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A Theoretical Framework of Smart Supply Chain Innovation for Going Global Companies: A Multi-case Study from China

Abstract

Purpose: This study explores the influencing factors of smart supply chain innovation (SSCI) for going global companies and designs a theoretical framework.

Methodology: This paper is a multi-case study that includes a combination of exploratory and explanatory case studies.

Findings: First, we find that SSCI is embodied in product development and supply chain empowerment, which represent exploitative innovation and explorative innovation, respectively. Meanwhile, supply chain empowerment has a positive impact on product development. Second, the going global policy affects the transformation of supply chain empowerment to SSCI practices. Third, in terms of exploitative innovation, personalized demand positively affects SSCI through product development. Finally, explorative innovation, including emerging technology application and supply chain ecologicalization, has a positive effect on supply chain empowerment and thereby affects SSCI.

Originality/value: Supply chain innovation in the context of a smart economy has gained great popularity. This study sheds light on the influencing factors and mechanisms of SSCI from the exploitative and explorative aspects of innovations.

Keywords: Smart supply chain innovation, explorative innovation, exploitative innovation, going global companies, multi-case study

Paper type: Case study

1. Introduction

Today, the world has entered the smart economy based on information and communication technology to solve system uncertainty and realize the optimal allocation of resources (Kumar, 2017). Additionally, the supply chain that integrates logistics, business, information, and capital flows is rapidly transforming into a smart supply chain (Wu et al. 2016). Based on pertinent literature, we define smart supply chain as a human-like operation form embedded in emerging technologies such as big data, blockchain and artificial
intelligence to achieve efficient collaboration throughout the processes of product design, procurement, production and sales through intelligent decision-making, digital management, and automated operation. The "smart" characteristics of supply chains are embodied in emerging technologies, digital processes and ecological organizations (Wu et al. 2016; Frank et al. 2019; Liu et al. 2020).

As an important part of the supply chain, innovation can be divided into two different strategies, exploration and exploitation (March, 1991). Exploration means searching and acquiring new technologies and resources, while exploitation uses the knowledge already mastered to create new activities (Lee et al. 2018). Therefore, smart supply chain innovation (SSCI) is the integration of explorative and exploitative activities to realize the smarter operations of the supply chain through the application of emerging technologies (such as big data, blockchain, artificial intelligence, etc.), the improvement of existing (digital) processes, and so on (Liu et al. 2021b).

In recent years, some companies that have already occupied the domestic market have gone global through SSCI. In the process of going global, these companies integrate resources all over the world and provide products or services according to different market demands (Buckley, 2019). Compared with domestic companies, going global companies face more potential challenges in personalized demand service, organizational management and technological upgrading in SSCI. Hence, the SSCI mechanism based on going global companies has exemplary significance for other companies. As a typical case, Haier has built a number of smart factories and R&D centers controlled by big data platforms all over the world, connecting and leveraging global innovation resources and talent. In addition, Haier innovatively implements mass customization, which allows customers to directly participate in product design (Jiang et al. 2019). Given the development of SSCI, Haier has created more value for customers and partners in the supply chain. However, to the best of our knowledge, there are limited studies that systematically explore the mechanism of SSCI.

From a theoretical point of view, the existing literature mostly focuses on the innovation mechanism of the traditional supply chain (Arnljörn et al. 2011; Caniato et al. 2013; Seo et al. 2014; Kwak et al. 2018; De Goey et al. 2019). For example, Caniato et al. (2013) state that
supply chain innovation should be driven by three dimensions: market, business and external environment. According to Seo et al. (2014) and Kwak et al. (2018), supply chain innovation involves technology-improved processes as well as changes in products, processes or services that either enhance efficiency or improve final customer satisfaction. The above studies put forward the factors influencing traditional supply chain innovation from multiple dimensions. However, in this study, we construct a theoretical framework of SSCI by considering both traditional and smart factors.

The main conclusions are as follows. First, there are two core factors that influence the SSCI of going global companies: product development and supply chain empowerment, both of which have a positive effect on SSCI. Product development reflects exploitative innovation, while supply chain empowerment reflects explorative innovation. Second, as a moderating variable, going global policy affects the transformation of supply chain empowerment into innovation practices. In addition, personalized demand has an indirect positive impact on SSCI through product development. Emerging technology application and supply chain ecologicalization both positively affect SSCI through supply chain empowerment. Finally, the improvement of supply chain empowerment is also conducive to product development.

The rest of the paper is organized as follows. Section 2 reviews the relevant literature, and Section 3 introduces the methodology of the multi-case study. In Section 4, we describe the SSCI practices of four sample companies. In Section 5, a cross-case analysis is conducted based on the relevant literature. The proposed theoretical framework is presented in Section 6. Finally, in Section 7, the conclusions and future works are discussed, and the limitations are emphasized.

2. Literature review

2.1 Smart supply chain

The smart supply chain can be defined as a human-like operation form embedded in emerging technologies such as big data, blockchain and artificial intelligence to achieve efficient collaboration throughout the processes of product design, procurement, production and sales through intelligent decision-making, digital management, and automated operation
(Wu et al. 2016; Frank et al. 2019; Liu et al. 2020). As stated by Shokouhyar et al. (2019), smart supply chains generate new value via the development of original business models, enhancing business procedures, and decreasing the relevant expenses and risks. In a similar vein, Chen et al. (2020) demonstrate that smart supply chains are engineered to be agile and customized to be flexible based on the application of advanced emerging technologies.

Compared with the traditional supply chain (see Appendix B for more details), the "smart" supply chain is embodied in the update of technology application, process management and organization operation. Specifically, emerging technologies enhance real-time management and maximize supply chain transparency (Liu et al. 2020). In terms of process management, smart supply chains fully enable data collection and real-time communication across all processes to better serve customers (Wu et al. 2016). In addition, smart supply chains can effectively support the horizontal integration of suppliers to realize the dynamic adjustment of delivery time (Frank et al. 2019).

Additionally, some scholars have also proposed concepts similar to smart supply chains, such as intelligent supply chains (Srinivasan, 2007). The differences between these concepts and smart supply chains are summarized in Appendix B. In fact, the key to intelligent supply chains is to realize human-computer interaction, while smart supply chains emphasize the realization of human-like operation, independent decision-making and optimization for systems on the basis of intelligent supply chains.

2.2 Supply chain innovation

Supply chain innovation combines developments in information and related technologies with new logistics and marketing procedures to improve operational efficiency and enhance service effectiveness (Bello et al. 2004, Hazen et al. 2012). Hence, following Arlbjørn et al. (2011), supply chain innovation is defined as a change (incremental or radical) within the supply chain network, supply chain technology, or supply chain processes (or combinations of these). Similarly, Abdelkafi and Pero (2018) distinguish two types of innovation: supply chain concept innovation and technological innovation, where the first consists of three categories: structural/configurational, operational, and revolutionary innovations. Based on these definitions, many scholars are committed to exploring the mechanisms of supply chain

Many studies have employed March's (1991) “exploration-exploitation framework” to describe organizational learning activities for innovation. According to March (1991), exploration includes things captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery, and innovation. Exploitation includes things such as refinement, choice, production, efficiency, selection, implementation, and execution. Traditional supply chain innovation focuses on a certain point of explorative innovation or exploitative innovation, while SSCI focuses on the comprehensive use of technical, process and organizational advantages to design a set of smart solutions (Liu et al. 2021b). Hence, SSCI can be defined as a series of explorative and exploitative activities to realize the smarter operations of the supply chain through the application of emerging technologies (such as big data, blockchain, artificial intelligence, etc.), the improvement of existing (digital) processes, and so on (Liu et al. 2021b). In summary, although some scholars have conducted in-depth research on supply chain innovation from different dimensions, there is still a research gap in the mechanism of SSCI for going global companies.

2.3 Supply chain empowerment

Supply chain empowerment reflects the core company's ability to improve supply chain decision-making and customer experience by providing resource integration and technical support to other supply chain members (Sun et al. 2018; Liu et al. 2020). Liu et al. (2020) propose the concept of empowerment in the smart logistics ecological chain (SLEC), which refers to the ability of a dominant ecological operator to improve SLEC's competitive advantage through R&D investment and other means. In fact, supply chain empowerment aims to motivate stakeholders to explore their potential value (Xiao et al. 2020; Liu et al., 2022).

Currently, in smart supply chains, many companies empower their suppliers through platforms. Some scholars have captured this phenomenon and conducted research through game theory modeling. For instance, Qiao et al. (2018) introduce digital empowerment into waste electrical and electronic equipment collection ecosystems. They believe that online
platforms could empower suppliers, customers and other participants through structural psychology and resources. Xiao et al. (2020) investigate the motivation of retailers to accept platform empowerment in the supply chain. The abovementioned literature only focuses on empowerment itself, and few scholars have explored how supply chain empowerment interacts with other factors and jointly promotes SSCI.

2.4 Literature summary

In summary, there is a large amount of literature on supply chain innovation, but these studies cannot provide guidance for SSCI due to the deficient consideration of the characteristics of smart supply chains. To compensate for this research gap, this paper explores the theoretical framework of SSCI for going global companies. Table 1 shows the differences between this study and pertinent studies.

[Table 1 near here]

3. Research method

We adopt a multi-case study method in this paper. This method is appropriate because the mechanism of how going global companies develop SSCI needs to be verified from practice and forms theories. The multi-case study allows researchers to discover practically relevant knowledge through in-depth contact with interviewees, which helps to understand a phenomenon that includes complex and multiple processes and variables (Liu et al. 2020).

3.1 Case selection

We select China’s going global companies from the manufacturing sector as the study target. First, as the most representative companies in China, going global companies face greater challenges in the market environment and operation, which drives them to continue to explore supply chain innovation. Second, as the world’s factory, China has cultivated many powerful global manufacturing companies (Li et al. 2019). With the implementation of the "Made in China 2025" plan, it is easier to find evidence of SSCI in the manufacturing sector.

Since 2014, the Center for China and Globalization (CCG) has published the annual "Report on the Chinese Enterprises Globalization" which is based on massive globalization
cases from China. We select samples from the list of China's top 50 global companies released by CCG in 2019. Referring to the relevant literature, we show the selection criteria in Table 2.

[Table 2 near here]

[Figure 1 near here]

The selection procedures of the sample companies are shown in Figure 1. Through telephone and e-mail communication, we obtained interview permission from four companies. The four companies are involved in four different manufacturing backgrounds: ICT, home appliances, automobiles, and rail transit, which is conducive to forming a more comprehensive and exemplary theoretical framework. To avoid disclosing company information, we use companies A, B, C and D to represent the four sample companies. The basic information of the four companies is shown in the table below.

[Table 3 near here]

3.2 Data collection

We interviewed each company's senior management team members (including the CEO and his subordinates). The data sources include three aspects: (1) initial interviews with senior management, (2) semi-structured interviews with members of the company's senior management team, and (3) secondary data. Details of the data collection procedures are provided below.

(1) Conduct initial interviews with senior managers. First, managers introduced their SSCI practices. Second, managers showed the company's product positioning, core capabilities and business performance. Finally, each senior manager was asked to propose possible influencing factors for SSCI. The research team selected several factors for in-depth analysis and discussed them in detail in the semi-structured interviews with the company's senior managers.

(2) Conduct semi-structured interviews with senior managers. Based on the influencing
factors obtained in the first-round interview, members of the research team proposed the influencing mechanism and propositional hypotheses. Then, the research team developed a detailed interview questionnaire consisting of 8 questions with no definite answers. The interview usually lasted 30 minutes to 60 minutes but sometimes up to 2 hours.

(3) Collect data from other second-hand materials. As a supplement, we also searched industry reports and documents and sorted out the public information of each company's operations to fully grasp their SSCI history and latest developments.

3.3 Data analysis

In this subsection, we first coded the data via an iterative process with both the interview transcripts and secondary data independently. Then, a within-case analysis and a cross-case analysis were conducted successively. The purpose of within-case analysis is to identify the constructs and the relationship between constructs, and cross-case analysis is aimed at identifying the patterns in different settings and improving the external validity of the findings.

The coding process is shown in Table 4. By analyzing the initiatives of the four companies in SSCI, we first identified and refined the corresponding concepts. Through cross-case analysis, we obtained the major categories as findings (Section 5).

[Table 4 near here]

In the coding process, we extracted two concepts that did not appear in the traditional supply chain: supply chain empowerment and supply chain ecologicalization. Specifically, supply chain empowerment reflects the core company's ability to improve supply chain decision-making and customer experience by providing resource integration and technical support to other supply chain members (Sun et al. 2018; Liu et al. 2020). In essence, smart supply chains emphasize data-driven rather than factor-driven processes. Therefore, through empowerment, the supply chain eliminates information islands, creates more value, and gains a competitive advantage. Supply chain ecologicalization reflects the transformation of companies from individual profit optimization to value co-creation alliances (Jiang et al.
3.4 Reliability and validity

We followed the classic criteria to ensure the validity and reliability of our case study design (Yin, 2008).

(1) **Construct validity.** Construct validity means forming a set of correct and operable measurements of concepts to be studied. To ensure construct validity, the members of the research team explained concepts that were prone to ambiguity to the interviewees before the initial interview. In addition, multiple comparisons of hypotheses and evidence were conducted to enhance the construct validity of the study.

(2) **Internal validity.** Internal validity refers to the validity of internal relations extracted from data. We used the triangulation method, that is, not only reviewing the existing literature but also selecting multiple interviewees in the same case company to improve the internal validity.

(3) **External validity.** External validity refers to whether the conclusions of a case study can be summarized into a theory and extended to other cases. We selected the four most typical companies and conducted multi-case studies through repetition and replication.

(4) **Reliability.** Reliability refers to the repeatability of each step in a case study. To ensure reliability, we adopted case study drafts and established a case study database during the data collection process. When establishing a theoretical framework, team members held a continuous discussion on divergent views until consensus was reached.

4. Case descriptions and within-case analyses

4.1 Company A

Company A is a worldwide leading provider of ICT infrastructure and smart terminals. In 2019, R&D employees accounted for half of the total number of employees, and 131.7 billion RMB was invested in product development.

Company A’s mechanism of SSCI is summarized as follows.

- Company A actively expands product categories to meet customer needs. At present, Company A’s product development is divided into three major segments: (1)
network products and solutions for telecommunications operators, (2) ICT infrastructure products and services for enterprises, and (3) smart terminal products such as smartphones and smart watches.

- Company A attaches importance to technology applications. On the one hand, Company A adopts many emerging technologies (e.g., artificial intelligence, cloud computing, etc.) in product design and process operation. On the other hand, Company A is committed to breaking through the existing chip design technology and 5G communication technology.

- Company A forms a stable business alliance and establishes an industrial ecosystem based on a big data platform. Under this circumstance, Company A and all partners (such as hardware equipment providers and software developers) are motivated to share information on the platform and provide personalized ICT solutions for customers.

4.2 Company B

Company B has maintained the largest market share of the world's large home appliances since 2009. It operates 10 R&D centers, 25 industrial parks, and 122 manufacturing centers all over the world. To date, Company B has created seven global brands based on different product positioning and sales countries.

Company B's mechanism of SSCI is summarized as follows.

- Company B not only responds quickly to personalized needs but also analyzes potential needs based on big data. Specifically, Company B can quickly provide a set of smart home design solutions as long as customers put forward general requirements.

- Company B allows customers to participate in product design. It has established a big data platform that allows customers to feedback demand information and even participate in product development. The massive personalized needs effectively support the continuous innovation of the R&D department.

- Company B is changing from a home appliance manufacturer to a service provider. In other words, Company B is committed to empowering its partners and customers.
Specifically, partners can implement big data-based analytics and predictions through Company B’s platform, which reduces the R&D expenditures of these partners, improves business operations and enhances cooperation between supply chain members.

4.3 Company C

Company C is the largest state-owned automobile manufacturer in China. Although Company C mainly sets up its R&D center in China, its product sales cover 49 countries. Moreover, 16 international capacity cooperation projects have been invested in 14 countries, such as South Africa and Vietnam.

Company C’s mechanism of SSCI is summarized as follows.

- Company C applies emerging technologies in smart factories to improve the quick response of suppliers. Through cloud computing and cloud storage technologies, Company C has reduced the cost of deploying the Internet of vehicles by 40%.
- Company C strengthens cooperation with other brands to meet personalized demand. To this end, Company C has jointly developed cars with Toyota, Volkswagen and other automakers.
- Company C is committed to extending the product value chain. It realizes that technological investment should be increased for not only automobiles but also relevant services. Therefore, Company C has established an information technology company focusing on smart transportation services.

4.3 Company D

Company D is the world’s leading supplier of rail transportation equipment. It forms a complete product system that can adapt to various complex geographic environments. Company D has 83 companies and 15 overseas R&D centers in 26 countries and regions. At present, it is gradually changing from product exports to technology exports.

Company D’s mechanism of SSCI is summarized as follows.

- Company D adopts emerging technology on rail transportation equipment, which increases the added value and competitive advantage of products. For example, Company D has developed high-speed trains with automatic driving and fault
self-diagnosis functions.

- Company D insists on optimizing the intelligent manufacturing process. Through the application of algorithms, the production scheduling platform will automatically predict the operational links with higher risks. In addition, Company D has established platforms for purchasing and smart scheduling accordingly.
- Company D provides smart maintenance services for trains. In particular, it establishes a status monitoring and warning system that integrates 5G technology to track key parameters in real time. In addition, the system can propose train maintenance recommendations based on operation data.

5. Cross-case analysis

According to Section 4, the four companies have formed some consensus in the process of SSCI. Overall, SSCI can be implemented from two dimensions: exploitation and exploration. Specifically, exploitative innovation refers to product development, while explorative innovation refers to supply chain empowerment. Through further comparison and sorting, we extract 7 propositions from the cross-case analysis.

5.1 SSCI through product development

Product development is the process of moving new products from idea generation into market introduction, including product design, market study and marketing analyses (Tolonen et al. 2017). The existing literature has shown that product development has a positive impact on supply chain innovation. For example, Tan et al. (2015) believe that the product development process requires companies to identify development ideas with partners in the supply chain based on existing data to improve supply chain innovation. Moreover, some scholars claim that product development itself is a part of supply chain innovation (Pérez-Luño et al. 2019). Going global companies often adopt localization strategies when developing global networks, which makes product development more diverse and complex. Specifically, under localization strategies, companies adjust their products and service systems according to different market environments, which undoubtedly promotes SSCI.

Furthermore, all four companies mentioned the importance of product development. As
shown in Table 5, the manager of Company B says, “We are the first in the United States to provide customers with smart home solutions that integrate personalized custom appliances”. However, the four companies have different views on the meaning of product development. For example, Companies B and C only meet customer needs through product innovation. In contrast, Companies A and D not only focus on product development but also provide customers with value-added services such as technical and operational support. Based on the above evidence, we propose Proposition 1.

|Table 5 near here|

Proposition 1: Product development has a positive impact on SSCI.

5.1.1 Relationship between personalized demand and product development

Demand personalization refers to the different preferences shown by consumers for product features, purchase location, purchase time and other factors (Liu et al. 2020). Due to the regulations, production standards and customer preferences of different countries, going global companies always face more personalized demand. However, product innovation is often driven by the demand side (Wei et al. 2020). To better cater to market demand, many manufacturing companies have to continuously develop new products and even new services, such as allowing customers to directly participate in product design (Zhang et al. 2012). Rather than just providing personalized services according to customer needs, some companies also proactively predict customer needs. From a long-term perspective, improving the level of personalized demand will continue to subdivide the service scenarios, which pushes companies to innovate products and provide an in-time response to market demand.

The interviewed managers of the four companies all agreed that product development depends on the personalized demand of customers, as shown in Table 6. As the manager of Company D said, “In entering the Indonesian market, we innovatively designed train products according to the local climate and geographical conditions”. It is worth noting that Companies A and D belong to the high-end manufacturing industry, so their personalized
demands cover multiple dimensions, such as products, technology support and operational solutions. Accordingly, we propose Proposition 2.

[Table 6 near here]

Proposition 2: Personalized demand has a positive effect on SSCI through product development.

5.2 SSCI through supply chain empowerment

Empowerment originally refers to the company's top-down release of power, especially the power of employees to work independently. Through empowerment, the talents and potential of employees can be maximized (Thomas and Velthouse, 1990). Thus, empowerment leads individuals to exploratory innovation. In smart ecological chains, empowerment can be understood as the ability of the core company to improve supply chain decision-making and customer experience through resource integration and technical support (Liu et al. 2020). Digital empowerment prompts the explorative innovation of business and society, thereby promoting organizational reformation (Sun et al. 2018). High empowerment means that existing competitiveness can transform into stronger development momentum.

When interviewing managers of the four selected companies, they all stated that the competitiveness of the supply chain was enhanced by empowering their partners in the development of SSCI. For example, Company A treats its suppliers as ecological partners in Germany and achieves a win–win situation through collaboration on R&D. For Company B, customers feedback product requirements to the platform, and then the platform collaborates with suppliers to customize products. Under this circumstance, suppliers and the manufacturer cooperate more closely. In contrast, Companies C and D have a weaker awareness of supply chain empowerment, but they have strengthened the training and quality supervision of their suppliers. In summary, we propose Proposition 3.

[Table 7 near here]
Proposition 3: The improvement of smart supply chain empowerment is conducive to SSCI.

5.2.1 Relationship between supply chain ecologicalization and supply chain empowerment

Supply chain ecologicalization refers to the open, collaborative, shared, and harmonious relationships between companies and is a manifestation of the soft power of the supply chain (Liu et al. 2021a). In contrast to collaboration in the traditional supply chain, supply chain ecologicalization emphasizes the value cocreation of stakeholders. For going global companies, regional differences and information deviations will inevitably bring greater challenges to supply chain ecologicalization. Therefore, ecologicalization is conducive to gathering the advantages of supply chain members, thereby significantly improving the empowerment level (Subramanian et al. 2016).

As shown in Table 8, the managers of the four companies are aware of the importance of supply chain ecologicalization. The manager of Company A says, “If the innovation alliance is not built, it would be difficult to optimize and empower the supply chain”. The manager of Company B believes that the key to building a supply chain ecosystem is to share information and discover new value nodes. The manager of Company C demonstrates that supply chain ecologicalization guarantees the product quality and after-sales service of automobiles, which is helpful to empower customers. The manager of Company D claims that the ecosystem requires real-time feedback from the big data platform, which undoubtedly improves empowerment. On this basis, we propose Proposition 4.

[Table 8 near here]

Proposition 4: Supply chain ecologicalization has a positive impact on SSCI through supply chain empowerment.
5.2.2 Relationship between emerging technology application and supply chain empowerment

In recent years, emerging technologies represented by cloud computing, IoT, and big data analytics have been widely used in the manufacturing sector (Chen et al. 2020). To a certain extent, supply chain empowerment shows technological dependence. On the one hand, the application of algorithms and technologies can solve problems such as information transmission delay and data inaccuracy to effectively achieve empowerment (Liu et al. 2020). For example, the IoT can be used to track and monitor the status of vehicle transportation and promptly alert logistics service providers in the case of emergencies (Wu et al. 2016; Liu et al., 2018). From the perspective of supply chain ecologicalization, emerging technology reduces communication barriers and improves organizational efficiency (Adner and Levinthal, 2001; Liu et al. 2021a). In addition, the development of innovative technologies and algorithms can improve the visibility of the supply chain and help reduce conflicts between companies (Liu et al. 2020).

The interview confirms that emerging technology has played a multi-dimensional role in improving SSCI. First, we can see the value of emerging technology for improving supply chain empowerment on Table 9. The manager of Company A said that empowerment is ultimately driven by technology, which is why so many companies invest resources in technological breakthroughs. The managers of Companies B and C introduce how they can empower the supply chain through emerging technology from the perspectives of production and service. The manager of Company D says that emerging technology is used to predict and monitor operation faults. Second, the managers of the four companies explain the role of emerging technology in promoting supply chain ecologicalization, as shown in Table 10. The manager of Company A says that the status of products on the production line can be fed back to all nodes in real time, which greatly improves production efficiency. The manager of Company B says that platforms and emerging technology play irreplaceable roles in production collaboration. The managers of Companies C and D take transportation and after-sales as examples and show how emerging technology can improve supply chain ecologicalization. To this end, we propose Proposition 5.
Proposition 5(a): Emerging technology application has a positive impact on SSCI through supply chain empowerment.

Proposition 5(b): Emerging technology application is conducive to improving supply chain ecologicalization.

5.3 Relationship between supply chain empowerment and product development

There is little research on supply chain enablement, but we found that supply chain empowerment creates an explorative innovation environment in which information and resources are fully shared to facilitate product development. Jha et al. (2017) point out that product development can be better implemented by sharing information and technology from upstream and downstream. Meanwhile, empowerment also allows supply chain members to form a reciprocal relationship. Ayala et al. (2020) state that the effective use of cooperative work systems is the key to product development. In addition, Pérez-Luño et al. (2019) denote that cross-functional integration, which has been defined as "the degrees of interaction, communication, and information sharing across functional areas", is a vital factor that facilitates coordination and enables product innovation. In this paper, the enhancement of supply chain empowerment means that the supply chain can operate more efficiently, thereby creating favorable conditions for product development. When empowerment capability is high, the company can stimulate higher exploitative innovation capabilities, expanding from product output to technological output or even strategic output.

All managers believe that only when the supply chain has strong supply chain empowerment can product development be better implemented. The manager of Company A says, “Although product development depends on market demand, it needs a strong technical reserve in the supply chain.” The manager of Company B points out that they have formed a close cooperative relationship with their supply chain partners in product development. The
managers of Companies C and D believe that strong innovation competitiveness effectively supports product development on the demand side. In summary, we propose Proposition 6.

[Table 11 near here]

Proposition 6: Supply chain empowerment has a positive effect on product development.

5.4 The role of the going global policy

Promulgating proactive industrial policies is an important means of improving innovation performance (Özçelik and Taymaz, 2008). Therefore, going global policy plays an indispensable role in transforming empowerment into SSCI practices (Li et al. 2020). For example, after the Chinese government proposed the “One Belt One Road” initiative, a large number of Chinese manufacturing companies implemented a strategy of going global and actively establishing smart factories around the world. For going global companies, policy support has provided impetus and lowered risk barriers for the development of SSCI (Chan et al. 2019).

From Table 12, we can see that all managers mentioned the impact of going global policy on the layout of the smart supply chain. The manager of Company A says, “Our partners are mainly in Europe, so we will evaluate the opening-up policies of European countries and dynamically integrate supply chain resources”. The manager of Company B says that they are more willing to build a complete smart supply chain system in countries with policy guarantees. In particular, Companies C and D, as state-owned companies, accelerated the SSCI in Indonesia, Serbia and other countries after China proposed the "One Belt One Road" initiative. Therefore, we propose Proposition 7.

[Table 12 near here]

Proposition 7: The greater the support of the going global policy is, the greater the positive impact of supply chain empowerment on SSCI.
6. Results and discussion

Through within-case and cross-case analyses, we identify the influencing factors of SSCI. The final theoretical framework is shown in Figure 2.

As shown in Figure 2, SSCI relies on two important factors: product development and supply chain empowerment. First, product development promotes SSCI (P1). This is because when the company has higher product development capabilities, it can create more service scenarios or product categories. Product development focuses on the enhancement of the productivity of the supply chain, but it tends to be limited to short-term gradual innovation. Therefore, we classify product development as exploitative innovation. Second, strong supply chain empowerment is beneficial to SSCI (P3). In particular, empowerment not only indicates the competitiveness of the supply chain but also presents its potential to generate new driving forces. Therefore, when empowerment capability is high, all supply chain members can take advantage of creating technologies and resources and then create new business models collaboratively. Supply chain empowerment aims to generate variation and is characterized by both high uncertainty and slow performance in learning outcomes. In the long run, it allows organizations to create more radical innovations. Therefore, we classify supply chain empowerment as explorative innovation (Lee et al. 2018). Furthermore, we find that the positive effect of supply chain empowerment on SSCI is regulated by the going global policy (P7). Going global companies face an uncertain international environment; therefore, it is of significant importance to adjust smart supply chains in accordance with the policy environment.

We further reveal the potential connotation of the above two core factors and enrich the understanding of the mechanism of SSCI. We find that personalized demand has a positive impact on product development (P2). Obviously, the purpose of product development is to meet the growing personalized demand globally. In turn, personalized demand provides new
ideas and insights for product development. In addition, both emerging technology application and supply chain ecologicalization have positive impacts on supply chain empowerment (P5(a) and P4). Specifically, emerging technology application mainly improves companies’ internal operations, while supply chain ecologicalization improves the relationship and coordinates the operation process of supply chain members. According to Proposition 5(b), the emerging technology application is also conducive to constructing the open business ecosystem, so it has become the fundamental driving force for the enhancement of supply chain empowerment. Furthermore, Proposition 4 shows that in the context of a smart economy, supply chain innovation is no longer the single innovation based on core companies but a collaborative innovation in which companies make full use of their own advantages in an open and shared environment.

In addition, supply chain empowerment and product development are not independent. In fact, supply chain empowerment has a positive impact on product development (P6). When going global companies develop products, they should not only capture personalized demand but also coordinate the operation of the global supply chain. This indicates that product development is dependent on not only the pull of personalized demand but also the push of empowerment.

The existing literature has constructed theoretical frameworks on supply chain innovation from different perspectives (Arlbjørn et al. 2011; Caniato et al. 2013; Hahn, 2019; De Goey et al. 2019). This study improves the existing frameworks from the following three aspects. First, Arlbjørn et al. (2011) and Hahn (2019) believe that supply chain innovation consists of three core elements: technology, process and supply chain network. However, we find that the boundaries between the process and supply chain network are gradually blurred in SSCI. Specifically, process and supply chain network gradually evolve into a part of the supply chain ecologicalization and then together have a positive effect on supply chain empowerment under the support of emerging technology. Second, Caniato et al. (2013) demonstrate that innovation is a one-way activity pushed from the supply side to the demand side. However, this paper believes that supply chain innovation is not only driven by the supply side but also embodied in product development capabilities, which often require the
pull of personalized demand. Finally, compared with the study conducted by De Goey et al. (2019), in which only the traditional factors of supply chain innovation are sorted out, this study extracts both smart factors (i.e., supply chain empowerment, emerging technology application, supply chain ecologicalization) and traditional factors (i.e., personalized demand, product development, and going global policy). On this basis, this study further explains the influence mechanism between the two types of factors.

7. Concluding remarks

By applying a multi-case study method, this research examines the mechanism of SSCI for going global companies in China. This paper sorts out some “smart” characteristics of the supply chain and systematically answers the question of which factors affect SSCI. Seven propositions provided answers to this question. By answering this question, several important theoretical and managerial contributions are drawn as follows.

7.1 Theoretical contributions

On the one hand, we contribute to the literature on supply chain innovation. We have learned that supply chain innovation is a valuable theoretical framework (Arlbjørn et al. 2011; Caniato et al. 2013; Hahn, 2019; De Goey et al. 2019), so we extend it to the “smart” area. More specifically, the existing literature believes that supply chain innovation includes three factors: technology, process and supply chain network. However, in the smart economy, process and network structure are gradually integrated and are evolved into supply chain ecologicalization, which promotes supply chain innovation with the support of technology. In addition to the above driving factors, personalized demand has pulled the innovation of the smart supply chain from the customer side.

On the other hand, our research conclusions also provide rich insights to achieve smart supply chain management. In contrast to previous research on smart supply chains (Wu et al. 2016; Liu et al. 2021a), this study is the first to reveal the correlations between the SSCI, supply chain empowerment and product development based on real-world cases. In fact, empowerment reflects the vision of the collaborative evolution of smart supply chain members. The relevant conclusions provide a hypothetical basis for follow-up research on
smart supply chain management.

7.2 Managerial contributions

First, the reason why the mechanism of SSCI becomes complicated is the interaction between smart factors (i.e., supply chain empowerment, emerging technology application and supply chain ecologicalization) and traditional factors (i.e., personalized demand, product development and going global policy). Therefore, managers should emphasize the ecological construction of the supply chain. Furthermore, collaborating upstream and downstream by leveraging emerging technologies and digital platforms can better facilitate SSCI.

Second, SSCI is not equivalent to the application of emerging technologies; rather, it empowers operations and organizations with the support of emerging technologies. On the one hand, based on emerging technology, smart supply chains can quickly grasp customer needs, subdivide entire processes, and automatically solve potential problems. On the other hand, the smart supply chain should form a platform-based, shared and collaborative ecosystem to enhance soft power.

Finally, we emphasize the importance of going global policy. According to the theoretical framework, going global policy will affect the transformation of supply chain empowerment to innovation practices. Therefore, companies should pay attention to the policies of different countries and adjust the global resource layout accordingly.

7.3 Limitations and future research

Although our framework is well supported by the literature and well motivated by various industrial practices, this paper has some limitations and several potentially interesting avenues for future research. First, this paper does not provide further indicators and methods for the evaluation of SSCI; therefore, research in this area will be worth exploring. Second, when analyzing the influencing factors of SSCI, this paper does not consider the development stages of smart supply chains of different companies. In follow-up studies, scholars can explore the impact of different development stages on SSCI. Finally, it will be necessary to conduct empirical research through surveys to quantify the influences of these factors given the proposed theoretical framework.
References


technology and business process redesign”.


### Table 1 Differences between this study and related studies

<table>
<thead>
<tr>
<th>Theme</th>
<th>Literature</th>
<th>Research content</th>
<th>This study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart supply chain</td>
<td>Wu et al. (2016)</td>
<td>Literature review and insights of smart supply chain</td>
<td>Explores the innovation mechanism of smart supply chain from the perspective of exploitation and exploration</td>
</tr>
<tr>
<td></td>
<td>Liu et al. (2021b)</td>
<td>Factors influencing the SSCI performance of commodity distribution enterprises</td>
<td></td>
</tr>
<tr>
<td>Supply chain innovation</td>
<td>Arlbjørn et al. (2011)</td>
<td>Definition and key elements of supply chain innovation</td>
<td>Explores the differences of supply chain innovation mechanisms in the context of smart economy</td>
</tr>
<tr>
<td></td>
<td>Caniato et al. (2013)</td>
<td>The role of dynamic capabilities in the supply chain innovation of fashion luxury goods</td>
<td></td>
</tr>
<tr>
<td></td>
<td>De Goey et al. (2019)</td>
<td>Enablers and barriers in design-driven innovation</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2 Case Selection Criteria

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core manufacturing company</td>
<td>The selected case has a perceptible, adjustable and visual intelligent manufacturing plant, and a global product development-production-sales system. The selected case has accumulated rich experience in SSCI at least three years (Liu et al. 2021b). Specifically, the supply chain has conducted in-depth explorations on emerging technology innovation, smart equipment innovation, and smart supply chain structure innovation, which indicates that the company has a certain empowerment capacity.</td>
</tr>
<tr>
<td>Smart supply chain innovation</td>
<td>The company can use the global network to share information among its members and provide fast response to customers (Yam et al. 2007). In addition, the company's SSCI can further support its global network layout.</td>
</tr>
</tbody>
</table>
### Table 3 Basic information of sample companies

<table>
<thead>
<tr>
<th>Enterprise Name</th>
<th>Year Founded</th>
<th>Enterprise size (number of employees)</th>
<th>Company positioning</th>
<th>Global coverage</th>
<th>Service object and content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company A</td>
<td>1987</td>
<td>Large (About 194,000)</td>
<td>The world's leading provider of ICT infrastructure and intelligent terminals.</td>
<td>More than 170 countries and regions</td>
<td>ICT infrastructure construction and smart terminal production, leading the global 5G commercialization</td>
</tr>
<tr>
<td>Company B</td>
<td>1984</td>
<td>Moderate (87447)</td>
<td>The world's leading home appliance manufacturer.</td>
<td>More than 160 countries and regions</td>
<td>Building an IoT ecosystem that integrates life, travel, medical care and education, and personalized smart life solutions</td>
</tr>
<tr>
<td>Company C</td>
<td>1956</td>
<td>Large (132,083)</td>
<td>China's large state-owned car manufacturer.</td>
<td>78 countries and regions</td>
<td>Producing various types of cars, trucks, city buses and highway buses.</td>
</tr>
<tr>
<td>Company D</td>
<td>2015</td>
<td>Large (187959)</td>
<td>A leading rail transportation equipment supplier with a complete range of products.</td>
<td>105 countries and regions</td>
<td>Providing high-end rail transportation system solutions and technologies to countries around the world.</td>
</tr>
</tbody>
</table>

### Table 4 Coding analysis

<table>
<thead>
<tr>
<th>Major Category</th>
<th>Subcategory</th>
<th>Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply chain empowerment</td>
<td>Capability building</td>
<td>Supplier training, quality supervision, process reengineering</td>
</tr>
<tr>
<td></td>
<td>Digital supply chain building</td>
<td>Transparent supply chain, supply chain collaboration</td>
</tr>
<tr>
<td></td>
<td>Product innovation</td>
<td>Function innovation, service innovation</td>
</tr>
<tr>
<td>Product development</td>
<td>Product optimization</td>
<td>Product design optimization, product function optimization</td>
</tr>
<tr>
<td></td>
<td>Product personalization</td>
<td>Customized products, product value-added points</td>
</tr>
<tr>
<td>Personalized demand</td>
<td>Personalized service</td>
<td>Diversified service requirements, personalized service solutions</td>
</tr>
<tr>
<td>Emerging technology</td>
<td>Intelligent algorithm</td>
<td>Artificial intelligence algorithm, machine learning</td>
</tr>
<tr>
<td>application</td>
<td>Smart platform</td>
<td>Supply chain collaboration platform, scheduling platform</td>
</tr>
<tr>
<td></td>
<td>Emerging technology</td>
<td>Internet of Things, AI, etc.</td>
</tr>
<tr>
<td>Supply chain ecologicalization</td>
<td>Value co-creation</td>
<td>Win-win cooperation, upstream and downstream interaction</td>
</tr>
<tr>
<td></td>
<td>Symbiotic relationship</td>
<td>Harmonious relationship, community of interests</td>
</tr>
<tr>
<td></td>
<td>Evaluation of going global policy</td>
<td>Policy analysis, environmental assessment</td>
</tr>
<tr>
<td>Support of going global policy</td>
<td>Going global policy</td>
<td>One Belt One Road, economic reform and open up</td>
</tr>
</tbody>
</table>
Table 5 Relationship between product development and SSCI

<table>
<thead>
<tr>
<th>Companies</th>
<th>The relationship between product development and SSCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company A</td>
<td>We have extended different product development series from multiple dimensions such as ICT infrastructure, smart terminal equipment, and software platforms. We are the first in the United States to provide customers with smart home solutions that integrate personalized custom appliances. Through continuous investment in capital and technology, we improve the comfort and safety of cars while reducing production costs. We are gradually changing from product export to technology export, capital export and global operation, so the supply chain structure is adjusted accordingly.</td>
</tr>
</tbody>
</table>

Table 6 Relationship between personalized demand and product development (SSCI)

| Companies | Relationship between personalized demand and product development | Relationship between personalized demand and SSCI |
|-----------|---------------------------------------------------------------|-------------------------------------------------
| Company A | We have changed from push production to pull production, that is, mass production has transformed into product development determined by customers. We focus on providing customers with smart home solutions. The concept of smart home is the integration of customized products, that is, scenario + ecosystem. We have worked with Japanese and German automakers respectively, which have different brand styles and production standards. The different types of trains we develop and produce can adapt to various complex geographic environments and meet diversified market demands. | A On the premise that technology is not a bottleneck, product innovation is the main method of supply chain innovation. Customers only need to put forward overall requirements, then we can quickly provide a complete set of smart home design solutions. The consumption habits of young people are different from before. Hence, we constantly adjust the style of product design to better cater to the tastes of Chinese consumers. All the innovations we do are to satisfy customers. In entering the Indonesian market, we innovatively designed train products according to the local climate and geographical conditions. |
Table 7 Relationship between supply chain empowerment and SSCI

<table>
<thead>
<tr>
<th>Companies</th>
<th>Relationship between supply chain empowerment and SSCI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Company A</strong></td>
<td>In Germany, we treat suppliers as ecological partners with a common development vision, and achieve a win-win situation through technology sharing and joint R&amp;D.</td>
</tr>
<tr>
<td><strong>Company B</strong></td>
<td>Customers feed back product requirements to the platform, and the platform can collaborate with suppliers to achieve product customization.</td>
</tr>
<tr>
<td><strong>Company C</strong></td>
<td>To implement SSCI, we monitor suppliers based on key indicators such as product quality and tact time, and achieve good performance.</td>
</tr>
<tr>
<td><strong>Company D</strong></td>
<td>We need to make more efforts in supply chain empowerment. There is no doubt that the empowerment from the production link to the entire supply chain will continue to optimize all links in the supply chain, and thus improve SSCI.</td>
</tr>
</tbody>
</table>

Table 8 Relationship between supply chain ecologicalization and supply chain empowerment (SSCI)

<table>
<thead>
<tr>
<th>Companies</th>
<th>Relationship between the supply chain ecologicalization and supply chain empowerment</th>
<th>Relationship between the supply chain ecologicalization and SSCI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Company A</strong></td>
<td>If the innovation alliance is not built, it would be difficult to optimize and empower the supply chain.</td>
<td>The characteristics of supply chain ecologicalization are openness and sharing. Hence, we have established an enabling department to form closer partnerships with suppliers and promote collaborative product design.</td>
</tr>
<tr>
<td><strong>Company B</strong></td>
<td>Supply chain coordination and information sharing are conducive to the competitive advantage.</td>
<td>The key to the supply chain ecosystem is to share information, and thus discover new value nodes. On the one hand, we strengthen the guidance and supervision of suppliers; on the other hand, we bring customers a better purchasing experience through innovative marketing, such as live streaming.</td>
</tr>
<tr>
<td><strong>Company C</strong></td>
<td>The supply chain ecologicalization guarantees product quality and after-sales service of automobiles.</td>
<td>Ecologicalization can provide power for supply chain empowerment, which in turn contributes to the smart transformation of the supply chain.</td>
</tr>
<tr>
<td><strong>Company D</strong></td>
<td>The ecosystem requires real-time feedback from the big data platform, which undoubtedly improves empowerment.</td>
<td></td>
</tr>
</tbody>
</table>
Table 9 Relationship between emerging technology application and supply chain empowerment (SSCI)

<table>
<thead>
<tr>
<th>Companies</th>
<th>Relationship between emerging technology application and supply chain empowerment</th>
<th>Relationship between emerging technology application and SSCI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Company A</strong></td>
<td>Our development strategy is &quot;Platform + AI + Ecology&quot;, where the ecology reflects the attention to the demand side, while the platform and AI reflect our emphasis on leading the industry through technology empowerment. From the manufacturing, the welding accuracy of robotic arms controlled by 5G technology is higher. We realize that not only the R&amp;D of automobiles, but also the services surrounding automobiles should increase technological investment. Therefore, we have established an information technology company, focusing on smart transportation business areas. We use data mining and AI algorithms to develop a failure prediction model for key train components, which significantly reduces the failure rate and improves our competitive advantage.</td>
<td>Empowerment is ultimately driven by technology, which explains why we have invested so much money in technological breakthroughs. The simple superposition of technology is difficult to form competitiveness. It is necessary to integrate processes, technologies, and algorithms to form a comprehensive empowerment capability. Through the input of emerging technology, the operation process and mode of the supply chain can be iteratively innovated. The application of new technologies has enabled the digital transformation of the supply chain, thereby accelerating SSCI.</td>
</tr>
<tr>
<td><strong>Company B</strong></td>
<td>From the product, we have built a series of smart life solutions, which has improved our market competitiveness. The integrated platform and emerging technology play irreplaceable roles in production coordination. With the support of emerging technology, suppliers can directly view transportation information through a shared platform. This information sharing is the first step in building a supply chain ecosystem. In the past, for train parts with quality problems, the purchasing department needs to negotiate with the supplier over the phone. Now, parts information can be passed to suppliers through the platform.</td>
<td></td>
</tr>
<tr>
<td><strong>Company C</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Company D</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 10 Relationship between emerging technology application and the supply chain ecologicalization

<table>
<thead>
<tr>
<th>Companies</th>
<th>Relationship between emerging technology application and the supply chain ecologicalization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Company A</strong></td>
<td>The status of production line can be fed back to all nodes in real time, which greatly improves production efficiency. The integrated platform and emerging technology play irreplaceable roles in production coordination. With the support of emerging technology, suppliers can directly view transportation information through a shared platform. This information sharing is the first step in building a supply chain ecosystem. In the past, for train parts with quality problems, the purchasing department needs to negotiate with the supplier over the phone. Now, parts information can be passed to suppliers through the platform.</td>
</tr>
</tbody>
</table>
Table 11 Relationship between supply chain empowerment and product development

<table>
<thead>
<tr>
<th>Companies</th>
<th>Relationship between supply chain empowerment and product development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company A</td>
<td>Although product development depends on market demand, it needs a strong technical reserve in the supply chain.</td>
</tr>
<tr>
<td>Company B</td>
<td>We have formed a close cooperative relationship with their supply chain partners in product development.</td>
</tr>
<tr>
<td>Company C</td>
<td>To better carry out product development, we actively invite suppliers to participate in R&amp;D.</td>
</tr>
<tr>
<td>Company D</td>
<td>Empowerment is always the core driving force for the supply chain to gain competitive advantage. Once the empowerment capability is improved, the product development capability will also increase.</td>
</tr>
</tbody>
</table>

Table 12 Regulatory role of the going global policy

<table>
<thead>
<tr>
<th>Companies</th>
<th>Relationship between going global policy and SSC1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company A</td>
<td>Our partners are mainly in Europe, so we will evaluate the opening-up policies of European countries and dynamically integrate supply chain resources.</td>
</tr>
<tr>
<td>Company B</td>
<td>We are more willing to build a complete smart supply chain system in countries with policy guarantees. As the countries along the &quot;One Belt One Road&quot; are more open to infrastructure investment and capacity cooperation, we are actively developing markets in this region.</td>
</tr>
<tr>
<td>Company C</td>
<td>As a state-owned enterprise, our globalization strategy is more susceptible to policies such as going global.</td>
</tr>
</tbody>
</table>
Figure 1 The screening procedures of the sample companies

Figure 2 The theoretical framework of SSCI for going global companies

a The “P” and numbers correspond to this paper’s propositions
Appendix A:

Questionnaire

1. Basic information

1) What is your company's service area, service object and service scope?
2) How about the construction of smart supply chains in your company? What are the important factors involved in the innovation of smart supply chains?
3) What activities does your company carry out in the construction of smart supply chains?

2. About the framework for factors affecting SSCI

4) What kind of personalized demand is your company facing? Can you give us a brief introduction of the company's product development? What do you think of the impact of personalized demand on product development and SSCI?
5) How do you understand the meaning of supply chain empowerment?
6) Can you introduce the application of emerging technology of the company? What is the impact of the application of emerging technology on supply chain empowerment and SSCI?
7) Does your company form an ecosystem with the upstream and downstream? What is the impact of supply chain ecologicalization on supply chain empowerment and SSCI?
8) In the process of going global, has your company paid attention to some relevant policies? What impact will these policies have on supply chain empowerment?
Appendix B:

The core new concept in this paper is the smart supply chain. To better define this concept and distinguish it from existing concepts, in this appendix, we provide supplementary comparisons between (1) smart supply chains and traditional supply chains, (2) smart supply chains, digital supply chains and intelligent supply chains.

1. Differences between smart supply chains and traditional supply chains

We have summarized the relevant descriptions and definitions of smart supply chains in the existing literature, as shown in Table 13.

<table>
<thead>
<tr>
<th>Literature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wu et al. 2016</td>
<td>The smart supply chain includes technologies such as IoT, smart machines, and intelligent infrastructure, and capabilities such as interconnectivity, fully enabling data collection and real-time communication across all supply chain stages, intelligent decision-making, and efficient and responsive processes to better serve customers.</td>
</tr>
<tr>
<td>Tiwari et al. 2018</td>
<td>There are three unique capabilities required by a smart supply chain: descriptive capability, predictive capability, and prescriptive capability.</td>
</tr>
<tr>
<td>Chen et al. 2020</td>
<td>A smart supply chain is engineered to be agile and customized to be flexible based on the application of advanced emerging technologies.</td>
</tr>
<tr>
<td>Shokouhyar et al. 2019</td>
<td>Smart supply chains generate new value via the development of original business models, enhancing business procedures, and decreasing the relevant expenses and risks. Additional information, improved decisions, improved processes and improved products are produced by the smart supply chain.</td>
</tr>
<tr>
<td>Frank et al. 2019</td>
<td>As front-end technologies of Industry 4.0, a smart supply chain includes technologies to support the horizontal integration of the factory with external suppliers to improve the raw material and final product delivery in the supply chain, which impact the operational costs and delivery time.</td>
</tr>
<tr>
<td>Sun et al. 2020</td>
<td>The smart supply chain is a large-scale business strategy that brings as many links of the chain as possible into a closer working relationship with each other. The goal is to improve response time and production time and reduce costs and waste.</td>
</tr>
<tr>
<td>Shao et al. 2021</td>
<td>As the final stage of Industry 4.0, the goal of the smart supply chain is to link the data together, and based on the identification of defects, the system becomes self-adaptive by taking corrective actions.</td>
</tr>
</tbody>
</table>
The attributes of smart supply chain include connection, collaboration, customization, and the characteristics of smart supply chain consist of functional flexibility and structural flexibility.

Table 13 indicates that the existing literature has explained the smart supply chain from different perspectives and dimensions but has not yet formed a unified view. According to Table 13, we can see that the key points of the smart supply chain include technology application, process management and organization operation. First, there is no doubt that smart supply chains adopt massive emerging technologies to achieve a wide range of data collection, identification, transmission, processing and even decision-making processes. Second, based on the aforementioned technologies and data, the operation process becomes perceptible, adjustable and visual. For example, the smart supply chain can identify signals automatically, make decisions independently and trace the whole process. Finally, the organizations gradually evolve into an orderly ecosystem through efficient data transmission and collaborative operation.

In summary, a smart supply chain can be defined as a human-like operation form, embedded with emerging technologies such as the Internet of Things and big data, to achieve efficient collaboration throughout the entire process of product design, procurement, production and sales through intelligent decision-making, digital management, and automated operation.

2. Differences between smart supply chains, digital supply chains and intelligent supply chains

To better distinguish the three terms, we describe the attributes of intelligent supply chains and digital supply chains in the existing literature, as shown in Table 14.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Literature</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital supply chain</td>
<td>Rai et al. 2006</td>
<td>Their digitization across the extended enterprise is being enabled by web technologies, workflow tools, portals for customers, suppliers, and employees, and information technology innovations targeted at supply chains and customer relationships. Firms are investing in these...</td>
</tr>
</tbody>
</table>
technologies and related partnerships to develop their extended enterprise capabilities.

**Liu et al. 2013**
The digital supply chain enables wider availability of information and infinitely superior interactions, communication, and collaboration, which lead to improved trust, agility, and productiveness.

**Kinnett, 2015**
The digital supply chain is an intelligent, value-driven network that leverages new approaches with technology and analytics to create new forms of revenue and business value through a centric platform that captures and maximizes the utilization of real-time information emerging from a variety of sources.

**Garay-Rondero et al. 2019**
It is important to emphasize how dealing with the digitalization of the supply chain is more than maintaining the same method of managing traditional supply chains and simply digitizing all knowledge and information flows. Therefore, it is significant to highlight that the whole structure, as well as all of the processes, managerial components and flows in the chain are changing because of the emergent and customized markets that need rapid responses.

**Nasiri et al. 2021**
This study defines the digital supply chain as a bundle of interconnected activities, handled with novel technologies, involved in supply chain processes between suppliers and customers.

**Srinivasan, 2007**
A supply chain deals with the movement of materials or services and information. At the most abstract level, it has three data components: demand, supply and capacity. Intelligent supply chain management mandates that decisions be made about matching supply and capacity to demand at various points in the supply chain.

**Xie et al. 2020**
The core of the intelligent supply chain is to eliminate asymmetric information in the supply chain and achieve seamless integration among procurement, planning, production, logistics, and warehousing. The intelligent supply chain can be analyzed in aspects such as visibility, legality, personalization, information governance, supply chain warning, green, innovation, and learning.

According to Table 14, the existing literature shows that the digital supply chain places more emphasis on the roles of technology, data and information. Therefore, we define a digital supply chain as an organizational form that combines digital technology with supply chain operation. A digital supply chain can obtain data from the whole supply chain process in
real time, which can provide a quantitative judgment basis for managers' decision-making.

In fact, digital supply chains focus on data collection, which can effectively support the operation of supply chains and thus change the traditional business operation mode. In contrast, smart supply chains are a more advanced form than digital supply chains. Specifically, based on the digital supply chain, the smart supply chain adopts machine learning, AI and other decision-making technologies, which enable the human-like operation of the supply chain, such as the functions of sensitive perception, accurate judgment, independent learning function, and effective execution.

In addition, as shown in Table 14, few studies use the expression of intelligent supply chain; thus, it lacks a clear definition. However, there are also obvious differences between smart supply chains and intelligent supply chains. Specifically, the key to the intelligent supply chain is human-computer interaction, while the smart supply chain is committed to autonomous adaptation, adjustment and optimization based on human-computer interaction.