learning opportunities. Song *et al.* (2003)
6 recognised that the interfirm knowledge transfer is more likely to happen on the condition
7 that firms possess different technological expertise, as their current technological trajectory
8 might affect the receptivity to knowledge gained from the outside. If firms' operational
9 activities proceed along established technical paths, then they are less likely to incorporate
10 external knowledge (Song *et al.*, 2003). Therefore, a diversified technological base, which
11 indicates that the firm possesses knowledge in a broad range of technology domains, with
12 established technological trajectories, practices, and procedures, would lower a firm's
13 openness to knowledge sourced from external stakeholders through SCL.

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15 On the other hand, leveraging diversified digital technologies could also reduce the value
16 of knowledge gained via SCL in shaping a resilient organisation. Marhold and Kang (2017)
17 argued that the need for firms to acquire external knowledge becomes less urgent as they can
18 use their diverse internal knowledge to create alternative solutions when facing disruptions.
19 This is also applied to the case of SCL: when disruptions occur, digital-technological
20 diversity enables firms to develop novel solutions. This is because firms are exposed to
21 diverse technological knowledge, a vital precondition of successful knowledge
22 recombination. Apart from this, firms are more likely to develop flexible and outside-the-box
23 thinking since they see how problems could be solved differently (Gao *et al.*, 2015). Thus,
24 the second hypothesis is postulated as follows:

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26 **H2.** The greater a firm's digital-technological diversity, the less positive the influence of SCL
27 on its operational resilience.

28 29 3.2.2 Customer concentration

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31 Of all the inter-organisational relationships, customers are the most pivotal for revenue
32 generation (Yli-Renko and Janakiraman, 2008). Given that operations are a primary value-
33 creation function to produce revenues, major customers have the power to influence a firm's
34 strategies and practices at the operational level. Therefore, the influence of customers
35 requires consideration.

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37 Customer concentration is the extent to which a firm depends upon its major customers for
38 financial resources (Zhu *et al.*, 2021a; Kim and Zhu, 2018). It is a critical characteristic that
39 depicts the relationship between a firm and its customers (Huang *et al.*, 2016). A higher
40 customer concentration, indicated as a more concentrated customer base, will decrease the
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3 firm's bargaining power, and consequently, make the firm more reliant on its customers (Liu
4 *et al.*, 2022b). In addition, the firm is more prone to lower profitability (Hui *et al.*, 2019) and
5 faces more uncertainty in long-term survival.
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9 Regarding inter-organisational relationships, a higher dependence on other supply chain
10 members indicates a firm's lack of control and power, and would bring about greater
11 uncertainty (Bode *et al.*, 2011; Flynn *et al.*, 2016). Therefore, higher knowledge processing
12 needs could be expected in firms with more concentrated customers. In this case, the positive
13 effect of SCL on operational resilience could be magnified. First, the knowledge gained from
14 SCL can be easier to transfer and apply in addressing supply chain disruptions when firms
15 have a more concentrated customer base. Firms tend to invest more resources to build strong
16 relationships and foster mutual trust with their major customers, which could contribute to the
17 quality and efficiency of knowledge acquisition (Zhou *et al.*, 2014). Meanwhile, the firm's
18 knowledge may be idiosyncratic and context-specific. Hence, using this knowledge to deal
19 with disruptions effectively means that firms must apply the knowledge they learnt their own
20 context and the knowledge must have a certain level of tailoring (Maritan and Brush, 2003).
21 It must be noted that a dispersed customer network largely improves the difficulty of
22 knowledge application, since it is hard for focal firms to customise knowledge based on the
23 characteristics of a large customer base.
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35 Second, for firms with more concentrated customers, processing and applying the
36 knowledge obtained through SCL is more effective. This is because when a firm is highly
37 dependent upon major customers, the change in one major customer's demand could directly
38 impact the firm's operations (Zhu *et al.*, 2021a). The knowledge gained from those major
39 customers is of great significance in sensing and responding to the demand change, enabling
40 firms to remain operationally stable and flexible. Bode *et al.* (2011) have a consistent view
41 that firms tend to maintain stable relationships with customers upon whom they depend
42 significantly. This increases firms' motivation to maintain stability by taking proactive steps
43 to cope with the increasing uncertainty. For instance, by learning about supply chain partners'
44 experiences of coping with emergencies, firms may learn how their customers would respond
45 in similar situations and make corresponding reactions, such as modifying production
46 schedules, changing market strategies, and developing new products. Thus, we propose our
47 third hypothesis:
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56 **H3.** Customer concentration positively affects the relationship between SCL and operational
57 resilience.
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3.2.3 Pilot programme

The term ‘pilot’ is political in nature with the tenet of ‘experimentation’. It is ‘reserved for rigorous early evaluations of a policy... before that policy has been rolled out nationally and while it is still open to adjustment’ (Jowell, 2003, p. 11). A pilot programme refers to a policy programme restricted by geography and time (Ettelt *et al.*, 2015). As Bailey *et al.* (2017) stated, policymakers choose to implement pilot programmes due to some degree of ‘ambiguity and conflict around the conception and implementation’ (p. 211) of a particular policy. Since the role of a pilot programme is to test the likely impact of a policy before it is fully implemented, the result of pilot programmes would result in the proof of the policy’s effectiveness, its adjustment, or even its abandonment (Jowell, 2003).

Pilot firms are selected to implement and engage in the pilot programme. Pilot firms accumulate practical experience learnt from performing an action and maintain an attitude of curiosity in the face of new challenges (People’s Daily, 2018). The pilot programme is in line with the ‘learning-by-doing’ process; that is, pilot firms need to test the new ideas instead of duplicating existing paradigms. Hence, these firms have little experience to follow and no predecessors to learn from. Thus, pilot firms face a higher level of uncertainty thanks to the uncertain business world. To perform well and achieve the policy goals, pilot firms have greater knowledge processing requirements.

By investigating the role of national policy pilots, Ettelt *et al.* (2022) suggested that pilot programmes encouraged experimentation with ideas and development of innovative solutions. This argument implies that pilot firms are early pioneers of innovative operation modes or processes, which enables them to generate unique technical and administrative know-how. Therefore, given that a key task of the pilot programme is to test potential practices and disseminate successful experience, pilot firms have more incentives to actively engage in SCL and diffuse their experience or learn from others. Additionally, their supply chain partners are also more likely to engage in the learning process to acquire their valuable knowledge. The frequent communication and deep involvement of multiple supply chain actors indicate that more valuable knowledge would be shared and disseminated through SCL. Moreover, pilot firms will then better apply knowledge to facilitate operational resilience. Li *et al.* (2022a) assumed that a pilot programme provides firms preferential treatment from the government such as the additional support of dedicated policies and funds. Thus, pilot firms are equipped with more resources that can be organised to absorb relevant knowledge to deal with emergencies. In this way, SCL-induced knowledge processing fits

well with the pilot firms' enhanced processing requirements, leading to outstanding performances. Based on this, the last hypothesis is posited as follows:

H4. A pilot programme positively moderates the relationship between SCL and operational resilience. The relationship will be stronger for pilot firms compared to non-pilot firms.

The proposed research framework summarising the above hypotheses is shown in Figure 1.

Insert Figure 1

4. Research design

4.1 Construct development of SCL and data collection

As noted earlier, the research context is grounded on the first 'Supply Chain Policy' issued by the Chinese government in 2017, named '*the Guideline on Promoting Supply Chain Innovation and Application*' (SCIA). The China Federation of Logistics & Purchasing (CFLP) is the most influential organisation in the Chinese SCM community. As one of the policy panel members, the CFLP held several events disseminating the SCIA policy, such as conferences, pilot programmes, and training. These activities were meant to allow firms to experiment and innovate with supply chain operations.

In May 2018 and November 2019, the CFLP organised two conferences for disseminating the SCIA policy. Due to a 'top-down' policy implementation strategy in China, the SCIA policy was interpreted by government officials at the conferences. They encouraged firms to pursue supply chain innovation. However, without the government officials' and experts' interpretation and explanation, the participating firms might overlook some key issues in the SCIA policy paper. Therefore, the two conferences provided excellent opportunities for participating firms to learn about the practices of supply chain innovation under the SCIA policy framework. In this regard, the first conference aimed to introduce and explain the SCIA policy and share knowledge about its implementation. The second conference served a similar purpose, but it further reinforced the key features of the first conference. Most importantly, some firms were invited to respond to the SCIA policy and share their successful experiences.

Essentially, the CFLP provides an effective platform for firms to engage in SCL. Various supply chain actors may obtain supply chain-related knowledge, such as the conception of supply chain innovation, disruption technologies and their applications, best SCM practices,

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3 and resource accessibility provided by SCIA. Although the conferences did not offer formal
4 academic-style lectures, they served as a knowledge hub in which all participating firms
5 could share successful cases and useful knowledge and learn from each other's experiences.
6 Specifically, in a conference, various activities such as keynote speeches, parallel
7 presentation sessions, round table discussions, industrial exhibitions, and other social
8 engagements (such as tea breaks and buffet/gala dinners) can provide opportunities to
9 observe how others operate, ask questions, share stories, communicate casually (Aramo-
10 Immonen *et al.*, 2016), and share and reflect on others' practices and experiences (Jeong *et*
11 *al.*, 2018), which offer different forms of informal learning. Following on from Hartley and
12 Allison (2002), we infer that participating firms could gain knowledge of SCM practices of
13 other supply chain members as well as from the policy interpretation and speeches presented
14 by government officials and experts at these two conferences. Participating firms then
15 acquired, transferred, assimilated, and exploited this knowledge. In addition, these firms were
16 members of different supply chains and occupied different supply chain positions. It should
17 be noted that, under such a setting, the content of SCL has exceeded the traditional sense of
18 SCL, that is, knowledge of supply chains; rather, it goes to the knowledge of supply chain
19 policies, which is indispensable for Chinese firms to enjoy SCL.

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22 Moreover, the construct development of SCL in the present study also fits with Bessant *et*
23 *al.* (2003)'s three phases of SCL. In the setting up phase, triggers converge, and a learning
24 network is established, probably by a third party. The present study examined two
25 conferences organised by the CFLP to respond to firms' rising demand for supply chain-
26 related knowledge. Next, some core processes, such as network creation (i.e. identifying and
27 maintaining conference memberships), information management activities (e.g. keynote
28 speeches, parallel presentation sessions, etc.), are aligned with the operating phase of SCL.
29 Finally, the sustaining stage of SCL has a twofold mechanism: the consecutive annual
30 conference setting and the benchmarking framework, built upon the model of leading pilot
31 firms. Thus, the SCL construct was identified from the two conferences based on the agenda
32 and list of participating firms provided by the CFLP.

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35 Among the participating firms mentioned above, this study targeted the publicly listed
36 firms. Figure 2 depicts the data collection process. The list provided by the CFLP shows that
37 the conferences had 711 participating units consisting of 645 firms and 66 government
38 agencies, industrial associations, and universities. In the second step, we also cross-checked
39 the data to avoid missing information. Particularly, we searched the public information about
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two conferences on the internet (e.g. through news articles, company news, and some conference pictures) to verify participating firms. Additionally, we collected information about the keynote speakers, participants in the roundtable discussion and parallel forums, industrial exhibitions, and senior membership of the advisory board from official websites and news releases. Next, we checked whether the 645 participating firms were listed firms using TianYanCha, a widely accepted data source containing information about Chinese firms. This check yielded 79 listed firms that engaged in SCL. To test the moderating role of the pilot programme, we collected relevant data from a specific pilot programme launched in October 2018, to implement SCIA effectively and ensure supply chain innovation. In the programme, 266 firms were accredited as pilot firms. We then verified whether the 79 listed firms were approved as pilot firms or not. Finally, other data were collected from the China Stock Market & Accounting Research (CSMAR) database, a leading and widely used data source for Chinese listed firms, related to the 79 sample firms between 2018 and 2019. Owing to missing data, the final sample consisted of 130 firm-year observations.

Insert Figure 2

4.2 Construct measurement

Table I presents the construct and measurement, which also notes the data sources.

Insert Table I

SCL. As indicated above, three binary indicators were developed to measure SCL. First, participation: did the firm participate in the conference? (yes=1, no=0). Second, the extent of communication and interaction: did the firm communicate and interact with other supply chain members during the conferences, such as giving a keynote speech, chairing the roundtable discussion, engaging in parallel forums, or setting up an exhibition? (yes=1, no=0). Third, membership: was the firm nominated as a senior member in the advisory board responsible for proactively sharing experiences as well as communicating and providing valuable insights and suggestions? (yes=1, no=0).

Operational resilience. Following Li *et al.* (2022b), operational resilience is measured as the change in operating revenue per unit production cost (ORPPC) before and after facing

external adversity, as shown in equation (1). This is because, within a given period, a smaller decline in a firm's performance indicates greater resilience. For example, for operational resilience in 2019, we set the average ORPPC from 2016 to 2018 as the benchmark.

$$\text{Operational resilience} = \frac{ORPPC_t}{\sum_{t-3}^{t-1} \frac{ORPPC}{3}} \quad (2)$$

Digital-technological diversity. The measurement of digital-technological diversity follows that of prior studies dealing with digital transformation and diversity. The digital transformation literature (see Tu and He, 2022; Wu *et al.*, 2022) identified firms' adoption of digital technologies using the occurrence of certain keywords in firms' open reports. As in other studies on diversity (Kahiluoto *et al.*, 2020), digital-technological diversity was calculated as in equations (2) and (3). f_i is the frequency of a certain keyword for each firm and F is the total keyword frequency of all the digital technologies of this firm. H equals zero when the firm adopted only one kind of technology, and H increases as the number of technologies and/or the evenness among different technologies increased. Then, to facilitate interpretation, digital-technological diversity was calculated by the exponential of H , such that the index could be explained on a linear scale. Digital-technological diversity is equal to zero when firms do not adopt digital technologies.

$$H = -\sum_{i=1}^n \left(\frac{f_i}{F} \times \ln \frac{f_i}{F} \right) \quad (3)$$

$$\text{digital-technological diversity} = e^H \quad (4)$$

Customer concentration. As with prior studies (e.g. Zhu *et al.*, 2021a), customer concentration was assessed by utilising the ratio of the top five customers' sales to the total annual sales.

Pilot programme. The pilot programme is one of the important dissemination activities to promote the SCIA policy. The measure was evaluated as a dummy variable determining whether a firm is included in the policy programme.

Control variables. A set of control variables encompassing both firm and industry levels were considered to remove alternative influence factors of operational resilience. The five variables are age, size, profitability, R&D intensity, and state ownership at the firm level. Firm age represents the years since incorporation, which was logarithm-transformed. Firm size was measured as the natural logarithm of the number of employees. Firm profitability was measured by the return on assets. As to R&D intensity, the consideration was to control

for the firms' innovation. Finally, state ownership was a dummy variable equal to 1 if the firm is state-owned and 0 otherwise to indicate whether the state is the ultimate controller of a firm.

At the industry level, industry concentration and munificence, were controlled. Industry concentration was measured as the sum of the squared market share of each firm that operates in the same industry. Industry munificence represents firms' growth possibilities. Specifically, the industry-level total sales for the previous ten years were regressed in time for each industry and sample year. Industry munificence was measured as the regression slope coefficient divided by the mean sales in the same timespan (Jacobs *et al.*, 2015).

4.3 Research modelling

Various control variables were included in the model to reduce the endogeneity concerns. Additionally, firm-level fixed effects were controlled to remove any unobservable time-invariant firm characteristics. Similarly, the year-level fixed effect helped capture those unobservable time-specific effects.

To test **H1**, we constructed the regression model to estimate how SCL is related to a firm's operational resilience, as Equation (4) below shows:

$$\begin{aligned}
 \text{Operational resilience}_{i(t+1)} = & \beta_0 + \beta_1 \text{Supply chain learning}_{it} \\
 & + \beta_2 \text{Firm age}_{it} + \beta_3 \text{Firm size}_{it} + \beta_4 \text{Firm profitability}_{it} \\
 & + \beta_5 \text{R \& D intensity}_{it} + \beta_6 \text{State ownership}_{it} \\
 & + \beta_7 \text{Industry concentration}_{it} + \beta_8 \text{Industry munificence}_{it} \\
 & + \alpha_i + \delta_t + \varepsilon_{it}
 \end{aligned} \tag{5}$$

To test for the moderating effect (**H2-H4**), the moderators (i.e. digital-technological diversity, customer concentration, and pilot programme) and their interactions with SCL were added separately in Equation (5), as follows:

$$\begin{aligned}
 \text{Operational resilience}_{i(t+1)} = & \beta_0 + \beta_1 \text{Supply chain learning}_{it} \\
 & + \beta_2 \text{Moderator}_{it} + \beta_3 \text{Supply chain learning}_{it} \times \text{Moderator}_{it} \\
 & + \beta_4 \text{Firm age}_{it} + \beta_5 \text{Firm size}_{it} + \beta_6 \text{Firm profitability}_{it} \\
 & + \beta_7 \text{R \& D intensity}_{it} + \beta_8 \text{State ownership}_{it} \\
 & + \beta_9 \text{Industry concentration}_{it} + \beta_{10} \text{Industry munificence}_{it} + \alpha_i + \delta_t + \varepsilon_{it}
 \end{aligned} \tag{6}$$

Where α_i and δ_t indicate firm- and year-level fixed effects, respectively. ε_{it} represents the error term. To avoid the potential influence of multicollinearity, variables were mean-centred to compute interaction terms. A one-year lag for all independent and control variables was employed to cope with the reverse causality concern and reflect the causal relationship.

5. Results

5.1 Empirical findings

Table II presents the summary of correlations, means, and standard deviations of all variables. The correlation coefficients were below 0.40, indicating a low likelihood of multicollinearity. Table III exhibits the results with six models based on the regression analysis. Model 1 shows all control variables and the firm/year-level fixed effects. Model 2 adds the independent variable SCL to the previous model. Models 3 to 5 add the moderators of digital-technological diversity, customer concentration, and pilot programme, respectively. Finally, Model 6 includes all three moderators and interaction terms.

First, Table III shows that the coefficient of SCL was significantly positive in Model 2 ($\beta = 0.035, p < 0.05$), indicating that SCL is positively related to a firm's operational resilience; hence **H1** was supported. Regarding the moderating effects, the interaction between SCL and digital-technological diversity was significantly negative ($\beta = -0.016, p < 0.05$ in Model 3, $\beta = -0.014, p < 0.05$ in Model 6). Thus, **H2** was supported. There was a significant positive interaction between SCL and customer concentration ($\beta = 0.230, p < 0.01$ in Model 4, $\beta = 0.214, p < 0.01$ in Model 6). Accordingly, **H3** was supported. Similarly, the positive coefficient of the interaction term indicated a positive moderating effect of the pilot programme ($\beta = 0.068, p < 0.05$ in Model 5, $\beta = 0.072, p < 0.05$ in Model 6). Thus, **H4** was supported.

Insert Table II

Insert Table III

To better understand the moderating effect, simple slopes at the high (+1 standard deviation above the mean) and low (-1 standard deviation above the mean) levels of corresponding moderators were plotted. As shown in Figure 3a, when a firm has a high level of digital-technological diversity, the simple slope was not statistically significant ($\beta = -0.021, p > 0.1$). In contrast, the simple slope was positively significant ($\beta = 0.042, p < 0.05$) with low diversity. These results indicated an interference effect of digital-technological diversity. Concerning customer concentration, a higher concentration would lead to a higher level of operational resilience ($\beta = 0.060, p < 0.01$), while insignificant association ($\beta = -0.039, p > 0.05$).

was shown under a low level of concentration (see Figure 3b). Figure 3c shows that firms participating in the pilot programme see a significantly positive influence of SCL ($\beta=0.046$, $p<0.01$), while an insignificant effect ($\beta=-0.026$, $p>0.1$) was present for non-pilot firms.

Insert Figure 3

5.2 Robustness tests

Table IV summarises the results of the robustness tests. Due to limited space, only the results for the hypothesised variables were reported. First, we replaced the measurement of the dependent variable. The time window to calculate operational resilience was changed from a three-year window to a wider range, namely, four years, to capture the change in a firm's performance in a longer time interval. The results were largely consistent with the above findings.

Second, two alternative measures of digital-technological diversity were employed. First, the digital technology-related keywords were further classified into five categories: artificial intelligence, blockchain, cloud computing, big data, and digital technology application. Digital-technological diversity was then calculated based on the new classification. Second, we used industry-adjusted digital-technological diversity as the proxy, computed as the firm's digital-technological diversity divided by the average diversity value of all firms from the same industry, to address industry heterogeneity. The findings remained unchanged.

Third, as the measure of the pilot programme was a dummy variable, a new scale was used. After the initiation of the pilot programme, the pilot firms' performance was evaluated, and those that outperformed were chosen to act as demonstration firms. Taking this differentiation into account, demonstration firms, that is, firms that performed better in the programme, were assigned a higher value (i.e. 2), and the rest of the pilot firms were set a lower value (i.e. 1). This gave rise to consistent results.

Then, an additional control, operational efficiency, was included to support our research further. The efficiency level indicates the amount of operational resources that could be leveraged to survive crises (DesJardine *et al.*, 2019). Referencing Lam *et al.* (2016) and Zhu *et al.* (2021b), operational efficiency was measured using stochastic frontier estimation, modelling the firm's relative efficiency by converting operational input resources (i.e. the number of employees, cost of goods sold, and capital expenditure) into operational output

(i.e. operating income). The results were still consistent.

Insert Table IV

6. Discussion and implications

The study develops the construct of SCL and empirically examines its impact on operational resilience in China. Moreover, three moderators are used to test whether the relationship between them varies. The empirical analysis results are interesting. SCL enables firms' resilience-building, and the relationship between SCL and operational resilience weakens with high digital-technological diversity. It is enhanced through a concentrated customer base and firms' engagement in the pilot programme. The discussion and implications of the results are provided as follows.

6.1 Research and theoretical implications

6.1.1 Development of the SCL construct

A close examination of extant SCL literature finds that the content of SCL is concerned with SCM-related knowledge. In the present study, the construct of SCL is conceptualised and further developed in a Chinese context. Given that the Chinese government plays a significant role in promoting SCM (e.g. the announcement of the SCIA policy), for which SCL is encouraged, the knowledge associated with supply chain policies announced by the Chinese government is supposed to be essential. This finding corroborates the discourse regarding the undertaking of SCM studies in China. Indeed, the uniqueness of the socio-economic setting makes China an interesting and appropriate research context for SCM, and the SCM phenomena in China have distinct features (Liu and McKinnon, 2016). Moreover, exploring the Chinese SCM phenomena requires an intimate understanding of the contexts, particularly the prominent role of the government (Liu and McKinnon, 2019). An extension of SCL to the policy environment verifies this need.

6.1.2 Effects of SCL on operational resilience

While many efforts were carried out to investigate the possible influence of SCL, few empirical studies investigate the relationship between SCL and operational resilience. Drawing upon IPT, our results verify the positive role of SCL to operational resilience, demonstrating the importance of SCL for firms' survival in a VUCA environment. The study contributes to the SCL literature by extending the current understanding of SCL. SCL helps

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3 firms to resist adversity by increasing firms' knowledge processing capacity. On the one
4 hand, this finding supports the claim of Zhu *et al.* (2018b) that the performance of firms
5 could be promoted through increased processing capability, given that the VUCA era induces
6 greater knowledge processing needs. This finding corroborates the results of prior empirical
7 studies on the benefit of SCL regarding a firm's operations (Haq, 2021; Huo *et al.*, 2021).
8 Additionally, the present study is consistent with studies identifying the role of learning in
9 enabling a resilient firm (see Battisti *et al.*, 2019).

15 6.1.3 Moderating role of three factors

17 6.1.3.1 *Digital-technological diversity.* The findings reveal that diversified digital
18 technologies could weaken the influence of SCL on operational resilience. This result is
19 aligned with the view of Chen *et al.* (2013). They contend that low technological diversity
20 can enable firms to accumulate technological competence in adjacent fields and produce a
21 higher learning effect. The influence of digital technologies has been a popular topic in the
22 field of SCM. Furthermore, differing from prior studies which appreciated the role of various
23 digital technologies in building resilience individually, such as AI (Modgil *et al.*, 2022), big
24 data (Bag *et al.*, 2021), this study provides a unique perspective in exploring the role of
25 digital-technological diversity. First, the breadth of the firm's digital technology portfolio is
26 investigated instead of a specific technology. Second, rather than directly influencing
27 resilience, we included digital technologies as a potential factor, exploring its interaction with
28 SCL. Essentially, the measurement pertinent to the diversity of digital technologies is
29 developed. This significantly substantiates the moderating role of digital-technological
30 diversity.

31 6.1.3.2 *Customer concentration.* As evident in empirical analysis, customer concentration
32 could magnify the effect of SCL. Researchers have devoted substantial attention to exploring
33 the influence of customer concentration on organisational outcomes, as customers are one of
34 the most crucial stakeholders. Nonetheless, the findings remain controversial (Zhu *et al.*,
35 2021a). This study provides empirical evidence supporting the 'bright side' of a concentrated
36 customer base. Inherently, customers are more powerful (Huo, 2012), as firms rely heavily on
37 their customers. As a result, customers, especially major ones, can influence firm
38 performance (Zhu *et al.*, 2021a). Furthermore, a concentrated customer base forms a
39 convenient environment to transfer and apply knowledge gained from SCL. Moreover, given
40 that a firm's operations depend on revenues from transactions with customers, the impact of
41 major customers is significant, and acquiring knowledge from them is very important to
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3 maintain flexible operations.

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5 *6.1.3.3 Pilot programme.* The results show the positive moderating effect of a pilot
6 programme, which is in line with preceding studies that highlight the possible influence of
7 government interventions in responding to external adversities (Sheu, 2016). This study takes
8 an empirical approach to examine the interplay between supply chain activities and
9 government intervention by exploring the role of the government, an important stakeholder
10 among supply chain members. A pilot programme plays an important role since it serves the
11 objective of learning, testing, and evaluating the adaptability of a certain policy before its
12 wider application (van Hoek, 2020). Additionally, a pilot programme's purpose may lie in
13 discovering new things, which could be spread and diffused (Bailey *et al.*, 2017). Under this
14 circumstance, pilot firms are motivated to share their experiences and actively absorb
15 knowledge from others. Moreover, in emerging economies like China, becoming a pilot firm
16 could be advantageous, as we identified the enabling role of the pilot programme.

17 18 19 20 21 22 23 24 25 26 *6.1.4 Applicability of IPT to SCL*

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28 IPT suggests that firms deal with uncertainty through information processing, where good
29 organisational performance relies on a proper alignment between information processing
30 needs and capacity (Tushman and Nadler, 1978). The current study applies IPT to determine
31 the effect of SCL on operational resilience and the setting in which the effects occur. From
32 the IPT perspective, SCL, which enhances firms' knowledge processing capacity, meets the
33 rising processing needs in the VUCA era and leads to a better performance outcome (i.e.
34 operational resilience). Under different settings, including digital-technological diversity,
35 customer concentration, and a pilot programme, the effect of SCL on operational resilience
36 varies, weakening or strengthening.

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The present study provides evidence to explain SCL through the theoretical lens of IPT. This perspective is distinct from other studies that viewed SCL in terms of the resource-based view (Ojha *et al.*, 2016), knowledge-based view (Roy, 2019), resource orchestration theory (Gong *et al.*, 2018), organisational learning (Mubarik *et al.*, 2021), dynamic capability (Aslam *et al.*, 2020; Chen *et al.*, 2019), and absorptive capacity (Huo *et al.*, 2021). The applicability of IPT in this research endeavour not only extends the theoretical groundings of SCL, but also advances the knowledge base of SCL.

6.2 Managerial implications

In addition to our research implications, this study's results also have significant managerial

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3 contributions. First, the research findings reveal that SCL is valuable for building firms'
4 operational resilience. This suggests managers must grasp possible opportunities to pursue
5 SCL and learn supply chain solutions and policies. Firms could actively interact with their
6 supply chain partners, conduct training and workshops, and collaborate with other knowledge
7 providers (such as third-party service providers, academic institutions, and industry
8 associations). For firms operating in China, participating in renowned conferences is
9 important. These conferences provide a chance to learn from the interpretation and
10 explanation of policies; otherwise, they are likely to miss potential development
11 opportunities. Moreover, managers should foster the 'learning culture' within the
12 organisation and among the supply chain members. Activities could be carried out to
13 encourage SCL, such as initiating regular meetings and discussions with supply chain
14 partners to allow them to access SCM knowledge.

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24 Second, the results manifest that digital-technological diversity could give rise to over-
25 diversification problems, preventing firms from specialising in a specific technological area,
26 hindering interfirm knowledge transfer, and eroding the value of knowledge gained from
27 SCL. Additionally, adopting digital technologies is costly, requiring the investment of
28 extensive resources. Therefore, managers should carefully launch the technological
29 diversification strategy. It would be better for managers to concentrate on core digital
30 technology closely related to their business operations rather than investing considerable
31 resources in developing a full range of technologies.

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38 Third, the findings provide insights for managers regarding the positive effect of customer
39 concentration when firms are engaged in SCL. As the effect of SCL on operational resilience
40 varies depending on the firm's customer concentration, managers should know more about
41 their customer base profile. The more a firm understands about its relationship with supply
42 chain partners, the better decisions it could make. This study finds that SCL can generate
43 better outcomes for firms with a highly concentrated customer base. This result suggests that
44 firms, especially those who are highly dependent on major customers, should dedicate more
45 resources to SCL and actively engage in the learning activities. Firms should strengthen
46 collaboration and coordination and build close relationships of mutual trust with major
47 customers to facilitate knowledge transfer.

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55 Then, managers should be aware of the government policy and seize the opportunity of
56 SCM developing favoured by the policy environment. Firms are urged to proactively step
57 forward to becoming pilot firms in policy programmes. In this way, they could obtain policy
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3 support from the government, such as in finance or taxation. Moreover, after the policy is
4 announced, the pilot firms that synchronise with the development goal set by the government
5 could accumulate relevant managerial experiences. As the pioneer in policy implementation,
6 they could gain a first mover advantage over their competitors. Moreover, being a pilot firm
7 brings a reputation and a responsibility to set a good example for other firms. Therefore, pilot
8 firms need to embrace learning to improve themselves.
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14 *6.3 Limitations and future research*

16 Despite the promising implications delivered by the study, some limitations should be
17 considered. First, the data used in this study are limited to two years, given that the policy
18 was announced only a few years ago. Therefore, future research using panel data covering a
19 wider time range should be conducted. For example, researchers may pay close attention to
20 conferences, such as frontier or recent trending topics related to Chinese SCM. Second, the
21 scope of this study could be widened by considering how SCL may impact other firm- or
22 supply chain-level constructs. The current study focuses on how and under what conditions
23 SCL can influence firms' operations, that is, their operational resilience. Future research may
24 focus on the relevance between SCL and other phenomena, such as, operational efficiency,
25 risk management, and the underlying mechanisms transferring SCL into firm value, to gain a
26 more holistic view of SCL.
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Table I. Construct measurement

Construct	Measurement	Data source
SCL	The sum of three binary indicators: 1) participation, 2) the extent of communication and interaction, and 3) membership	Firm list from CFLP
Operational resilience	$\frac{ORPPC_t}{\sum_{t-3}^{t-1} \frac{ORPPC}{3}}$	CSMAR
Digital-technological diversity	$e^{-\sum_{i=1}^n \left(\frac{f_i}{F} \times \ln \frac{f_i}{F}\right)}$	CSMAR
Customer concentration	The ratio of the top 5 customers' sales to the total annual sales	CSMAR
Pilot programme	Pilot firm= 1, otherwise, 0	Firm list released by policy panel members
Age	The natural logarithm of the number of years since firms' foundation	CSMAR
Size	The natural logarithm of the number of firm's employees	CSMAR
Profitability	Return on assets	CSMAR
R&D intensity	R&D expenditures over sales	CSMAR
State ownership	State-owned firm=1, otherwise, 0	CSMAR
Industry concentration	$\sum \left(\frac{Sales_i}{Total\ sales\ of\ firms\ in\ the\ same\ industry} \right)^2$	CSMAR
Industry munificence	Slope coefficient generated by regressing sales over ten years/mean sales in the same period	CSMAR

Table II. Descriptive statistics and correlations

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Operational Resilience	1											
2. Supply Chain Learning	0.056	1										
3. Digital-technological Diversity	0.146*	0.088	1									
4. Customer Concentration	0.012	0.051	-0.123	1								
5. Pilot Programme	-0.002	0.117	-0.138	-0.058	1							
6. Firm Size	0.090	0.044	0.056	-0.348***	-0.019	1						
7. Firm Age	-0.018	0.040	0.010	-0.067	-0.090	-0.144	1					
8. ROA	0.151*	-0.183**	-0.159*	-0.022	-0.015	0.101	0.007	1				
9. R&D Intensity	0.053	-0.119	0.237***	0.093	-0.149*	-0.095	-0.147*	0.152*	1			
10. State ownership	0.045	0.393***	-0.075	-0.031	0.105	0.345***	-0.076	-0.090	-0.235***	1		
11. Industry Concentration	-0.002	0.061	0.152*	-0.145*	-0.125	0.243***	0.037	-0.071	-0.174**	0.120	1	
12. Industry Munificence	-0.134	-0.034	0.159*	-0.066	-0.164*	-0.330***	-0.000	0.016	0.042	-0.208**	0.020	1
Mean	0.992	0.969	2.807	0.230	0.538	9.238	3.000	0.047	0.026	0.523	0.143	0.155
Standard deviation	0.100	0.948	2.192	0.232	0.500	1.547	0.263	0.048	0.055	0.501	0.159	0.081

Table III. Regression analysis results

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	1.544(0.434)	-0.085 (-0.024)	-0.064(-0.018)	-0.822(-0.254)	1.099(0.341)	2.055(0.694)
<i>Control variable</i>						
Size	0.276**(2.121)	0.251*(1.976)	0.285**(2.303)	0.330*** (2.911)	0.242*(1.960)	0.364*** (3.430)
Age	-0.775(-0.758)	-0.220(-0.215)	-0.317(-0.307)	-0.211(-0.220)	-0.573(-0.566)	-1.249(-1.295)
ROA	-0.570(-1.001)	-0.555(-1.005)	-0.771(-1.399)	-0.685(-1.408)	-0.747(-1.370)	-0.880*(-1.881)
R&D Intensity	-5.413**(-2.506)	-6.004***(-2.840)	-4.316*(-1.944)	-4.115**(-2.157)	-4.986**(-2.357)	-2.599(-1.366)
State ownership	0.316(0.369)	0.707(0.830)	0.596(0.711)	0.692(0.867)	0.439(0.524)	-0.043(-0.056)
Industry Concentration	-0.029(-0.068)	0.155(0.370)	0.014(0.034)	-0.057(-0.154)	0.001(0.003)	-0.454(-1.226)
Industry Munificence	-1.845(-1.464)	-1.636(-1.333)	-1.320(-1.106)	-1.504(-1.382)	-2.171*(-1.777)	-1.876*(-1.823)
<i>Independent variable</i>						
SCL		0.035**(2.130)	0.035**(2.155)	0.023(1.604)	0.028*(1.693)	0.010(0.711)
<i>Moderator and interaction</i>						
Digital-technological Diversity			-0.006(-0.510)			0.012(1.083)
SCL × Digital-technological Diversity			-0.016**(-2.361)			-0.014**(-2.451)
Customer Concentration				0.442**(2.051)		0.540**(2.596)
SCL × Customer Concentration				0.230*** (4.031)		0.214*** (3.926)
Pilot Programme					-0.267(-0.506)	-0.402(-0.853)
SCL × Pilot Programme					0.068**(2.050)	0.072**(2.588)
Firm-level fixed effects	Included	Included	Included	Included	Included	Included
Year-level fixed effects	Included	Included	Included	Included	Included	Included
Number of Observations	130	130	130	130	130	130
F-value	1.785**	1.932***	2.093***	2.703***	2.072***	3.216***
Adjusted R ²	0.305	0.345	0.389	0.498	0.381	0.573
Note(s): *p < 0.1, **p < 0.05, ***p < 0.01; T-value in parentheses; One-year lag between the dependent variable (operational resilience) and all independent variables.						

Table IV. Results of robustness tests

Models	Main effect				Moderating effect					
	SCL	n	F-value	Adjusted R ²	SCL × Digital-technological Diversity	SCL × Customer Concentration	SCL × Pilot Programme	n	F-value	Adjusted R ²
1. Operational resilience measured based on a four-year window	0.033** (2.065)	128	2.336***	0.428	-0.014** (-2.376)	0.208*** (3.893)	0.072** (2.614)	128	3.778***	0.624
2. Diversity measured based on new categories					-0.025** (-2.350)	0.182*** (3.256)	0.066** (2.379)	130	3.193***	0.570
3. Industry-adjusted digital-technological diversity used					-0.035** (-2.504)	0.182*** (3.255)	0.063** (2.281)	130	3.192***	0.570
4. Alternative measurement of the pilot programme					-0.016*** (-2.942)	0.221*** (4.297)	0.051*** (3.792)	130	3.731***	0.623
5. Additional control included	0.037** (2.476)	125	2.477***	0.465	-0.014** (-2.501)	0.180*** (3.458)	0.073*** (2.744)	125	3.849***	0.642

Note(s): *p < 0.1, **p < 0.05, ***p < 0.01; T-value in parentheses; One-year lag between the dependent variable (operational resilience) and all independent variables.

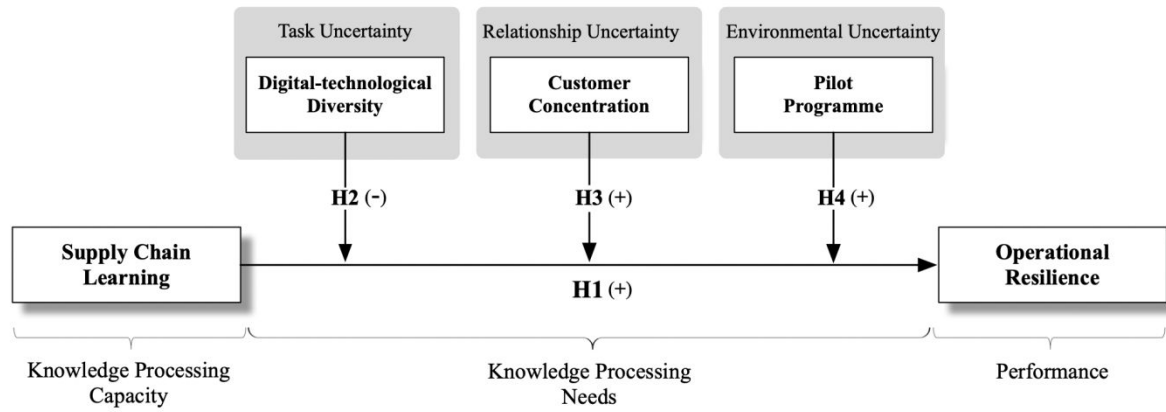


Figure 1. A research framework of supply chain learning and operational resilience

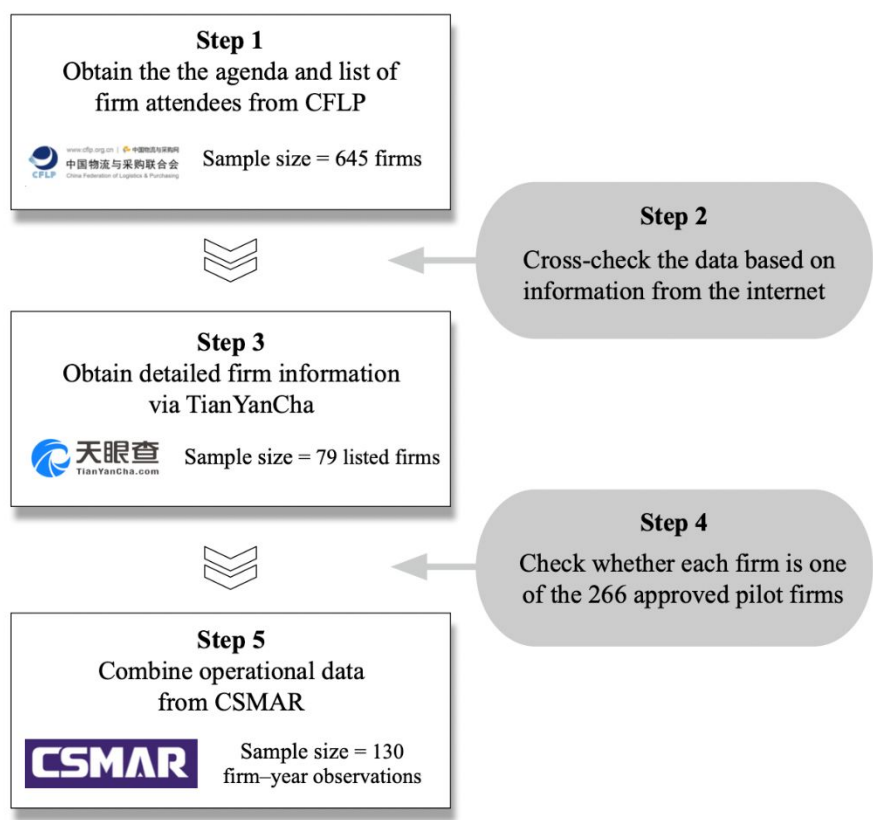


Figure 2. Data collection process

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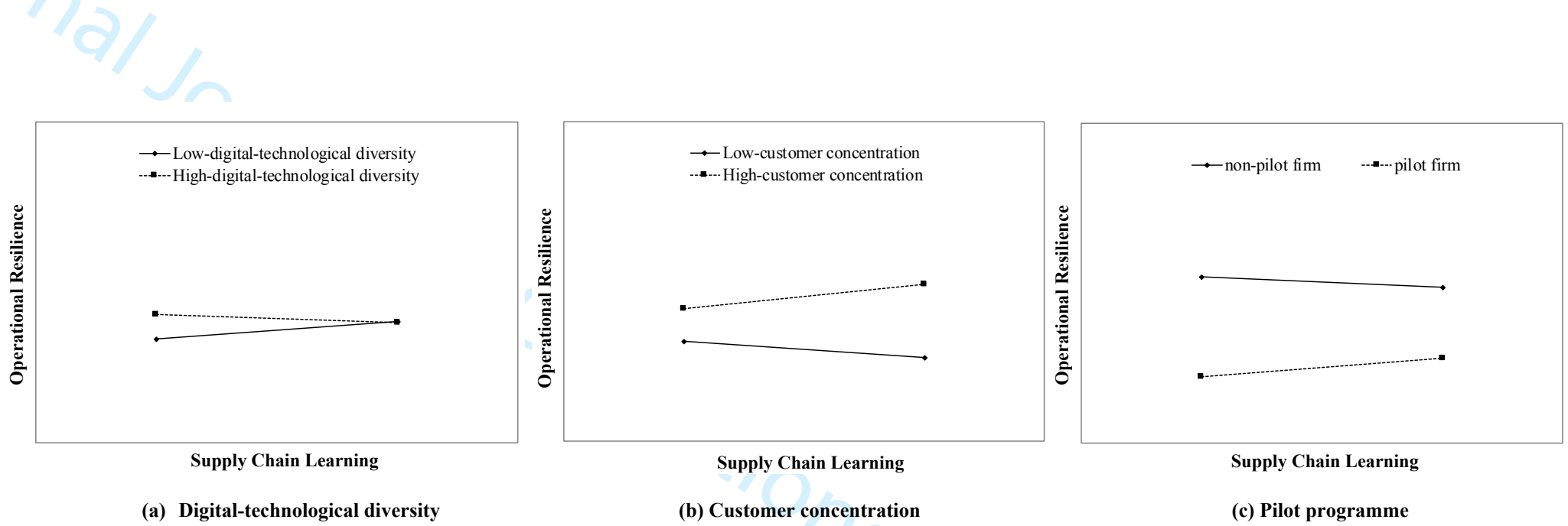


Figure 3. Decomposing the moderating effects

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