Responsible Innovation in Industry

Xiande Zhao · Hing Kai Chan
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Supply Chain Risk and Innovation Management in "The Next Normal"

Proceedings of the 15th International Conference on Operations and Supply Chain Management

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Responsible Innovation in Industry

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Creating new knowledge sustainably will be a pre-requisite to meet the future dynamic competitive environment. Innovation, as a core competency in a country's drive to develop modern industry, plays a significant role in self-reliance in science and technology as the strategic support for future development. In recent years, however, innovation embraces more specific responsibility as individuals and companies have increasingly encountered sustainability and responsibility issues. Responsible innovation is a process that seeks to promote creativity and opportunities for science and innovation that are socially desirable and undertaken in the public interest. Specifically, responsible innovation acknowledges that innovation can raise questions and dilemmas, but it is often ambiguous in terms of purposes and motivations and unpredictable in terms of impacts, beneficial or otherwise. Responsible innovation creates spaces and processes to explore these aspects of innovation in an open, inclusive and timely way. This is a collective responsibility, where funders, researchers, stakeholders and the public all have an important role to play. It includes, but goes beyond, considerations of risk and regulation, important though these are. Responsible innovation associates with different levels of analysis, including individuals, systems, organizations and societies, and is a multi-disciplinary research topic. Therefore, there is a need to work in-depth towards the practical applications of responsible innovation and to develop an academic series of monographs on emerging issues regarding responsible innovation.

The series will provide an opportunity to explore in-depth and rigorous themes that are particularly relevant to responsible innovation. Examples of themes to be featured in the series are digital innovation, international business strategy, production and operations management, science and engineering applications, innovation and entrepreneurship, etc. The main objectives of the book series are to promote cross-disciplinary studies in Responsible innovation, and to encourage core research expertise to produce high-quality outcomes to influence the socio-economic systems.

More information about this series at https://link.springer.com/bookseries/16802

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Introduction

2020–2021 is an unaccustomed year for everyone. Enterprises and supply chains are no exception. The economic shock of the current crisis is unparalleled. Although no one knows when the pandemic will come to an end, McKinsey coined the period after the COVID-19 pandemic era as "The Next Normal".

Before "The Next Normal", digital transformation or digitalization in supply chains was rising but had not hit its peak. Humble speaking, digital transformation before 2020 was premature. In 2020, however, many enterprises have witnessed the possibilities of many impossible commissions in the past: work from home, restricted travelling, virtual meetings, stay-at-home economy, and so on. Digital technologies play a crucial role to the possibilities! Suddenly, digital transformation is no longer a future.

Perhaps, it is more an observation than a verdict that digital transformation has been accelerated in 2020–2021. No one can deny that, however, digital technologies have helped organizations and supply chains being more resilient during this difficult time period. It is predicted that future operations and supply chain management will be more digital. Businesses must make strategic changes in order to adapt to "The Next Normal". Those who lack digital capabilities will fall behind and such capabilities will indeed define how organizations can survive.

This year, ICOSCM aims to promote latest research in supply chain risk and innovation management in order to prepare for "The Next Normal". On the one hand, digital transformation and digital technologies are all linked to traditional innovation processes in the operations and supply chain management domain. In "The Next Normal", there is a pressing need to connect risk management to the innovation process in order to make supply chains more resilient.

In this connection, studies that address the interaction between risk and innovation management in supply chains are encouraged: How can innovation be linked to risk management to improve supply chain resilience and responsiveness? How can organizations transform to synergise innovation management and risk management in supply chains? How can supply chain partners work collaboratively towards resilient supply chains? This conference attempts to address above issues.

In this year, we continue to organize the 4th Strategic Supply Chain Though Leaders Forum in conjunction with the academic conference. The prestigious scholars and business leaders will share their insights and experiences on how the supply chain innovation improves the global supply chain management and how the domestic supply chain interacts with the global supply chain.

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Sustainable Transformative Innovation in Response to Covid-19 and Beyond

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Abstract. New product innovation is a vital capability for firms to compete globally. Governments in both developed and emerging economies are increasingly concern over low success rate in tech start-ups. Policy on supporting technology start-ups - originally intended to create and sustain knowledge-intensive good-paying jobs - has become difficult to materialise over time. Using three case studies, this paper demonstrated how - even under the fallout from Covid-19 disruptions- tech-driven SMEs could adopt transformative innovation to systematically identify and reliably transform low-value commoditized products of having sustained consumer needs into high-value, radically new products and services leveraging on emerging technologies as enablers. These new products are specifically targeted to replace and disrupt those high-to-mid segments of incumbent's conventional product range built with outdated technologies and ultimately seek to take over its entire market share. This innovation approach enables startups and SMEs to leapfrog from imitators to become global market leaders in a transformative manner. Not only is this innovation approach enables startups and SMEs to develop radically distinctive new products, it is strategic yet disruptive in nature in displacing incumbent old-fashioned products. It would potentially be one of the leading trends in innovation and technology management in the near future.

Keywords: Transformative innovation · New product development · Covid-19 · Supply chain resilience · SMEs

1 Introduction

In addition to technological capabilities and resources, time plays a vital role in new product innovation, for both SMEs and large organizations alike. Increasingly, industries are now facing the challenge of shortening product life cycles, firms have realized the urgent need to improve innovation performance to develop competitive advantage (Li et al. 2014; Tan et al. 2015). Hence, accelerated or rapid innovation has become a means for firms to obtain a first-mover or second-mover advantage in the industries (Williamson and Yin 2014; Tan et al. 2015; Zhan and Tan 2020). Especially, accelerated innovation has become the much sought-after capabilities during the fallout of Covid-19 disruptions. Firms that capable to ride the wave of sustainable and rapid innovation come out stronger to face Covid-19 disruptions and beyond.

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Researchers have pointed out that a large proportion of Chinese industrial products have won a significant share of global revenues, markets and profits. McKinsey Global Institute (2015) argued that China performs well in consumer focused and efficiency-driven manufactured products such as mobile phones, household appliances, solar panels and railway equipment. This suggests that Chinese manufacturing firms have strong cost-management capabilities that leveraging on a comprehensive China's manufacturing supply chain. This cost-management innovation achievement of China manufacturers have been widely acknowledged. Many consumers continue to see China as a 'duplicative imitation' country (Cheung 2011; Tan et al. 2019). To overcome this common stereotype and enhance the sustainable competitiveness of Chinese products in the global market, the Chinese government aims to transform itself from "Made in China" to "Design in China" by establishing many initiatives to boost innovation capabilities (China StateCouncil 2015; Chung and Tan 2017). Some scholars further noted that Chinese SMEs tend to imitate or copy market hot-selling or sellable product design in order to mitigate saleability risks and overcome the resource as well as technological capability limitations and to reduce product development cost (Minagawa et al. 2007). This approach tends to be less riskier than developing original aesthetic and functional designs that are inherently encompassing higher uncertainties as the newly developed products may not able to get traction in the market.

Whilst mirroring large firms with respect to innovation strategy has been found to be helpful in improving SMEs' performance (Terziovski 2010), the obvious disadvantage of limited accumulated expertise and resources in SMEs has hindering their development of innovation capabilities. Moreover, the conventional innovation processes in general are lengthy and full of uncertainty as such these innovation processes were traditionally developed for large bureaucratic firms. Hence, introducing a new product – whether by a tech start-up, SME, or a business unit of a large firm internal initiative-can be a hit or miss proposition (Blank 2017).

In recent years, with the advent of big data and e-commence, a revolution approach for new product development and distribution has emerged to make the process for successfully launching a new product into global markets less riskier, using fewer resources and in much shorter time, particularly eradicating intermediaries within conventional distribution channels. In this paper, the authors introduce a methodology that emphasizes on systematically identify and reliably transform low-value commoditized products of having sustained consumer needs into high-value radically new products leveraging on emerging technologies as enablers and e-commerce platform networks to instantly gain access to global market. These new products resulted from the proposed transformational process are specifically targeted to replace and disrupt those high-to-mid segments of those conventional product range built with outdated technologies and ultimately seek to take over its entire market share. This approach enables tech start-ups or SMEs to be completely liberated bypassing those physical store intermediaries and to leapfrog from catch-up imitators to become owned-brand segmental/category market leaders in a systematic manner. Not only is this innovation approach enables SMEs to develop unique targeted niche products and services with indigenous technology capabilities, it is strategic yet disruptive in nature when they have reached a scale capable of displacing existing product range controlled by incumbent larger business players. This

pattern of innovation approach will likely be one of the leading trends in innovation and technology management in the near future.

In this paper, we will describe the transformative innovation approach for tech start-ups growing fast with leading-edge highly innovative new products and services to cross the innovation chasm displacing incumbents players' commoditised products built with outdated technologies. We develop a framework to help tech start-ups to think through the key steps needed to identify, establish intellectual properties, develop, and then commercialise their new products rapidly and successfully. This article demonstrates how SMEs could apply transformative innovation to rapidly develop and commercialise new products even under Covid-19 disruptions, and the implication of the findings especially on the theoretical and practical contributions.

2 SME Innovation Challenges

SMEs, in other words, often find themselves facing an uphill task as they embark on a risky product innovation journey. Although there have been efforts to shorten NPD processes through improvement of the previous models (Cooper 2008), the conventional NPD process remains long – Griffin (1997) reported that new product development cycle times range from 0.25–72 months, depending on product type and complexity. Estimates of new product failure rates ranges 37%–80% (Shah 2010), these high failure rates suggest that the current NPD approach is not cost-effective, especially to SMEs, which are normally in lack of financial resources, accurate consumers' needs and technological expertise (Freel 2000).

In recent years, various innovation models were proposed to assist firms in speeding up their innovation performance effectively in a systematic manner. Although most of these models are informative and provide a good overview of innovation processes, they fall short of SMEs expectations. Existing literature is based around well-established theories and concepts of the NPI and less helpful in assisting SMEs in reducing the failure rate and speed of new product ventures, or how to rapidly develop and commercialise distinctive new products under global supply chain disruptions.

The purpose of this research is to develop a transformative innovation approach that considers the perspective of limited resources, technological barriers and guide managers to allocate resources in a targeted way, so that new product innovation can be realised with fewer resources, less time and instant access to global market. This paper demonstrates how SMEs apply transformative innovation to rapidly develop and commercialise new products even under Covid-19 disruptions. Hence, the central questions are: which areas of the conventional innovation processes can be eliminated, altered or added to make the innovation process more effective and targeted? How to increase the success rate of innovation under limited resources and time, even under the fallout of Covid-19 disruptions?

3 Research Design and Methodology

The purpose of this research is to develop a radical transformative innovation approach that guides SME managers to allocate resources and identify emerging technologies in a targeted way, so that product innovation can be realised with fewer resources and less time. To answer the research question, this paper makes use of two complementary research methods proposed by Eisenhardt (1989). The research kicks start with a thorough review of innovation management related literature to understand the mechanisms and principles of different innovation models. Having realized that accelerated product innovations for SMEs was not sufficiently covered, a case research method is carried out to research best practices in the industry. Many researchers (Eisenhardt 1989) point out the strengths of case research, especially for allowing researchers to: a) documenting a phenomenon within its organization context; b) exploring the boundaries of a phenomenon; and c) integrating information from multiple sources (Li et al. 2011).

Participating Firms. Three cases of successful new SMEs product ventures are selected. These cases have been selected for a number of reasons. First, they provide a regional coverage. Second, they include some of the dynamic experiences of growth and competitiveness in local and global markets by Far East SMEs in recent years. This variety in the cases was a deliberate research design strategy chosen to increase the external validity of the study's findings, and to assure that the findings were generalizable and not specific to any one type of product or market (Yin 2003; Li et al. 2011). In order to select the cases for study, a number of criteria have been set. Firstly, the firm to be studied needs to be a SME, so that it faces the challenge of limited resources in their NPD. Secondly, the firm needs to demonstrate consistency in its ability to innovate with the same innovation approach. And, lastly, the firm needs to apply the same innovation approach to rapidly develop and commercialize new products during the Covid-19 lockdowns. Based on the above criteria, three cases of SMEs successful innovation development process have been selected. Synopses of the three firms: a) and b) are provided in Table 1.

Data Analysis. To uncover and examine the key processes in the cases, we used the approach out-lined by Miles and Huberman (1984). In particular, we used a cross case method for exploring and describing the innovation processes. This approach allows us to understand the phenomena beyond each individual firm's context and increased the generalisability of our observations (Eisenhardt 1989). Each cases' product history was first constructed, thus generating a series of 'minicases'. Then patterns of innovation were sought. Each case was then reviewed to see if the innovation pattern was confirmed, rejected or ambiguous, with appropriate theoretical literature consulted. As the proposed transformative innovation framework is developed from only three cases, it is necessary to verify that the generalisability of the framework. Hence, this paper also includes a discussion to validate the proposed framework to an existing product in the market. In this case, Dyson's vacuum cleaner with cyclone technology is chosen.

Table 1. Case background

Case	Innovation approach
A – leveling instruments	The firm specializes in the research, development, manufacture and distribution of high performance**,** quality yet affordable digital levels and high precision Dual-Axis smart inclinometers based on advanced MEMS semiconductor technology to replace the use of traditional spirit 'bubble' vial levels and conventional single-axis inclinometers built with old-fashioned pendulum/servo technology
B – smart luggage locks	This firm specializes in the research, development, manufacture and distribution of IoT-enabled security locking devices that replace the use of conventional combination padlocks built with outdated mechanical digit-dial wheels to form combination codes. This smart padlocks utilize state-of-art wireless proximity-access and cloud-based remote-authorized security technologies, world's first of its kind, granted with over a dozen patents in this field of invention and received numerous innovation awards in world-leading tradeshows. Winner of multiple CES Innovation Awards and Japan DIY Awards
C – intelligent face masks	This firm specializes in the research and development of N95-grade reusable intelligent face masks considering environment sustainability as a key differentiating factor. The mask is incorporated with sensors and electronic wireless communication system enabling interactions with embedded sensors, air filtering device interconnected with a miniature air tube to the mask, and voice communication to wireless speaker in proximity to form an unitary intelligent mask system. Winner of IPOS Innovation for Humanity Award 2020

3.1 Case A: Digi-Pas® Precision Levelling Instrument

Case A was conducted with JSB Tech, a SME located in South East Asia. The firm transformed existing commoditized product (levelling tools) into a high-valued precision instrument i.e. Digi-Pas 2-axis digital levels by utilizing leading-edge MEMS technology as enabler. As the precision levelling instrument with distinctive functional features unavailable in conventional levels i.e.: (i) *2-axis, (ii) wide measurement range (360°) and (iii) withstand high shock resistant* are truly differentiates itself from its conventional counterparts, professional users from various industries are willing to pay a higher price for those unique functional features, giving rise to a great sales opportunity (Li 2014). In the interview, the founder of JSB Tech explained the background and the innovation journey.

The modern spirit level with a single vial was invented in the 1920s, since then, improvements made to the conventional level have all been minimal (Montgomery 2009). Different modifications to the product mainly improve the ease to take readings but not increasing the angular measurement range (limited to a few degrees), precision and accuracy of the measurement (Montgomery 2009). The reason why the change is

minimal is because the focus of change is to fine-tune and to improve the existing design; without having any consideration on the needs for angular measurement beyond angles near zero degree (level). Working on simple principles of gravitational force, the spirit level tool itself is not difficult to produce nor is it difficult to use. However, measurement errors are prone to occur with spirit levels due to dimensional and sight errors. Most personal errors are errors resulted from physical limitations of the human senses of sight and touch (NJDOT 2014).

With the emergence of MEMS technology, microsensors embedded in the device convert the measured mechanical signal into an electrical signal (MNX n.d.), improving the precision of the device to <1.0 μm/m resolution, angular measurement range to 360°, adding another axis of angular measurement to 2-axis to measure a plane instead a line) as well as enhance the accuracy of reading with digital numeric display instead of relying on human judgement on the position of bubble vial against tiny inscribed lines on the vial as when using a conventional bubble level. Thus, MEMS technology acts as the catalyst for the new product development process of levelling device, making radical upgrading in functional features in the precision levelling processes (Li 2014). In this case, the MEMS technology acts as an enabler to create "stretch and space" around existing products and allows Digi-Pas® precision level to extend into different segments of precision measuring instruments, giving rise to a product family. By fully exploiting the emergent MEMS technology, JSB Tech is able to regain its high initial investments in R&D through developing a range of product line sold in ecommerce platforms globally to cater different segments of customer needs that consequently enable JSB Tech to dominate this niche market segment and becoming the sole category leader in this market space.

Indeed, the transformation of traditional spirit level to a digital precision levelling instrument was a strategic move that guaranteed high success rate in the new product development from the beginning. Traditional spirit level has been in the market for a long time, the market is very mature and stable for there is always a need for the levels. Although users always experienced inconvenience in using the traditional spirit level, there were no alternative products in the market that could solve the problems before; in other words, the market was waiting for a new product to change the status quo. Therefore, R&D manager of Case A pointed out that by riding on the disruptive emergent MEMS technology, a new generation of levels is developed which now have features that change completely how professional users should use the products. In Christensen's (1997) words, MEMS technology redefines how levels should perform for professional use, enabling the new product developed to take over the niche market in a short time.

R&D manager of Case A informed us that Digi-Pas® Precision Levelling Instrument was first developed in 2009 as a dual-axis precision level; two years later in 2011, the product line has been extended to make a dual-axis intelligent machinist level which can greatly simplify any high precision machine levelling and planar angle measurements. In 2012, the products were further upgraded to become a dual-axis ultra-precision inclinometer. Thus, now the company is the category leader in the precision levelling instruments for professional and personal use (Digi-Pas®UK 2014).

3.2 Case B: eGeeTouch® Smart Electronic Luggage Lock

Case B is also a SME located in South East Asia. The firm produces and markets smart electronic luggage lock i.e. eGeeTouch®. Case study was conducted with the R&D manager and one of the advisory member of the company who was able to describe the whole innovation journey from ideas to product commercialisation. Below is a brief summary of the background and innovation journey.

With the increase in the number of travellers and their frequencies of travel, there is a growing demand in luggage which in turns also increases the demand for luggage lock. Many of the luggage models in the market have incorporated with digit-dial wheels combination lock. However, the combination locks were not reliable, easy to be picked by thieves, and the users tend to forget the combination codes. Hence, conventional luggage locks do not offer sufficient protection over valuable items for travellers. Therefore, there is a demand for a more secured and convenient luggage lock for those frequent travellers who often carry important items while travelling; again. Like in Case A, luggage lock is a commoditised product but been neglected. Hence, the key to transform it to high-valued product lies in the presence of an emergent technology to actually change the rule of the game.

Case B chose the latest version of Radio Frequency Identification (RFID) technology i.e. Near Field Communication (NFC) technology to transform the luggage locks. NFC has a highly secure communication protocol commonly used by banks and point of sales for payments. Allowing identification of objects from a distance, an NFC system is composed of an NFC tag and an NFC reader. A NFC reader sends out radio frequency, which is captured by the NFC tag and reflected back to the reader (Igoe 2012). Working with the principle of Radio Frequency Communication technology, eGeeTouch® Smart Luggage Lock serves as an electronic lock to improve travellers' experience over conventional locks. It has a built-in Transportation Security Administration (TSA) compliant key lock to ensure that the luggage meets the TSA requirements of US airports. Patented in US, EU, Japan, China and India, the electronic luggage lock is built with NFC technology, which does not require keys, digit-wheels nor combination codes to unlock luggage, but rather by a user settable Near Field Communication (NFC) tags, any smartphone with Bluetooth or other smart devices such as smart watch. Thus, eliminating all the inconvenience associated with the mechanical locks or combination locks, allowing users to travel with great ease (eGeeTouch 2014).

3.3 Case C: eGee-Pro® Intelligent Face Mask

Case C is a SME located in South East Asia. The firm produces and markets intelligent face mask i.e. eGee-Pro®. Case study was conducted with the R&D manager and one of the firm advisory board members of the company who was able to describe the whole innovation journey from ideas to product commercialisation during the fallout of Covid-19 disruptions.

On late February 2020, in response to emerging Covid-19 threatening global mankind, Case C R&D, supply chain and manufacturing teams worked vigorously to speedily develop, patent, manufacture and obtain certification from accredited independent test bodies and launched the affordable eGeePro N95-grade Reusable Facemask for

healthcare personnel and the mass market. Facemask is an effective yet affordable tool to prevent an individual from being infected by airborne microbial and also infecting others. Drawing lessons from previous SARS and MERS epidemics that threatened the region, tackling virus spread require speed and clarity on several core elements. Thus, Case C set forth with an initial aim to make available a mask of high quality within the shortest possible time frame of two-month, in a small way contributing to alleviating the spread of the deadly virus. eGee-Pro reusable mask's cover material is reusable and easily sanitized, it is environmental friendlier to any one-time disposable masks or shorter-life reusable cloth masks, thus it is deemed more sustainable to environment. The innovation phase could be summarised in following milestones.

3.3.1 Milestone 1 (*Addressing the 'Don't have to have a safety mask' problem*)

Case C delivered first batch of N95 masks in early May 2020 to a hospital in Indonesia while simultaneously selling on Singapore's leading online shopping platform Lazada, which is owned by Alibaba. Within four weeks, over one million masks were shipped to Singapore, U.S, Japan, Malaysia, India, Africa and many other countries**.** By late June 2020, spikes of infections re-emerged in many cities globally upon re-opening of social and business activities. Wearing a face cover has since become a regulatory requirement in many jurisdictions, with individuals, businesses and governments integrating social distancing and facemask wearing as part of *'New Normal'* practices for face-to-face contact in public spaces.

3.3.2 Milestone 2 (*Shifting needs from 'a safety mask' to 'a comfortable AND safe mask'*)

As masks have become a daily necessity, many cite discomfort while wearing a N95 mask due to their tight fit, instead consumers preferring a comfortable but less safety mask with lower breathing resistance. To address such a market need, the FDA-approved soft silicone/rubber material was added as an interface between facial skin contact to mask cover while an antibacterial and refillable N95 filter with a multiple-folding design was made available to improve breath resistance yet without compromising the safety feature. The R&D manager called it as 2nd Generation eGeePro reusable mask. By early August 2020, prolonged social distancing regulatory measures imposed in many countries had severe impacts on the hospitality sectors, causing restaurants, pubs, airlines, travel operators, dentists, aesthetic clinics to further retrench workers at massive numbers. While the visibility of having a safe and effective coronavirus vaccine is still a distance away as well as the capacity of potential vaccine manufacturers to fulfil billions of vaccines would take even longer time. Therefore, the economic, social and political necessities for further opening up these sectors by many governments are unquestionable.

3.3.3 Milestone 3 (*Migrating needs towards an Aesthetic, Intelligent and Inclusive Mask*)

The R&D manager stated that in anticipation that under a semi lockdown mode, consumer facing personnel in firms operating within service sectors, are likely required to wear a

safety mask that does not look too sloppy or intimidating to customers during face-to-face contacts. Furthermore, numerous mainstream news highlighted the difficulties that mask users working with disabled communities were being unable to read lips, teach enunciation, or speak loudly enough for their audience to hear, and more evidently they missed the smile face from service personnel which were covered with facemask.

Hence, Case C launched 3rd generation eGeePro Intelligent mask in April 2021 to address this need. It is developed with micro-temperature and humidity sensors, nanometer filter technology, translucent materials and Bluetooth speaker connection to enable visible facial gestures, safety, and comfort with clear audio amplification that can be heard even in a relatively noisy setting.

4 Fingdings and Discussions

The three cases clearly showed that a systematic transformative innovation process was adopted. First, a 'neglected' commoditised product that still has vast market users was selected. Then, a suitable emerging technology was chosen to 'transform' or 'upgrade' the commoditised product with high-valued functional features in order to command a leading position in the market place (as well as to charge premium price and be the first mover in the market). To externalise the findings from the cases, we developed a systematic transformative innovation framework based on the inputs from the cases.

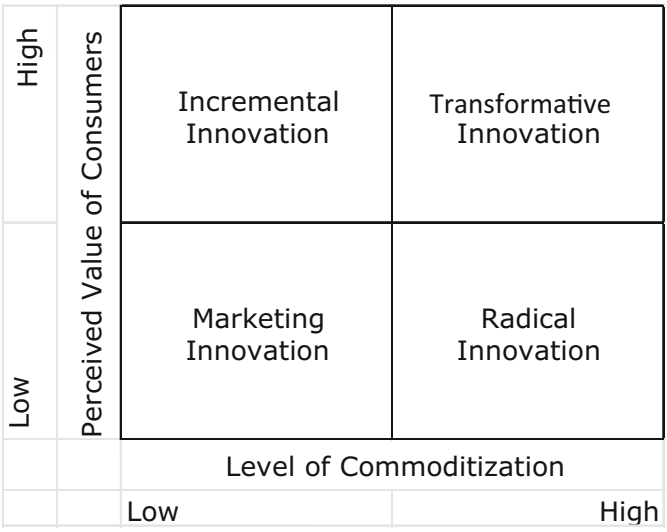

Fig. 1. Level of commoditization – customers' perceived value matrix

Figure 1 illustrates the innovation strategies of a product in market life cycle. The horizontal axis examines the level of commoditization of the product in the market; the vertical axis looks at customers' perceived value of the product. The matrix assists startups and SMEs to scan the market to identify suitable commoditised products, relevant

emerging technologies and the corresponding innovation strategy. Many researchers pointed out that commoditization occurs when products in the market have become so homogenous that there is a low switching cost for price-sensitive customers to switch from one product to another. Moore (2004) argues that a product become "ossified" when it moved past mature to decline stage in the market life cycle. In this stage, customers will start looking for alternative solutions. Overall, commoditization is considered as a key challenge in business markets (Matthyssens and Vandenbempt 2008) and the way to go is to break out from the status quo and to reshape the boundaries of the industry in order to regain competitiveness (Li and Tan 2004).

The vertical axis measures customers' perceived values on the product, which is closely related to the position of the product in the market life cycle (Ryan and Riggs 1996; Moore 2004). Firms provide different value propositions to remain competitive in the market (Matthyssens and Vandenbempt 2008), thus when customers perceive that the product is not providing sufficient value, the product will be phased out from the market. By mapping a product to the matrix, firms can identify which innovation strategies is appropriate for the chosen product, the four strategies are: 1) marketing innovation, 2) incremental innovation, 3) radical innovation, and 4) targeted innovation.

By targeting a neglected market, the new product development process focuses on specific product range thus reduces high risk associated to developing a new product for a completely unknown or untested new market. In this regard, limited investment resources in transformative innovation can be channelled with precision and the developed product is likely to be able to replace those conventional counterpart at ease due to its newly distinctive functional features deemed useful to users. As a market with steady demand on commoditized products already exists, lesser effort in market research is needed to analyse and assess the market demand risk as part of the upfront activities prior to product development, thereby reducing much time, risk and cost used in the process. Also, with the use of disruptive technology, the new product developed will have newly distinctive functional features that provide significant benefits to customers, switching users of existing products to use the new innovative product and progressively replacing them. The assessment and analysis of newly created functional features usefulness and values to users are vital to determine the set price and the impact of disruption to existing conventional products/counterparts. At the same time, sales are ensured as firms can sell at a higher unit price under product differentiation targeting the upper-medium and higher income consumers segments. As successful implementation of transformative innovation ensures high return of investment with the use of limited resources, lesser time and relatively lower risk, this approach is particularly suitable for start-ups and SMEs for it is highly cost-effective and agile to identify and enter a specific market.

5 Discussion and Conclusion

In order to propose a framework and process to assist Chinese Start-ups and SMEs to develop indigenous technology and radically new products defendable with IPs, faster, at lower cost and reliably thus liberating them from imitators mindset to become truly innovators – even under the fallout of Covid-19 disruptions - this research combed through innovation literature and conducted three case studies to identify best practices.

As a result, a transformative innovation framework was proposed to explicitly explain how Chinese Start-ups and SMEs could speed up new product development in systematic manners even under global supply chain disruptions during pandemic. Although the conventional innovation processes are able to deliver substantial outputs in the long term, this paper argues that resource limited SMEs could better direct resources to target certain segments of the market at global scale and scope to realise high innovation performance and turns to be innovators.

The proposed framework enables Start-ups and SMEs to identify commoditized products built with outdated technologies but possessing enduring consumers' needs that have been neglected in the market for decades. By using relevant emerging technologies to transform these products' functional features, the developed new products is irrefutakingbly distinctive and highly 'disruptive' yet capable of marginalising existing players selling conventional counterpart products. Not only is this new approach entrepreneurial, it is less riskier and enables a firm to strategically to gain competitive advantage in the market. As these cases demonstrated, this approach also allows Start-ups and SMEs to apply indigenous technology and develop new products with IP protection that ensures sustained profit stream for many years to come. It will certainly be one of the trends in innovation management in the near future. Nonetheless, few firms can experience this kind of renaissance, because targeted innovation—transforming neglected commodity products in an emerging market and coaxing them to flow uphill to Western or worldwide markets—poses immense challenges. It requires Start-ups and SMEs to overcome its technological knowledge acquisition barriers, R&D development strategies, overseas consumer perceptions, long term R&D investment funding, mindset adjustment from imitator to innovators, and develop in-house capabilities and competencies to utilise big data to and access to e-commerce platforms to channel and distribute new products globally by instantly tapping on leading ecommerce platform distribution networks globally and rapidly.

6 Limitation of the Framework

The main challenge in applying the transformative innovation pathway lies in the fact that most of the decisions made are based on entrepreneurs' technological knowledge and domain experience. For instance, a tech start-up entrepreneur or SME manager will have to have the domain knowledge capability and intuition to identity a suitable target market segment. Alternatively, technology expertise may be outsourced from external technology consulting firms to cover technological knowledge gap of entrepreneur. For example, to identify and assess the adoption of wireless technology to smart luggage lock, external consultant may offer the entrepreneur for Bluetooth, RFID, NFC, Zigbee etc. Managers also need to find out the consumer's perceived value gap of current products in the market and identify new functional features with high perceived values by consumers to fill the gap. Thus, a tech start-up entrepreneur may not have answers for all of these. Hence, further studies is needed to provide a structured process with clear guidance on how to apply the transformative innovation framework.

The proposed transformative innovation model is derived from only three case studies. The three cases mainly involving digital transformation of conventional products.

Moreover, the proposed model is verified with a similar example i.e. Dyson's dual cyclone vacuum cleaner, bladeless fan, and hair dryer, which are yet examples of transforming out-dated mechanical designs to become cutting-edge innovations. Therefore, further research is needed to test the proposed framework in other cases. The three cases are from SMEs in South East Asia, further research is needed to test the applicability of the proposed framework in other region such as China, Europe and the rest of the world.

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The Stock Market Reaction Brought by Supply Chain Innovation: Evidence from the Chinese Market

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Abstract. This paper uses the event study method to explore stock market reactions brought by supply chain innovation (SCI) announcements. It obtains many important conclusions as follows. First, it is found that SCI announcements issued by listed companies generate positive and significant market reactions on the same day. Second, it shows that the difference in SCI announcement content has different impact on stock market. The integrated form of SCI announcements bring more positive stock market reactions than the independent form of SCI announcements. SCI announcements of technology type bring more positive stock market reactions than SCI announcements of process type. Strategy-level SCI announcements bring more positive stock market reactions than operation-level SCI announcements.

Keywords: Supply chain innovation · Event study · Stock market reaction

1 Introduction

In the past few years, an increasing number of enterprises have begun to pay attention to supply chain innovation (SCI). SCI is a complex process that involves managing environmental uncertainty and optimizing supply chain operation process using new technologies or processes with the aim of providing a quick response to customer demands (Lee et al. 2011). SCI emphasizes the improvement of supply chain management through seamless interaction with suppliers, manufacturers, distributors and customers.

In the process of SCI, the involved information, capital and strategy will have a great impact on the future performance of enterprises and shareholder value. Therefore, to attract the attention of investors, enterprises often publish SCI-related information to show the form, type, level, cost and other relevant information to convey that they are actively responding to changes in the external environment and making continuous efforts to improve supply chain operations. Therefore, published SCI announcements are of great value. Analyzing the impact of SCI announcements on corporate stock market value can not only provide effective decision-making guidance for enterprises regarding SCI information disclosure, but it can also deepen corporate understanding of how SCI affects future enterprise operation performance, provide a basis upon which enterprise managers can analyze SCI performance and encourage enterprise managers to invest in SCI.

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In this context, this paper takes SCI as its research object and intends to study the following two aspects:

RQ1. How will the SCI announcements of Chinese listed companies affect the stock market?

RQ2. From the perspective of the content of SCI announcements, what impacts will the form, type, and level of SCI have on the enterprise stock market?

The event study method is used to empirically test the relationship between SCI announcements and enterprise stock market value. This paper selects 156 SCI announcements issued by 114 Chinese listed companies from 2012 to the second quarter of 2021 as research samples for empirical analysis, and it obtains many important conclusions. First, regarding RQ1, we find that the SCI announcements issued by Chinese listed companies will produce positive and significant market reactions on the same day. Second, regarding RQ2, we find that the difference in SCI announcement content has different impact on stock market. The integrated form of SCI announcements bring more positive stock market reactions than the independent form of SCI announcements. SCI announcements of technology type bring more positive stock market reactions than SCI announcements of process type. Strategy-level SCI announcements bring more positive stock market reactions than operation-level SCI announcements.

2 Research Framework and Research Hypotheses

2.1 SCI and Market Reaction

SCI is considered to be one of the key success factors of modern enterprise organizational performance. On the one hand, SCI can reduce cost and delivery time, create new operational strategies, provide consistent quality, and develop flexibility to cope with rapid changes in the business environment. On the other hand, SCI also plays a key role in the development of products and services to meet customer demand and realize customer value, which can improve the supply chain process through innovation and constantly strive to meet customer demand and enhance value (Flint et al. 2005; Flint et al. 2008). In fact, SCI can not only improve operational capability but also enhance risk management capability. As a catalyst, it can promote and strengthen many activities such as planning, monitoring, forecasting and purchasing in complex supply chain practice. Based on the above, we posit that SCI will bring competitive advantage to enterprises and that the trend of enterprises in the field of SCI will also attract the active attention of investors in the stock market because they believe that the SCI carried out by enterprises will enhance their competitiveness and obtain a good stock market reaction. Therefore, this article proposes Hypothesis 1.

Hypothesis 1. *The SCI announcements of listed companies will have a positive impact on the stock market.*

2.2 Influencing Factors and Market Reaction of SCI

In this part, we will further discuss the differences in the contents of SCI announcements and the different impacts of the stock market.

2.2.1 Different Forms of SCI and Market Reaction

Enterprises often have two forms of SCI. One is to innovate in the form of cooperation with supply chain service providers. Supply chain service providers can provide enterprises with advanced supply chain technology research and development services, supply chain platform construction services, supply chain infrastructure upgrading services and supply chain strategy planning services. The core enterprises only need to integrate the resources provided by supply chain service providers to achieve SCI, which is referred to in this paper as an integrated form of SCI. Corresponding to this form is that the enterprises that issue SCI announcements independently carry out R&D and design the technology and system needed by SCI or independently plan and design the supply chain strategy, which is referred to in this paper as an independent form of SCI.

Compared with the independent form of SCI, the integrated form of SCI is often more conducive to the development of enterprises. In the process of implementing SCI, the integrated form of SCI can also help enterprises avoid the risk of innovation failure (Leiponen and Byma 2009). This form of innovation often only requires enterprises to invest and does not require enterprises to change their internal structure and human resource allocation so that they can apply the new supply chain technology and new supply chain model of partners. Compared with the independent form of SCI, the integrated form of SCI can help enterprises avoid the risk of innovation failure. Therefore, this article proposes Hypothesis 2.

Hypothesis 2. *The integrated form of SCI announcement will bring a more positive stock market reaction than the independent form of SCI announcement.*

2.2.2 Different Types of SCI and Market Reaction

SCI is a complex process that mainly uses technological innovation and process innovation to generate information processing ability and new service ability to provide solutions for customer demand and determine better operation results. Therefore, this paper divides SCI into two categories: technological innovation and process innovation (Lee et al. 2011). Technological innovation aims to strengthen information systems, real-time tracking technology and innovative logistics equipment in the supply chain; help enterprises improve labor and capital productivity; and provide real-time visibility of goods flow, information and sales data to strengthen inventory management and expand an corporate value proposition to end customers (Autry et al. 2010). The application of modern supply chain technology, such as GPS, RFID and ERP, can effectively support the risk management of supply chains. Technological innovation also plays an important role in utilizing the economies of scale of procurement, logistics and central distribution centers, which may be a key means of logistics service differentiation (Kumar 2001; Davis-Sramek et al. 2010). Process innovation involves the effective redesign and reengineering of the supply chain. Understanding how the supply chain transmits innovation and knowledge helps enterprises focus on addressing business problems and strengthening management practice processes, networks, distribution and procurement (Paton and McLaughlin 2008).

In fact, technological innovation is the core driving force promoting the continuous innovation of supply chain enterprises, and it is also one of the bases of process innovation. Technological innovation not only brings new leading advantages to enterprises but also promotes process change with the help of technological change, enhances the collaborative integration of the supply chain through the continuous progress of technology, and realizes the upgrading of the supply chain structure. Therefore, we posit that the implementation of SCI in the category of technological innovation will have a more positive impact on listed enterprises. Therefore, this article proposes Hypothesis 3.

Hypothesis 3. *SCI announcements of a technology type will bring more positive stock market reactions than SCI announcements of a process type.*

2.2.3 Different Levels of SCI and Market Reaction

According to whether the content of the announcement contains the strategic layout of SCI, the announcement is divided into strategic-level SCI announcements and operational-level SCI announcements. Strategic-level SCI refers to the transformation and upgrading of the supply chain strategy in the process of SCI such as upgrading from a traditional supply chain to a smart supply chain or optimizing and adjusting the industrial layout of a supply chain (Zhou et al. 2014). Operation-level SCI refers to supply chain reform from the perspective of the corporate internal operation, paying more attention to the coordination of capital flow, information flow and logistics in the process of supply chain operation; achieving the process automation of purchasing, warehousing and payment through reasonable inventory balance; and realizing the integration of sales, warehousing and revenue. It does not involve the change and adjustment of a supply chain strategy.

A corporate management strategy will promote the corporate capability to maintain a competitive advantage, while based on the supply chain perspective, the supply chain strategy helps the company improve its integration with suppliers and customers. Supply chain strategy addresses how an enterprise gains competitive advantage through its supply chain capability such as cost, response speed and agility (Zhou et al. 2014). The core content of supply chain operation is reflected in the coordination of capital flow, logistics and information flow. The purpose of supply chain operation is to match the planning of the supply chain strategy at the practical operation level because the supply chain strategy determines the overall planning and development direction of supply chain operation.

We posit that the implementation of SCI at the strategic level will have a more positive impact on listed companies. Therefore, this article proposes Hypothesis 4.

Hypothesis 4. *Strategy-level SCI announcements will bring a more positive stock market reaction than operation-level SCI announcements.*

3 Empirical Analysis and Research

3.1 Sample Selection

The sample announcement of listed companies collected in this paper comes from CNINF, which is the information disclosure website of listed companies designated by the China Securities Regulatory Commission and contains comprehensive announcement information of listed companies. The time period selected for this study is from January 1, 2011, to the second quarter of 2021. Based on the keywords "Supply Chain Innovation" "Supply Chain Upgrading" and "Supply Chain Transformation", this paper searches the enterprise announcements of the second quarter of 2012–2020 disclosed in CNINF. The final sample includes 156 SCI announcements from 114 listed companies.

3.2 Research Methodology

3.2.1 Event Study

This paper uses the event study method to estimate stock market responses to supply chain innovation announcements. The event study method is used to study stock market responses to events by calculating the abnormal rate of return related to a specific event (Brown and Warner 1985).

First, we need to determine the event window period of this study. For each sample, the calendar time is converted into event time according to the following rules. The day when the supply chain innovation announcement is released is set as Day 0. If the announcement is released after the closing of the stock market on a nontrading day or trading day, the next available trading day is regarded as Day 0. The trading day before the announcement day is set as Day −1, the next trading day is set as Day 1, and so on. This paper selects the event window period [0, 1], which is commonly used in event study, as the window period of this study to capture the market response to supply chain innovation announcements (Cousins et al. 2020).

3.2.2 Abnormal Return Estimation Model

In this paper, we choose the general market model to estimate the abnormal return of stock after the release of supply chain innovation announcements (Brown and Warner 1985). The model reflects the linear relationship between the specific stock return and the market return in a given period of time.

3.2.3 Significance Test of Abnormal Return

This paper first uses a single sample t-test to test the significance of the abnormal return mean. To eliminate the influence of outliers on test results, in addition to the t-test, this paper also uses two nonparametric tests (Jacobs et al. 2010). On the one hand, the paper uses the Wilcoxon signed rank test to test whether the median of abnormal return is significantly not zero. On the other hand, the paper uses the binomial sign test to test whether the probability of positive abnormal returns is significantly higher than 50%. As we speculate that supply chain innovation announcements can bring positive

market reactions, we use a unilateral test for the above three test methods and aim to find consistency among the three test results to ensure their stability.

4 Single Sample Analysis

4.1 SCI Announcement and Stock Market Reaction

According to the market model, this paper calculates the abnormal returns of 156 SCI announcements of Chinese listed enterprises in the [0, 1] window period and tests the results according to the statistical method. The results are shown in Table 1.

Table 1. AR test results of SCI announcement

Window period	Day-1	Day0	Day1	Day0 and Day1
n	156	156	156	156
Mean abnormal return	0.039%	1.212%	− 0.168%	1.044%
T-test value	0.201	4.959***	− 0.855	3.454***
Median abnormal return	0.153%	0.607%	− 0.197%	0.495%
Wilcoxon signed rank test	− 0.605	4.494***	− 1.870**	3.125***
Positive rate of abnormal return	44%	64%	43%	63%
Binomial sign test value	1.521*	3.443***	1.681**	3.283***

(A: All tests were single tailed: *P <= 0.10, **P <= 0.05, ***P <= 0.01).

We analyze the results in Table 1. First, the average (median) abnormal return rate on Day 0 is 1.212% (0.607%), the stock market has a positive return, the t-test value is significant at the level of 1%, the abnormal return rate is approximately 64% (more than 50%), and it passes two nonparametric tests. Therefore, it can be shown that on the day of the SCI announcement, the stock market produced a significant positive market reaction. At the same time, the abnormal return of Day1 did not pass the t-test, which preliminarily shows that the positive market reaction of the stock market basically disappeared on the second day of the SCI announcement. Second, the abnormal return of Day0 and Day1 is significant at the level of 1%. It also shows that SCI announcements brought positive market reactions to the enterprise stock market. Finally, the results of Day-1 data do not pass the t-test and two nonparametric tests. It can be assumed that SCI information did not leak in advance and thereby obtain a stock market reaction in advance. Based on the above, we accept Hypothesis 1.

4.2 Different SCI and Stock Market Reaction

To further analyze the differences in stock market reaction caused by SCI announcements with different contents and SCI announcements issued by enterprises in different industries, this paper obtains classified statistics on the abnormal returns on Day0 of the SCI announcement, obtains the results shown in Table 2, and gives the corresponding descriptive analysis.

Table 2. Classification test results of AR in SCI announcement

	n	Mean abnormal return	T-test value	Median abnormal return	Wilcoxon signed rank test	Positive rate of abnormal return	Binomial sign test value
Part A: classified by SCI form							
Integrated form	76	1.926%	5.103***	1.123%	4.970***	74%	4.015***
Independent form	80	0.534%	1.798**	0.116%	1.189	55%	0.783
Part B: classified by SCI type							
Technology	53	2.028%	5.209***	1.433%	4.661***	75%	3.571***
Process	103	0.793%	2.603***	0.251%	1.902**	58%	1.577*
Part C: classified by SCI level							
Strategy level	41	2.364%	4.069***	1.296%	3.933***	80%	3.748***
Operation level	115	0.802%	3.210***	0.319%	2.662***	58%	1.679**

(A: All tests were single tailed: *P <= 0.10, **P <= 0.05, ***P <= 0.01).

According to the results in Table 2, we can draw the following conclusions.

For the Integrated Form of SCI announcement and Independent Form of SCI announcement, the mean abnormal return (median) of Integrated Form of SCI is 1.926% (1.123%), the t-test value is significant at the level of 1%, the positive abnormal return rate is 64% (more than 50%), and it has passed two non parametric tests. The abnormal return of the independent form of SCI announcement did not pass the t-test. The mean abnormal return (median) of the Integrated Form of SCI announcements is greater than that of the Independent Form of SCI announcements, and the abnormal return of the Integrated Form of SCI announcements is more significant than that of the Independent Form of SCI announcements.

We can also find that the mean value of abnormal return (median) of SCI announcement of Technological innovation is greater and more significant than that of Process innovation; the average abnormal return (median) of SCI announcement of Strategy Level is greater and more significant than that of Operation Level. All the single-sample results above are consistent with our assumptions.

5 Cross Section Regression Analysis

5.1 Cross Section Regression Model

To test whether the factors from Hypothesis 2 to Hypothesis 4 will affect the stock market reaction to SCI announcements, this paper further adopts a cross-sectional regression model for analysis. The dependent variable of the model is the actual abnormal return of SCI announcement Day0, and the independent variable includes the explanatory variable and control variable corresponding to Hypothesis 2 to Hypothesis 4.

First, we introduce two enterprise control variables and one industry control variable.

Enterprise Profitability (X_1): This paper uses the operating profit rate of listed enterprises in the accounting quarter before the SCI announcement to represent the profitability of enterprises to control for the potential impact of this variable on abnormal returns (Cahill et al. 2020). It is a continuous numerical variable.

Enterprise Scale (X_2): This paper uses the total assets of listed enterprises at the end of the fiscal year before the SCI announcement to measure the scale of listed enterprises to control for the potential impact of the variable on abnormal returns (Cousins et al. 2020).

Enterprise Industry (X_3): If the enterprise is in the service industry, it is assigned a value of 1. If the enterprise is in the manufacturing industry, the value is 0.

Second, three explanatory variables are introduced according to the hypotheses.

Innovation Level (X_4): If it is an SCI announcement of Strategy Level, it is assigned a value of 1. If it is an SCI announcement of Operation Level, the value is 0.

Innovation Type (X_5): If it is an SCI announcement of technological innovation, the value is 1. If it is an SCI announcement of Process Innovation, the value is 0.

Innovation Form (X_6): If it is an SCI announcement in Integrated Form, it is assigned a value of 1. If it is an Independent Form of SCI announcement, the value is 0.

5.2 Cross Section Regression Result

To control the outliers, the data with the highest 2.5% and the lowest 2.5% were excluded from the existing samples for cross-sectional regression (Hendricks and Singhal 2003). This paper constructs three regression models. Model 1 includes only four independent variables including innovation level, innovation cost, innovation type and innovation form. Model 2 adds industry control variables to Model 1, and Model 3 adds two control variables, enterprise profitability and enterprise scale, to Model 2. The regression results are shown in Table 3.

Table 3. Cross section regression results

Variable	Model 1	Model 2	Model 3
intercept	−0.01(−0.318)	−0.009(−1.615)	−0.010(−1.837*)
Corporate profitability (X_1)			0.005(0.303)
Enterprise scale (X_2)			−0.005(−2.048**)
Enterprise industry (X_3)		0.010(1.924*)	0.012(2.377**)
Innovation level (X_4)	0.013(1.948*)	0.014(2.118**)	0.013(2.042**)
Innovation type (X_5)	0.011(2.315**)	0.012(2.573**)	0.010(1.999**)
Innovative form (X_6)	0.011(2.030**)	0.011(2.110**)	0.011(2.123**)
N	148	148	148
F value	6.538***	6.069***	5.007***
R^2	15.5%	17.6%	20%
Adjusted R^2	13.1%	14.7%	16%

(A: All tests were single tailed: *P <= 0.10, **P <= 0.05, ***P <= 0.01).

According to the analysis results in Table 3, in model 3, the t-tests of enterprise scale and industry coefficient of the three control variables are significant at the 5% level, but the t-test of enterprise profitability coefficient is not significant, which indicates that enterprise scale and industry will significantly affect the abnormal returns brought by SCI announcements. From the positive and negative signs of the coefficient, it can be concluded that the larger the scale of the enterprise, the smaller the abnormal return brought by the SCI announcement. If the enterprise is a service enterprise, then the abnormal return may be greater.

The coefficients of innovation level, innovation type, innovation form and other variables are significant at the level of 5%, and the sign of the coefficient is positive and negative, which indicates that SCI announcements of strategic level, technology type and integration form will bring greater abnormal returns, which also supports Hypothesis 2, Hypothesis 3 and Hypothesis 4.

6 Conclusions

This paper selects 156 SCI announcements from 114 Chinese listed companies as research samples to study the impact of SCI announcements on stock value. First, our results show that SCI announcements will have a positive impact on the stock value of enterprises. Second, based on the announcement content, technological innovation/process innovation, integrated form innovation, strategic-level innovation and other announcement content factors will have a positive impact on the market response to SCI announcements. Finally, the market reaction in response to SCI announcements by service enterprises will be more positive than that of manufacturing enterprises.

There are still some shortcomings in this study. First, the sample size of the data selected in this paper is small, and the research conclusion may be affected by some

accidental factors and not robust. Second, due to data access rights and other reasons, the sample of this study only includes the enterprises listed in the Chinese market and does not include the representative Chinese enterprises listed in the United States and Hong Kong, which limits the calculation accuracy of this paper to a certain extent. Third, the performance evaluation based on the market reaction on the announcement date aims only at the short-term performance evaluation of enterprises but cannot represent the long-term performance level of enterprises.

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How Does Supply Chain Integration Impact Performance? The Role of Supply Chain Conflict

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Abstract. Supply chain integration is increasingly an important supply chain capability. This study tries to explore how supply chain integration impacts operational performance when dealing with supply chain conflict. This study may develop a model of supply chain integration – supply chain conflict – operational performance, to examine the direct and indirect impacts of supply chain integration on operational performance. Data was collected from 213 companies from different regions of China. The findings indicate that internal integration does not only directly improve operational performance, but also contribute to it through releasing the supply chain conflict. Customer integration is an effective enabler for performance improvement, since it can directly impact on performance. Although supplier integration fails to directly improve operational performance, it can contribute to it through releasing customer and supplier conflict. Different from most previous studies on similar topics, this study explored several different paths of internal, customer and supplier integration impacting operational performance. Meanwhile, many existing studies failed to confirm the significant influence of supplier integration. This study proposed that supplier integration is a fundamental capability to deal with supply chain obstructions. The findings may enrich the knowledge of the relationship between supply chain integration and performance.

Keywords: Supply chain integration · Supply chain conflict · Operational performance · Mediating effect

1 Introduction

In the past three decades, supply chain capabilities are increasingly important for intensifying links among supply chain participants, curbing supply chain uncertainties and sustaining competitive advantages (Frohlich and Westbrook 2001; Rungtusanatham et al. 2003). In particularly, supply chain integration (SCI) is an essentially and critical capability for successful supply chain management. SCI focuses on improving customer values through coordinating decisions, information, human resources, knowledge and other tangible and

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intangible resources (Flynn et al. 2010). As a result, it enables to resolve conflicts between supply chain partners, and facilitates to improve resource synergic effects in supply chains.

Existing studies have widely acknowledged the positive impact of supply chain integration for improving performance. For example, SCI can reduce resource duplications, improve flexibility and responsiveness, through integrate internal and external resources and abilities (Chen et al. 2009). Specifically, studies found that internal integration and customer integration are more important than supplier integration, because the former two dimensions can effectively improve operational performance, financial performance and supply chain performance (Flynn et al. 2010; Huo et al. 2014). However, few studies investigated that how SCI impacts on performance. Particularly, the impact of supplier integration on performance has got less significant evidences. Thus, the mediating factors are required to be investigated, to clarify the complex relationship between SCI and performance.

Inter-organizational conflicts are obvious and widely exist in supply chains, since the inconsistent goals between supply chain participants (Lumineau et al. 2015). Supply chain conflict (SCC) may increase communication costs and impedes supply chain efficiency. When companies intend to drawn benefits from supply chain management, it is required not only enhance resource synergy between companies, but also reduce the negative influence form SCC. As a result, this study investigates the mediating effect of SCC in the relationship between SCI and performance. In a word, there are two research questions examined: (a) Does SCI directly or indirectly improve performance by reducing SCC? (b) Do the dimensions of SCI play different roles for improving performance? This study may enrich the knowledge of the relationship between SCI, SCC and performance.

2 Literature Review and Hypothesis Development

2.1 The Impact of SCI on Performance

SCI means that "a company can strategically collaborate with its supply chain partners and collaboratively manage intra- and inter-organization processes" (Flynn et al. 2010). SCI contents three dimensions including internal integration, customer integration, and supplier integration (Flynn et al. 2010). Generally internal integration is a base for the other dimensions of SCI (Zhao et al. 2011).

Generally, supply chain integration facilitates companies to exchange information and tangible resources with their partners. Based on the relational view, SCI enables companies to improve their operational capabilities through external resources. Such synergic resource effects generated by SCI may be beneficial to supply chain participants. Exist studies have confirmed the positive effects of SCI on performance. For example, several studies have found internal integration may contribute to operational performance and financial performance, customer integration is beneficial to operational performance, while supplier integration has insignificant impact on these performance (Flynn et al. 2010; Huo et al. 2013). From the supply-chain perspective, studies found information sharing within companies and with customer may increase supply chain performance. Therefore, we propose:

H1 Internal integration positively impacts on operational performance
H2 Customer integration positively impacts on operational performance
H3 Supplier integration positively impacts on operational performance

2.2 The Mediating Effect of SCC in the Relationship Between SCI and Performance

Conflicts usually occur at an inter-organizational level, refers to a state in which a company perceives that the other supply chain partner's behavior hinders the achievement of its own goals (Mo et al. 2012). As same as SCI, SCC also includes three dimensions according to the different supply chain parties involving in conflict, namely integration conflict, customer conflict and supplier conflict. For a company, customer and supplier conflict are external conflict.

SCC is likely to give rise to opponent-centered behavior, which can slow down decision making and result in inefficient integration of activities (Barden et al. 2005). The presence of conflict may also reduce partners' engagement level and willingness to contribute needed resources to the alliance (Cullen et al. 1995). There are some evidences of the negative effect of conflict on alliance performance (Christoffersen 2013). Besides, conflict may interfere learning and sharing information with each other, and thus leads to tensions in the partnership (Malhotra and Lumineau 2011). There are a large of existing studies considered that inter-organizational conflict may hinder organizational cooperation and impede organizational performance. For example, conflict may decrease trust and relationship commitment in partnership, and leading to switching behaviors (Malhotra and Lumineau 2011). Therefore, we propose:

H4 Internal conflict is negatively related to operational performance
H5 Customer conflict is negatively related to operational performance
H6 Supplier conflict is negatively related to operational performance

Generally, opportunistic behaviors are obvious in supply chain management. Such behaviors may increase conflict and leads to inefficiency transactions in supply chains. From the perspective of transaction cost theory, SCI provides a kind of governance structure between market and organization (Zhao et al. 2008). SCI emphasis on win-win goals and specific investments, which enabling to curb supply chain partners' opportunistic behaviors, and contributes to the development of a harmony relationship.

Besides, supply chains involve independent economic entities. Due to inconsistent goal, organizational culture, task routines, supply chain partners inevitably face task conflict in daily tractions. Based on the relational view, SCI provides a relational capability to increase adaptability. It is because SCI helps companies turn external discrete, unmatched resources into stable and matched resources. In specific, information sharing increases the level of understandings of their supply chain tasks, and reduces conflicts

from inadaptation working relationship. Meanwhile, process coordination is also a kind of SCI capabilities. Process coordination provides an effective joint decision-making mechanism, such as joint planning, cross functional team for problem solving and work together. It may help supply chain partners to take their efforts for the same targets. Thus, SCI can successfully release SCC, and then reducing the negative influence of SCC on performance. Therefore, we propose:

H7 Internal conflict mediates the relationship between (a) internal integration (b) customer integration (c) supplier integration and operational performance
H8 Customer conflict mediates the relationship between (a) internal integration (b) customer integration (c) supplier integration and operational performance
H9 Supplier conflict mediates the relationship between (a) internal integration (b) customer integration (c) supplier integration and operational performance

3 Research Methodology

3.1 Sampling

Since China's economic development is uneven in different regions, data was collected from firms located in five representative regions (Zhao et al. 2006). In specific, Yangtze River Delta and Pearl River Delta are considered as highly developed economic areas, Bohai Bay Economic Rim as medium, and west and middle areas of China are in early stage of economic development. Therefore, all these regions were appropriately representative in China. Besides, we used stratified sampling technique to randomly select sample companies from the directory of National Bureau of Statistics of China, to guarantee the collected data was normally distributed. Besides, samples are typically selected, which are covered various types of industry, including metals, machinery and engineering, electronic product and electric appliance, chemical & petrochemical industry, food, beverages, alcohol and cigarettes, textiles and clothing, construction material, fine arts and crafts, etc.

Each company was identified one key informant who well understand internal and external SCM activities. Initially, a telephone call was made to these informants to explain the objective of our study and ensure their willingness to participate in the survey. We sent out 800 questionnaires with an invitation letter. In order to increase the response rate, we initiated a second wave of phone calls after two weeks of break. Finally, 213 valid questionnaires were used for further analyses, yielding a response rate of 26.63%. Profiles of respondents and informants are shown in Table 1.

Table 1. Profile of respondents

Region	Respondents (%)	*Number of employee*	Respondents (%)
Pearl River Delta	31.0	<50	3.6
The west areas of China	20.7	50–99	7.1
Yangzi River Delta	19.7	100–199	10.7
Middle Areas of China	19.7	200–499	14.3
Bohai Bay Economic Rim	8.9	500–999	17.9
		1000–4999	21.4
		>=5000	25.0

3.2 Questionnaire Design

A three-step approach was used to develop the questionnaire (Petra 2000). First, through an extensive literature review, we developed a draft questionnaire to identify measures for relevant constructs. Then, experts were asked to translate our primary English version into Chinese. In order to ensure the accuracy of the translation, this Chinese version was translated back into English by other experts. Comparisons were made between two English versions to identify any discrepancies and inconsistency. Finally, pilot tests were carried out in 20 companies. In the light of their feedbacks, we further refined and revised the questionnaire to ensure that it is understandable and applicable to practices in China.

SCI three dimensions including internal integration, customer integration and supplier integration is measured according to Flynn et al. (2010). SCC has three dimensions with internal conflict, customer conflict and supplier conflict. They were adapted from Dyer and Song (1997). Operational performance was measured by four dimensions including cost, quality, delivery, and flexibility, followed studies of Ferdows and De Meyer (1990) and Bortolotti et al. (2015). Initially, Each dimension measured by several items which adapted from Wong et al. (2011); Flynn et al. (2010); Ward and Duray (2000). Then, we calculated an average score of the items for each, to generate new item to represent each dimension, namely, cost, quality, delivery, and flexibility. We used a seven-point Likert scale to measure each item, where "1" indicated "strongly disagree" and "7" indicated "strongly agree." We also provided brief explanations of the more complex measurements, enabling the respondents to better understand them.

For common method bias, we employed Harman's single factor test using exploratory factor analysis (EFA) to test it (Podsakoff et al. 2003).The analysis revealed factors with eigenvalues greater than 1.0, explaining 69.31% of the total variance, and the first factor explained only 11.65%, less than half of the total variance. As a result, these results were acceptable.

3.3 Reliability and Validity

In order to test the reliability of constructs, we follow a two-step method. Firstly, we conduct exploratory factor analysis (EFA) with Principal components analysis and varimax-rotation with Kaiser normalization for purifying the instruments and exploring the constructs (Loehlin 1998). Some measurement items were dropped after comparing their loading on the construct that they were intended to measure to their loadings on other constructs. All the loading of the rest items on the construct they supposed measure are no less than 0.5. Secondly, Cronbach's alpha was then computed for each construct, to test for internal consistency. All Cronbach's alpha exceeds the threshold of 0.70 recommended (Zhao et al. 2008). Next, we calculated corrected item-total correlation (CITC) to confirm reliability of each construct. By using the intercorrelation matrix, items with a correlation value below the 0.30 cutoff value were discarded (Flynn et al. 1994). The Cronbach's alpha and CITC value were shown in Tables 2.

Table 2. Reliability

Constructs	# of items	Cronbach's alpha	CITC
Internal integration	6	0.85	0.82–0.83
Customer integration	5	0.87	0.85–0.87
Supplier integration	5	0.89	0.85–0.90
Internal conflict	5	0.83	0.78–0.81
Customer conflict	5	0.91	0.89–0.90
Supplier conflict	5	0.90	0.86–0.90
Operational performance	4	0.80	0.70–0.84

Construct validity consists of convergent validity and discriminant validity. Firstly, we use a CFA model as suggested by O'Leary-Kelly and Vokurka (1998) to estimate the convergent validity. In the model, each item is linked to its corresponding construct and the covariances among those constructs are freely estimated. The model fit indices are $\chi 2 = 1187.60$ with degrees of freedom = 539, root mean square error of approximation (RMSEA) = 0.079, non-normed fit index (NNFI) = 0.95, comparative fit index (CFI) = 0.95, standardized RMR = 0.077, which indicate that the model is acceptable (Hu et al. 1992). We used average variance extracted (AVE) values to assess discriminant validity. The results shown in Table 3 indicate square roots of AVE are higher than the correlations, indicating the acceptable discriminant validity (Fornell and Larcker 1981).

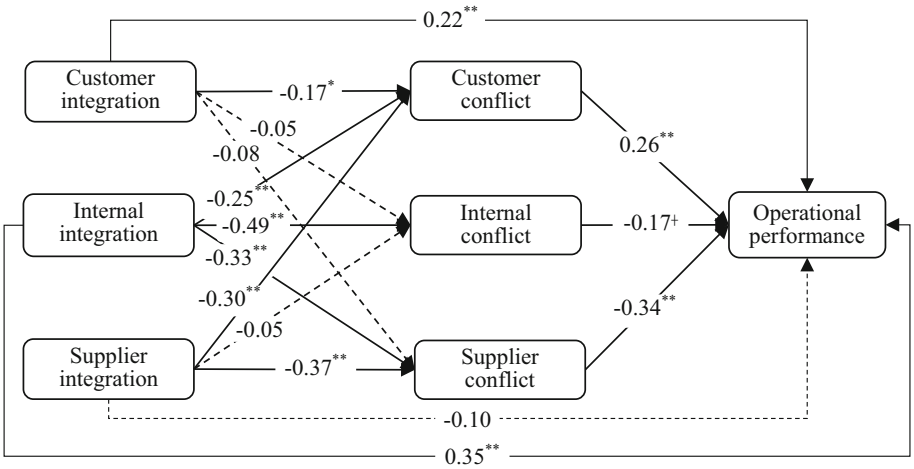
Table 3. Descriptive statistics and discriminant validity

	II	CI	SI	IC	CC	SC	OP
Internal integration (II)	.70[a]						
Customer integration (CI)	.39**	.78					
Supplier integration (SI)	.40**	.48**	.79				
Internal conflict (IC)	−.42**	−.26**	−.26**	.69			
Customer conflict (CC)	−.35**	−.42**	−.42**	.52**	.82		
Supplier conflict (SC)	−.42**	−.36**	−.49**	.55**	.71**	.81	
Operational performance (OP)	.49**	.40**	.32**	−.42**	−.31**	−.45**	.72
Mean	5.17	5.40	4.45	3.64	3.24	3.33	5.31
S.D	1.038	1.008	1.292	1.094	1.140	1.051	0.778

** $p < 0.01$; [a] *represents average variance extracted (AVE) value.*

3.4 Results and Analyses

Two-step method was used in LISREL 8.54 program with maximum likelihood estimation method. The measurement model was test prior to the structure model (Anderson and Gerbing 1988). The goodness of fit indices in SEM model are: $\chi 2$ (df) = 1313.939 (542), Non-Normed Fit Index (NNFI) = 0.94, Comparative Fit Index (CFI) = 0.94, Root Mean Square Error of Approximation (RMSEA) = 0.086, and Standardized Root Mean Residual (SRMR) = 0.011, these indices are better than the commonly accepted threshold values (Hu et al. 1992), which implied that our model was accepted.



+$p<0.10$; *$p<0.05$; **$p<0.01$

Fig. 1. SEM model

The results indicate that the dimensions of SCI are differently related to operational performance. Internal and Customer integration are significantly and positively related to operational performance, but supplier integration was not. Thus, H1 and H2 were accepted, but H3 was rejected. In the relationship between SCC and performance, internal and supplier conflict is significantly and negatively related to operational performance, while customer conflict is positively related to it. Thus, H4 and H6 were accepted, but H5 was rejected. All the results are shown in Fig. 1.

We conducted SOBEL test to confirm if internal, customer and supplier conflict play as mediator in the relationship between SCI and performance (Huo et al. 2017). When confirm the significant mediating path, we further examined the values of $\Delta\chi^2/\Delta df$, by comparing the original Model with the controlled model, to examine they are fully or partially mediators. All the results were shown in Tables 4 and 5. Finally, we found five mediating paths in this model. According to the mediating text results, we found internal and customer conflict partially mediated the relationship between internal integration and operational performance. Customer and supplier conflict fully mediated the relationship between supply integration and performance. However, the three dimensions of conflict failed to mediate the relationship between customer integration and operational performance. The hypothesis test results are summarized in Table 6.

Table 4. Mediated path between SCI and performance

Mediator	Mediated path	Path coefficient	Z statistics
Internal conflict	**II-IC-OP**	0.07	**2.25***
	CI-IC-OP	—[a]	0.48
	SI-IC-OP	—	0.44
Customer conflict	**II-CC-OP**	−0.07	**−1.93⁺**
	CI-CC-OP	−0.44	−1.23
	SI-CC-OP	−0.08	**−1.79⁺**
Supplier conflict	**II-SC-OP**	0.11	**2.34***
	CI-SC-OP	—	0.77
	SI-SC-OP	0.13	**2.18***

$^{+}p < 0.1$; $^{*}p < 0.05$.

II: Internal integration; CI: Customer integration; SI: Supplier integration; IC: Internal conflict; CC: Customer conflict; SC: Supplier conflict; OP: Operational performance.

[a]Path coefficient is not significant in SEM model.

Table 5. Full/partial mediating path tests

	χ^2/df	$\Delta\chi^2/\Delta df$	p-value[b]	F/P mediation
Baseline	1313.93/542			
Indirect model	1341.54/545	27.61/3	0.000^{***}	Partial
II-OP[a]	1327.35/543	13.42/1	0.000^{***}	Partial
SI-OP	1315.26/543	1.33/1	0.24	Full

$^{+}p < 0.1$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.
II: Internal integration; CI: Customer integration; SI: Supplier integration; IC: Internal conflict; CC: Customer conflict; SC: Supplier conflict; OP: Operational performance.
[a]This model does not include the direct path between these two variables.
[b]The mediating effects do not exist.

Table 6. Hypotheses results

	Path in the structural model	Results
H1	II → OP	Supported
H2	CI → OP	Supported
H3	SI → OP	Rejected
H4	IC → OP	Supported
H5	CC → OP	Rejected
H6	SC → OP	Supported
H7a	II → IC → OP	Supported
H7b	II → CC → OP	Supported
H7c	II → SC → OP	Supported
H8a	CI → II → OP	Rejected
H8b	CI → CC → OP	Rejected
H8c	CI → SC → OP	Rejected
H9a	SI → IC → OP	Rejected
H9b	SI → CC → OP	Supported
H9c	SI → SC → OP	Supported

II: Internal integration; CI: Customer integration; SI: Supplier integration;
IC: Internal conflict; CC: Customer conflict; SC: Supplier conflict;
OP: Operational performance.

4 Discussions

4.1 The Direct Impacts of SCI and SCC on Performance

In this study, we found internal and customer integration can directly improve operational performance, but supplier integration fails to impact on operational performance, which

is consistent with existing studies. For example, Flynn et al. (2010) commented that supplier was insignificantly related companies operational and financial performance. It is indicated that internal and customer integration are very critical enablers for companies' performance improvement.

Besides, the different dimensions of SCC also have different influences on performance. In specific, internal conflict and supplier conflict may significantly reduce operational performance, while customer conflict can enhance operational performance. It is probably because internal- and supplier-side interactions are fundamental roles for smoothing the information and logistics flow in supply chains. In contrast, in the buyer-market context, customer conflict may force companies to take more efforts to meet customer needs and requests. It in turn facilitates companies to improve their business processes and performance. Most of existing studies commented that inter-organizational conflict is a dysfunctional factor in systems, and easily leads to low level of efficiency and effectiveness of the whole system. However, this study explores the positive effect of conflict in supply context. It is implied whether SCC is a positive or negative factor, mainly depending on the specific context. When facing customers, it may force companies to conduct more improvements.

4.2 The Indirect Impact of SCI on Performance

The mediating results indicated how SCI impacts on performance. That is, internal, customer and supplier integration improve operational performance through different ways. Specifically, internal integration can directly and indirectly improve operational performance through reducing internal, customer and supplier conflict. It implies that internal integration not only generates synergic effects in and between companies, but also release the negative influences from SCC, and improving the level of harmony in supply chains. Zhao et al. (2011) arguments internal integration is a fundamental capability for external integration. This study confirmed the fundamental role of internal integration. The results indicated that internal integration is also a basic capability to resolve inter- and intra-conflict.

Besides, customer and supplier integration improve performance through differently ways. Specifically, customer integration directly improve performance but was not mediated by SCC. In contrast, supplier integration fully indirectly but not directly improves performance. It is interesting to show that customer and supplier integration play different roles in supply chain management. Although supplier integration can not directly generate performance advantage for companies, essentially, it can strongly support for successful inter-organizational interactions. Passably, supplier is closely related to the physical flow of supply chains, which maintain the downstream capabilities of on-time delivery and flexibly responsiveness. The low level of supplier integration may lead companies suffering more supply chain disruptions from both customer- and supplier-sides.

5 Conclusions and Limitations

This study investigated the complex relationship between SCI, SCC and performance, to demonstrate how SCI improves operational performance. By examining the mediating

effect of SCC, the study indicates that internal integration is a fundamental capability for the whole supply chain management. It can not only directly generate synergic resource competitiveness for operational performance, but also release the cost and uncertainties form inter- and intra-organizational disruptions. Meanwhile, supplier integration is an external support capability. Supplier integration fails to improve operational performance directly, but it can indirectly contribute to it through release the impact of customer integration and supplier integration. Finally, customer integration is an effective enabler performance improvement, since it only directly impacts on performance.

Existing studies mainly concerned that SCI is related to performance, this study provided in more details how SCI improves operational performance. It is illustrated that internal, customer and supplier have three very different approaches to improve operational performance. Meanwhile, many studies failed to find a significant relationship between supplier integration on performance. By considering the mediating role of SCC, this study found supplier integration is still an inevitable supply chain capability for companies. Particularly, it not only helps to deal with upstream conflict, but also restrains downstream conflict. In a word, it plays as a helpful base for companies to deal with uncertainties from inter-organizational conflicts, and to maintains harmony of supply chains.

Since this study mainly concerned whether SCI directly or indirectly impacts on performance, we typically selected operational performance as an outcome in this research model. In fact, the impact paths may be different when considering another performance. Further studies may examine more performance measurement from company or supply-chain perspective, to discuss the different mechanisms of SCI on performance. Besides, more mediators may be investigated to explore how SCI impacts on performance in more details. For example, is there some supply chain practices or performance capabilities such as adaptiveness existed between the relationship of SCI and performance.

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A Real-Time Integrated Inventory and Transportation Management Method for Multi-echelon Supply Chains

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Abstract. This paper proposes a real-time operation method of integrated inventory and transportation management for multi-echelon supply chains. This method can significantly reduce the operating cost of multi-echelon supply chains by providing optimal operations considering not only suitable inventory management but also efficient transportation management. This method is established based on economic model predictive control (EMPC). The overall objective is to optimize the total operating cost including both inventory and transportation costs and meanwhile satisfy the customer demands along a given prediction horizon. The proposed EMPC method can be implemented online so that the optimal operations are obtained in real-time and applied to the supply chain. Finally, the effectiveness of the proposed real-time management method is provided with a case study of three-echelon supply chain.

Keywords: Real-time management method · Economic model predictive control · Inventory · Transportation · Multi-echelon supply chains

1 Introduction

Modern supply chains are large-scale and complex systems, where a large amount of production and logistics companies are connected typically following a complex topology. With the rapid development of economics and technologies, any single company in a supply chain cannot independently solve all the issues encountered in the supply chain. Effective and efficient supply chain management is necessary and can potentially provide strong support for the core market competitiveness of companies in a modern supply chain. The competition between companies is increasing since most companies pursue the growth of revenue in a short term. However, the consequence of the competition sacrifices their long-term benefit as well as the benefits of some other companies in the same supply chain. To avoid this, a centralized management method plays a significant role in the maximum profit of the whole supply chain.

With the development of global trade, companies are typically connected in the global supply chains. If a company is affected by sudden incidents (i.e., sudden changes in customer demands), such changes can also affect the other companies. Recently,

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the COVID-19 pandemic has given huge pressure to increasing companies in the global supply chains. When this pandemic continues spreading all over the world, it can be seen that although the upstream and downstream companies in a supply chain collaborate in order to deal with this emergency, it is still challenging to provide sufficient products to meet unexpected customer demands [1, 2].

To overcome the product shortage, a typical solution is to reserve enough inventories in the supply chain. Holding a certain amount of inventories can adjust the imbalance between supply and demand and thus ensure that the customer demands can be met in time. However, the inventory holding cost as well as the holding time must be considered. Excess inventories will bring negative effects on economic performance. Effective inventory management is required to determine a suitable amount of inventories for the whole supply chain. For a supply chain, inventory management is also coupled with transportation. Reasonable transportation management can significantly reduce operating cost and bring potential environmental benefits with less greenhouse gas emissions [3–6].

Advanced control theory has been widely used in monitoring and operation of production and transportation systems over the past several decades. Model predictive control (MPC), as one of the most popular control strategies, has been demonstrated to be successful for a large number of industrial applications. The operational systems with an MPC controller can achieve desired performance and meanwhile satisfying all the required system constraints [7]. As a special class of MPC, economic MPC (EMPC) has been considered in the supply chain management, where a general economic cost function as a measure of the total operating cost is optimized subject to all the system constraints for inventory, order, backorder and transportation. As a result, the optimal operations can be obtained by solving a corresponding EMPC optimization problem. Over the past two decades, some researchers have investigated EMPC for the inventory management of supply chains, see e.g. [8–11].

In this paper, a novel real-time operation method for multi-echelon supply chains is proposed by integrating inventory and transportation management as a joint optimization problem. The main objective for this method is to optimize the total operating cost including both inventory and transportation and meanwhile satisfy the customer demands along a given prediction horizon. The overall scheme is shown in Fig. 1, where a multi-echelon supply chain is divided into three layers including Manufacturer, Distributor and Retailer. In each layer, multiple companies may be involved, which are denoted as different nodes in this paper. In this multi-echelon supply chain, multiple products from different nodes in manufacturer, distributor and retailer can be handled. By solving the established EMPC optimization problem, a sequence of optimal operations can be obtained over the considered prediction horizon. As in the context of EMPC, the optimization problem is implemented online and only the first optimal operation is applied into the actual supply chain at each time step. Finally, the proposed real-time EMPC operation method is tested with a case study of a three-echelon supply chain, where two products are processed inside. The effectiveness of the proposed method is shown with some simulation results.

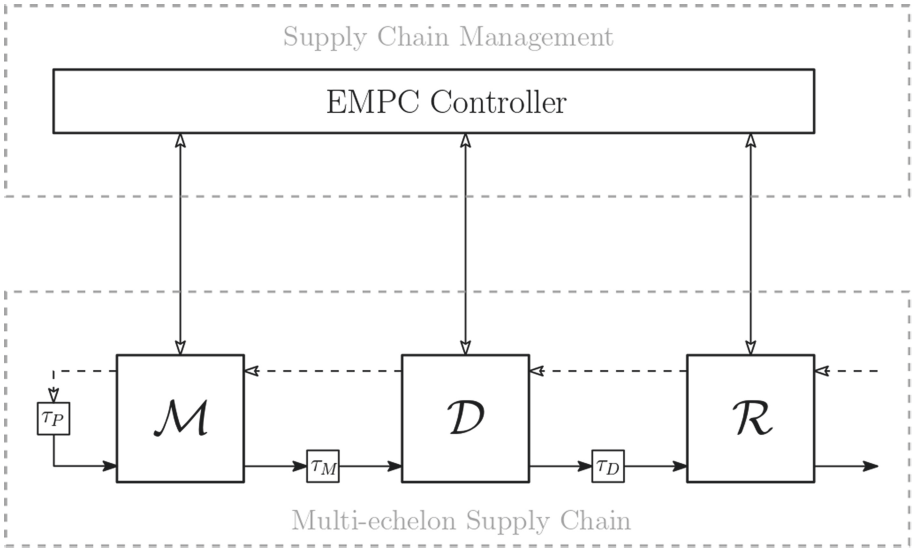


Fig. 1. The overall scheme of supply chain management.

2 EMPC for the Operational Management of Multi-echelon Supply Chains

2.1 Prediction Model

The characteristics of a multi-echelon supply chain can be described by dynamic equations for inventory levels and backorders. A linear dynamic model for the supply chain can be formulated as

$$x(k+1) = Ax(k) + Bu(k) + Dd(k),$$

where $x(k)$, $u(k)$ and $d(k)$ are the vectors of system states, inputs and demands at time step $k \in \mathbb{N}$. In principle, the system states include the inventory levels and backorders, the inputs include the orders and the shipments.

2.2 Defining Cost Functions

Inventory Holding Cost. To reduce risks for supply chain disruption, the companies including manufacturers, distributors and retailers in the supply chain may hold a certain amount of inventories to meet underlying orders and demands to the downstream companies. Consequently, holding some inventories will bring certain inventory holding costs. This cost is mainly caused by some necessary activities, such as inventory management, packaging and storage. For instance, when a company in a supply chain holds some inventories in its own warehouse or a leased warehouse, the construction cost for the warehouse or the lease rental must be considered. In this paper, an inventory holding cost per unit can be determined based on a total cost for a fixed inventory quantity and a

holding time. Then, the inventory holding cost function can be formulated by using the unit cost, the inventory quantity and the holding time.

Backorder Cost. The existence of lead times may cause backorders for some companies in the supply chain. In this paper, lead times contain delays in the production processing period and transportation time. If a company in the supply chain has too many backorders, its downstream companies may be hard to meet their orders or demands all the time. For supply chain management, it is necessary to minimize the backorders of most companies in the supply chain. Due to this reason, a penalty term is treated as the backorder cost to be minimized in the optimization problem to prevent the growth of backorders. The backorder cost function can be formulated by using a penalty unit cost, the backorder quantity and the time for releasing the backorders.

Production Cost. Manufacturers need to produce a certain number of products. The production cost refers to the cost of production activities. Only a suitable amount of products is required to be manufactured to meet the customer demands from the retailers. The production cost function can be formulated by a production unit cost and a product quantity.

Transportation Cost. Two transportation modes are typically considered in practice: (1) full truckload (FL) shipping; (2) less-than-truckload (LTL) shipping. The TL transportation cost has a fixed charge based on the usage charges of the whole truck. If a company chose the TL mode, the most economical way is to transport products until reaching the maximum vehicle capacity.

For the LTL shipping, LTL freight rates are billed by shipping each product. As discussed in [12], an actual LTL cost usually emerges that the unit price decreases as the shipping quantity increases, which leads to a piecewise linear, all-unit discount function. Moreover, when the shipping quantity falls within the range where the total cost is higher than the over-declared quantity, the activity of over-declaring is reasonable in the LTL mode. An actual LTL transportation cost calculation with shipment quantity is shown in Fig. 2. From this figure, a minimum shipping cost is set as a constant C_{min} for a range of small shipments until s_1. Then, the LTL transportation cost is increasing based on different freight rates α_1, α_2, α_3 . A discount feature is reflected by a monotonically decreasing rate $\alpha_1 > \alpha_2 > \alpha_3$. It can also be seen that between different freight rates, the LTL transportation cost remains the same for a given range. In the end, the maximum shipping cost C_{TL} for the LTL mode can be equal to the TL shipping cost, when the full truckload is used. In this paper, an approximation of the LTL cost (i.e. a proportional function) can be used as the LTL cost function in the EMPC optimization problem. The alternative approximation functions can be found in [12].

2.3 Setting up Constraints

Inventory Constraints. The inventory level for each product at each company in the supply chain must be non-negative. Furthermore, since each company in a supply chain has a fixed inventory capacity in practice, an upper limit is set as a constraint for the inventory level of each company.

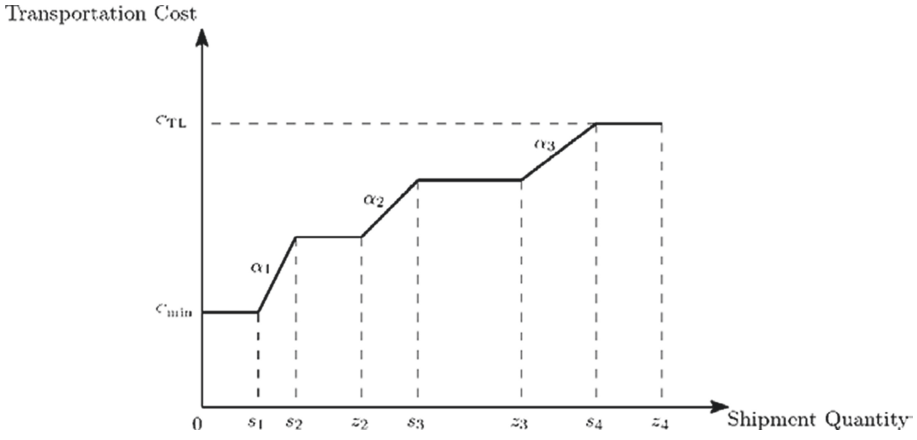


Fig. 2. Actual LTL transportation cost.

Order and Backorder Constraints. The orders and backorders for each product at each company must be non-negative. In a multi-echelon supply chain, an upper limit can be set as the maximum shortage allowed for some products in some companies.

Transportation Constraints

(1) *TL Constraints.* For the TL mode, the maximum number of products that the vehicle can transport depends on the size of the vehicle and the volume of the product. For economic reasons, vehicles are dispatched in a fully loaded manner.
(2) *LTL Constraints.* For the LTL mode, a company transports a certain amount of products according to the received orders. Each shipment can contain different products, and the total volume of the shipped products may be less than the full truckload of a vehicle.

2.4 EMPC Optimization

In general, the EMPC optimization problem can be established by collecting the aforementioned prediction model, all the defined cost functions and constraints. The proposed EMPC method is to minimize the total economic cost (the sum of inventory holding costs, backorder costs and transportation costs for the entire supply chain) along a considered prediction horizon subject to all the constraints of inventory, order, backorder and transportation. The optimal operations for the supply chain can be obtained from the optimal solutions of the EMPC optimization problem. Specifically, by using a receding horizon strategy, only the first optimal solution is chosen as the optimal operation for the supply chain at the current time step.

The EMPC optimization problem is implemented online for the management of a multi-echelon supply chain as a real-time operation algorithm. The procedure can be summarized as follows: at a discrete-time step,

(i) Measure and obtain the system information including the initial inventory levels, backorders, and the shipment in transit (the shipment dispatched before) for each company.
(ii) Obtain a sequence of demand forecasts for the whole prediction horizon.
(iii) Initialize the EMPC optimization problem by the obtained information and demand forecasts.
(iv) Solve the EMPC optimization problem by using an alternative optimization solver and obtain the optimal solutions.
(v) Apply the optimal operation to the actual supply chain.
(vi) At the next time step, repeat the procedure from step (i).

3 Case Study

3.1 Description

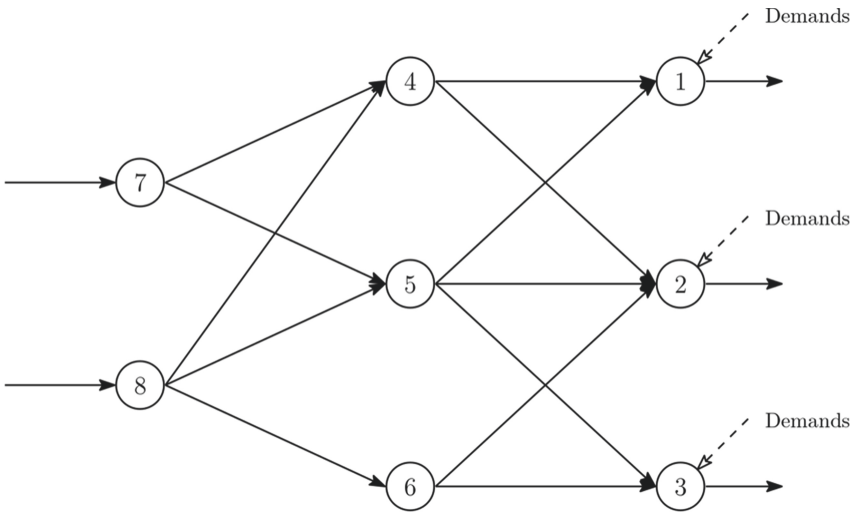
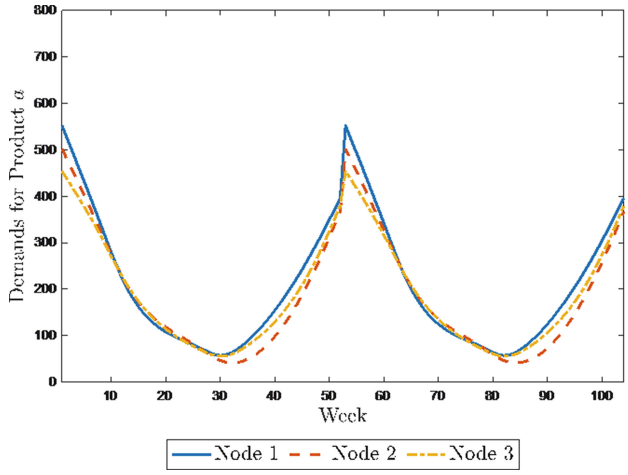
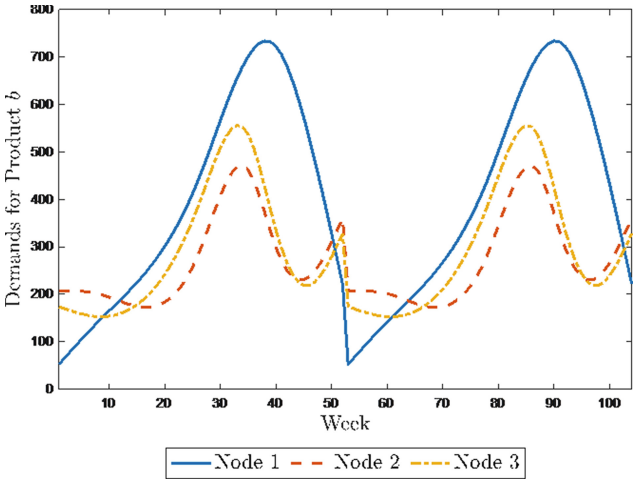


Fig. 3. The topology of a three-echelon supply chain.

The topology of a three-echelon supply chain is shown in Fig. 3. Eight nodes representing the companies are located in this three-echelon supply chain. In this paper, it is considered that nodes 1, 2, 3 are retailers, nodes 4, 5, 6 are distributors, and nodes 7, 8 are manufacturers. All the nodes have different storage capacities. In this supply chain, there are two products a and b are processed inside. Node 7 only manufactures product a while node 8 only manufactures product b. In addition, products a and b have different volumes. Considering a unitary density for two products, the volume of product a is $\sigma_a = 1$ while the product b is $\sigma_b = 2$. The customer demands products a and b for three retailers (nodes 1, 2, 3) are given for two years in Fig. 4.



(a) Product a



(b) Product b

Fig. 4. Customer demands at three nodes.

3.2 Supply Chain Model

For the three-echelon supply chain in Fig. 3, the mathematical model of inventory and backorder can be formulated as follows:

$$v_{m_i}(k+1) = v_{m_i}(k) + \sum_{l \in S_{m_i}} s_{m_{li}}(k - \tau_{li}) - \sum_{j \in Y_{m_i}} s_{m_{ij}}(k),$$

$$q_{m_i}(k+1) = q_{m_i}(k) + \sum_{l \in Y_{m_i}} o_{m_{il}}(k) - \sum_{j \in Y_{m_i}} s_{m_{ji}}(k),$$

where $v_{m_i}(k)$denotes inventory level at node $i \in \mathcal{C}$for product $m \in P$ at time step $k \in N$, $q_{m_i}(k)$ denotes the backorder at node $i \in \mathcal{C}$for product $m \in P$ at time step $k \in N$. Furthermore, i, j, l are the indexes of any nodes in the supply chain. $s_{m_{ij}}(k)$ denotes the shipment amount of product $m \in P$ from node $i \in \mathcal{C}$to node $j \in \mathcal{C}(i > j)$ at time step $k \in N$ and $o_{m_{ij}}(k)$ denotes the order of product m from downstream node i to upstream node $l \in \mathcal{C}(i < \mathrm{l})$ at time step k. τ_{ij} denotes the lead time of transportation or production from node i to node j and k is the discrete-time step.

In this paper, it is assumed that two manufacturers (nodes 7, 8) use the TL mode to transport products and three distributors (nodes 4, 5, 6) use the LTL mode to transport products. Moreover, different transportation lead times are given taking into account different distances between different nodes. For two manufacturers (nodes 7, 8), different production lead times are used to describe different production processing periods for two products. In Table 1, lead times of transportation and production are given.

Table 1. Transportation and production lead times

Node i	Node j							
	1	2	3	4	5	6	7	8
4	2	1	–	–	–	–	–	–
5	1	2	1	–	–	–	–	–
6	–	1	2	–	–	–	–	–
7	–	–	–	1	1	–	1	–
8	–	–	–	2	2	1	–	2

3.3 Simulation Parameters

The inventory holding and backorder cost per unit are given in Table 2. From Table 2, the inventory holding costs for all the retailers are higher than the ones for all the distributors. This is due to the fact that for the retailers, only a few products are used to display to the customer in the retailer stores while most products are expected to be stored in the distributor warehouses. Moreover, manufacturers are more inclined to

manufacture products rather than accumulate products so that the inventory holding costs are given to be largest for manufacturers. As discussed in Sect. 2, a backorder cost is set as a penalty term to minimize the backorders. The backorder cost per unit is set as a relatively larger value compared to the holding cost. Especially, the backorder cost per unit for the retailers is set as the largest value since for the whole supply chain, meeting customer demands in time is one of the main objectives. Furthermore, the production cost per unit for products a and b are 30 and 180, respectively.

Table 2. Holding and backorder costs per unit

	Product	Node							
		1	2	3	4	5	6	7	8
Holding	a	2	3	2.5	1.5	1.8	–	5	–
	b	5	6	4	2.5	2	3	–	10
Backorder	a	500	550	500	10	10	–	10	–
	b	200	300	200	15	15	15	–	15

The freight rate for the TL mode is $C_{TL} = 1470$ and the truckload capacity for the TL mode is 900. As shown in Fig. 2, the parameters for actual LTL freight rate include $C_{\min} = 441$, $C_{TL} = 1470$ (the maximum LTL cost for one vehicle is the same as in the TL mode), $\alpha_1 = 4.9, \alpha_2 = 3.675, \alpha_3 = 1.8375, s_1 = 90, s_2 = 180, s_3 = 360, s_4 = 800, z_2 = 240, z_3 = 730$ and $z_4 = 900$. The inventory capacities of each node are 500, 500, 500, 2000, 2000, 1000, 1000, and 500, respectively.

The other parameters for simulation are given in the following. The EMPC prediction horizon is set as 8 weeks and the total simulation time is set as 104 weeks (two years) with the sampling time of one week. The initial inventory levels of product a for nodes 1, 2, 3, 4, 5 and 7 are 200, 200, 200, 500, 400, and 200, respectively. The initial inventory levels of product b for nodes 1, 2, 3, 4, 5, 6 and 8 are 100, 100, 100, 300, 300, 300 and 150, respectively. The initial orders and backorders of both products for all the nodes are all set as zeros.

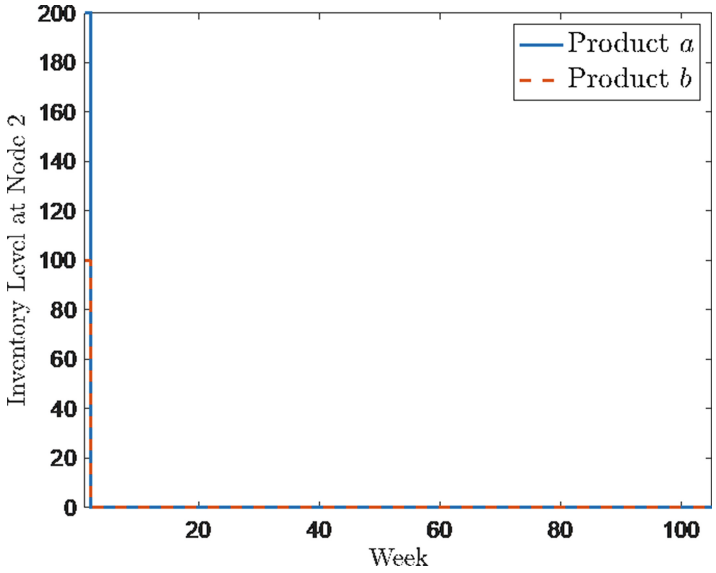
4 Simulation Results

With the given simulation parameters, the simulation with the case study in Fig. 3 has been carried out for two years and the simulation results are shown in the following.

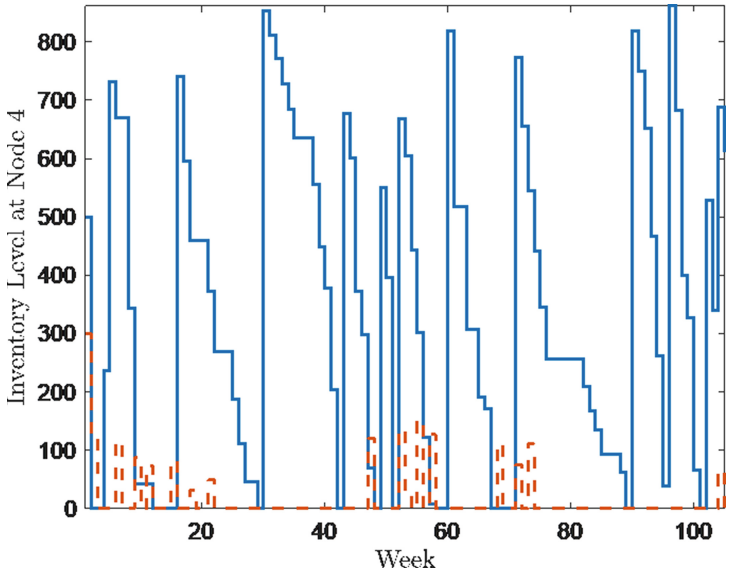
4.1 Inventory and Backorder Results

The inventory levels of products a and b at nodes 2, 4 and 7 are shown in Fig. 5. It can be seen that the inventory levels for both products at nodes 2 and 7 are mostly staying at a low level while most of the inventories are stored at node 4. This is because the inventory holding cost per unit for the distributor is less than the one for both retailer

and manufacture. From this result, it can be realized that the optimal operation from the proposed operation method can find a minimum total inventory holding cost for the whole supply chain.

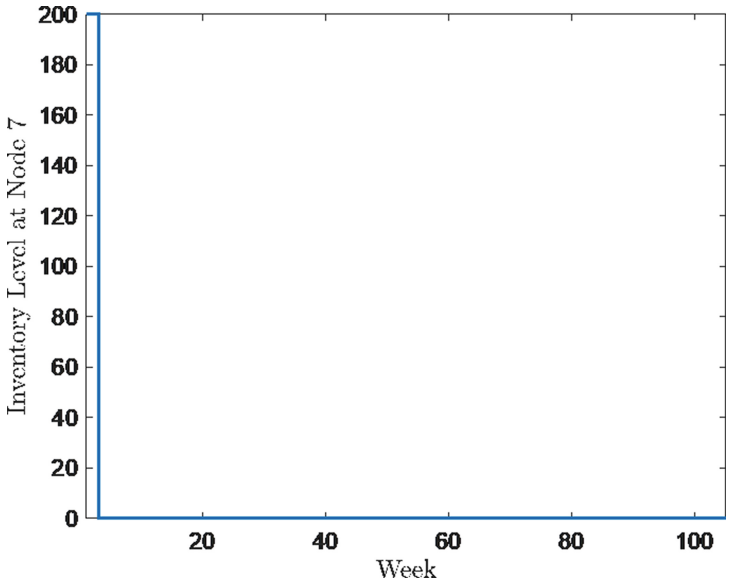


(a) Node 2



(b) Node 4

Fig. 5. Inventory levels of two products.



(c) Node 7

Fig. 5. continued

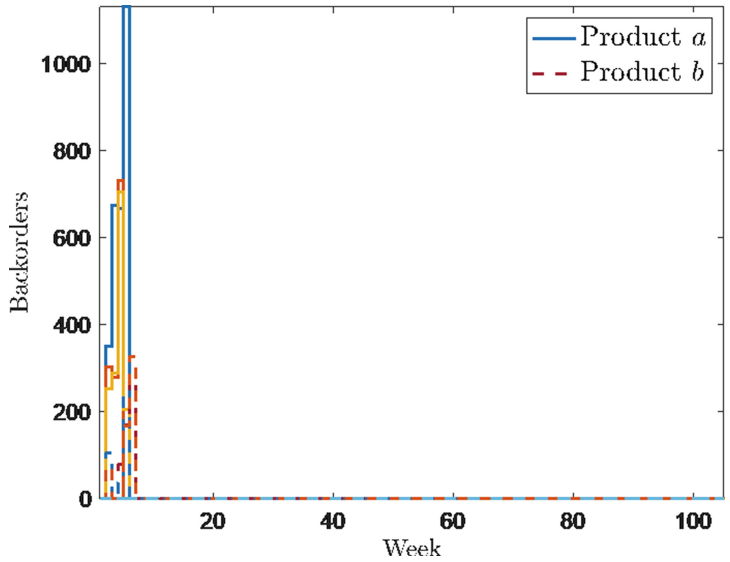
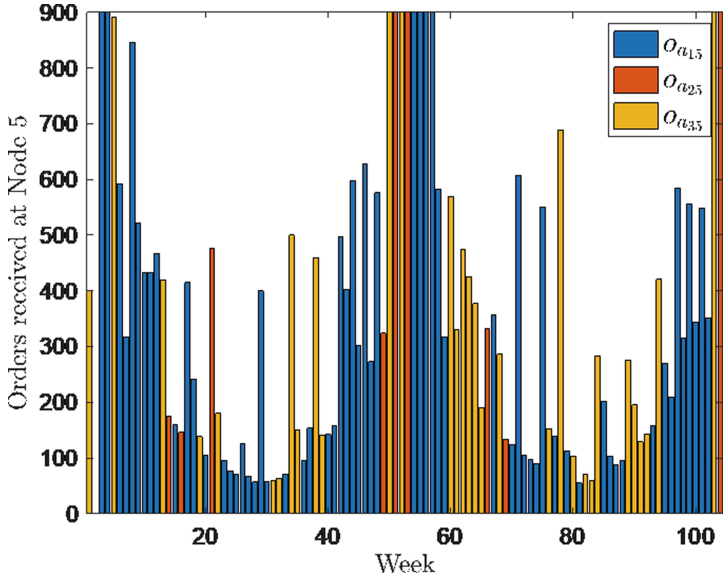


Fig. 6. Backorders of two products at all the nodes.

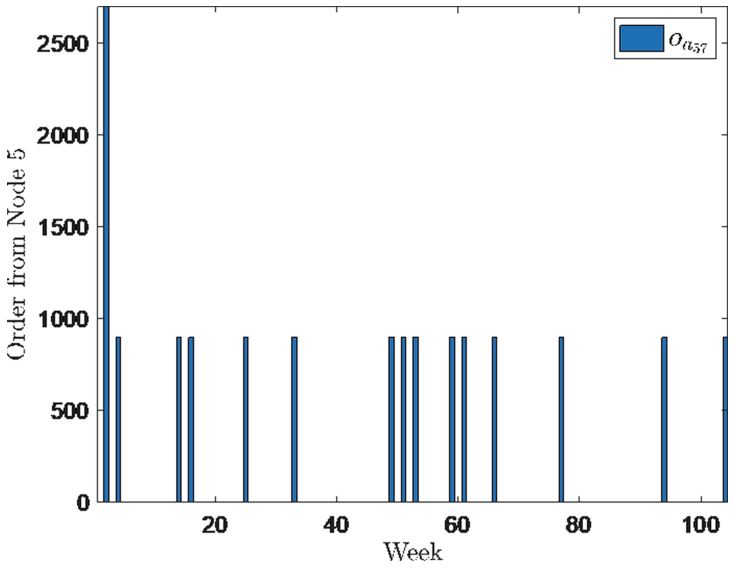
In Fig. 6, the simulation results of backorders for products a and b at all nodes are shown. The backorders for both products are close to zero after approximately 7 weeks. From this result, it can be concluded that the supply chain operated by using the proposed method can satisfy the customer demands in time after a transit time period and meanwhile the orders among different echelons are scheduled properly to avoid generating unnecessary backorders.

4.2 Order Results

The received orders for product a from nodes 1, 2 and 3 to node 5 and the sent order for product a from node 5 to node 7 are compared in Fig. 7. It shows that the total received orders for node 5 is not necessarily equal to the total sent an order from node 5. This behavior is reasonable because the received and sent orders are determined by the proposed EMPC method in a centralized way.



(a)



(b)

Fig. 7. Received and sent orders for product a at Node 5.

4.3 Transportation Results

The actual shipment and the used truck capacity for node 7 are shown in Fig. 8. From this figure, the amount of actual shipments from node 7 determined by the optimal operation from the proposed EMPC method is equal to the truck capacity, which verifies that this node used the TL transportation mode.

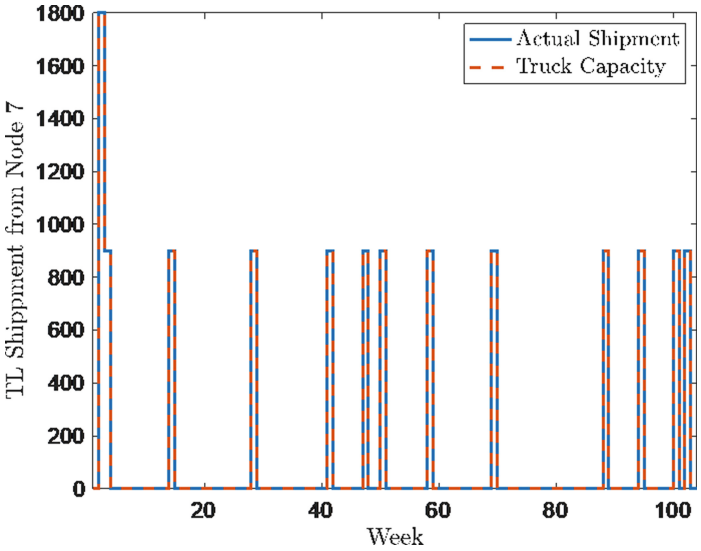


Fig. 8. TL shipment at Nodes 7.

Furthermore, the actual shipment and the used truck capacity for node 5 are shown in Fig. 9. In contrast to the TL mode, the amount of actual shipments from node 5 also determined by the optimal operation from the proposed EMPC method is less than the truck capacity, which also verifies that node 5 used the LTL transportation mode.

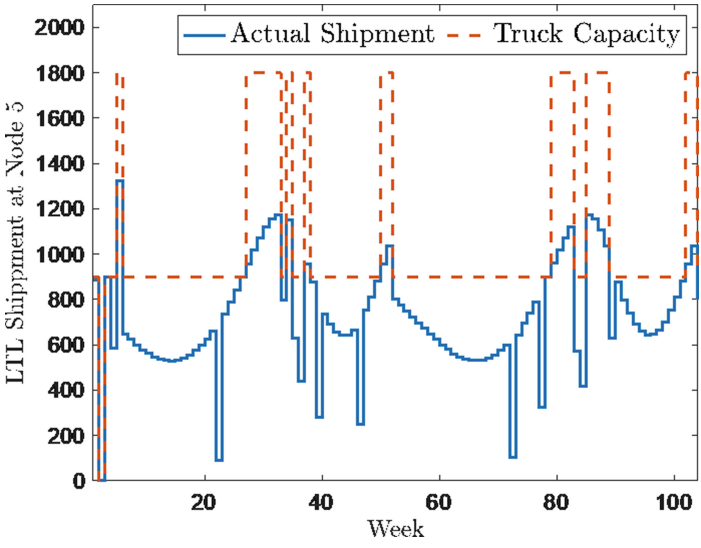


Fig. 9. LTL shipment at Node 5.

5 Conclusion

In this paper, we have proposed a real-time EMPC method for multi-echelon supply chain management by integrating inventory and transportation management. Two transportation modes, TL and LTL modes, are considered in transportation management. By using the proposed EMPC method, the total operating cost of the whole supply chain is minimized subject to system constraints including the prediction model, inventory, order, backorder and transportation constraints. From the provided simulation results of the case study, we have demonstrated that the proposed EMPC strategy can achieve the desired performance for the multi-echelon supply chain management.

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Antecedents of Supply Chain Finance Adoption: An Integrated Transaction Cost and Social Capital Perspective

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Abstract. Supply chain finance (SCF) is a collaborative financing approach that strives to reduce the transaction cost and strengthen inter-firm connections, maximizing the mutual benefits. Many studies have discussed the influencing factor of SCF adoption from the unilateral party. However, little attempt has tried to understand it from the nature of SCF. Based on the social capital theory and transaction cost economics, we develop a dual-theory framework to explain SCF adoption. Large-scale survey data from 430 companies in mainland China revealed that from a social capital perspective, structural capital and cognitive capital are two precursors of relational capital in the unique context of SCF, whereas relational capital is a factor that directly affects the focal company to adopt SCF. From a transaction cost perspective, uncertainty, frequency and asset specificity are associated with SCF adoption, respectively. We make theoretical contributions to SCF literature by revealing the roles of different efficient and social factors influencing SCF adoption. Our findings also help companies re-examine their decision to adopt SCF.

1 Introduction

During the expansion of the market over the past decades, the credit crisis of commodities has gradually emerged (Du et al. 2020). Some risk events triggered by asymmetric knowledge or uncertainty can wreak havoc on net cash flow and profitability during the transactions within the supply chain (Pellegrino et al. 2019). For example, since the Covid-19 epidemic, corporate accounts receivable have grown, the payment cycle has typically prolonged, and the risk of default payments has grown, resulting in a rise in the probability of capital rupture throughout the whole supply chain (Ketchen and Craighead 2020). In the first quarter of 2020, the Covid-19 caused losses to 50.73% of companies, 82.12% of companies' operating costs increased, and 97.08% of corporate profits fell (CSCSMRC et al. 2020). Under such an environment, companies' desire to actively collaborate with supply chain partners to implement supply chain financing (SCF) has expanded dramatically, sparking much debate among academics (Wuttke et al. 2019).

SCF is a flexible financing approach that can help reduce transaction costs and maximize mutual benefits by connecting supply chain members (Du et al. 2020). Previous studies have examined the influencing elements that may influence SCF adoption decisions from the specific factor of unilateral influence, such as the buyer's initial working

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capital (Huang et al. 2020), supplier's institutional environment (Wuttke et al. 2019), or even the collaborative factors of the financial service provider (Ma et al. 2020). However, the SCF may be ineffective if it is unilaterally adopted by anyone firm rather than the adoption of both suppliers and buyers (Wuttke et al. 2019). Therefore, it is important to have a more comprehensive understanding of the SCF influencing factors based on the nature of SCF rather than from the perspective of a single party. Based on the definition of SCF, it is obvious to find that one of the primary aims of organizations adopting SCF is to minimize total cost and financial risk in the supply chain; another is to maximize mutual benefit via cooperation with various supply chain members (Chakuu et al. 2019; Ma et al. 2020). The crucial aspects in encouraging the companies to adopt SCF can thus be summarized as cost motivation connected to the cost advantage of adopting SCF and social motivation related to enhancing inter-firm relationships. We aim to understand the SCF adoption by addressing the following research questions: Which cost and social factors may influence the company to adopt SCF? What is the mechanism of them?

We then integrate two theories, namely, social capital theory and transaction cost economics (Nahapiet and Ghoshal 1998; Williamson 1979), to develop a coherent explanation for SCF adoption willingness. Utilizing the data collected from 430 companies in China, we explore how different cost factors and social factors may influence the focal company to adopt SCF. Our study contributes to the literature in the following three respective. First, we provide new knowledge on the social capital theory by examining the relationship within three dimensions of social capital under the SCF scenario. Second, we further test these key concepts' effects on the SCF adoption willingness and extend the understanding of transaction cost economics. Third, we develop a dual-theory theoretical model to test theoretical predictions using a unique data set in the SCF literature and balance the overemphasis on the practical work in the existing research field.

2 Theoretical Background and Hypothesis Development

2.1 Social Capital Theory Perspective on SCF Adoption

The social capital theory is gaining prominence in exploring how companies are socially embedded in networks of relationships that incorporate a diverse set of organizational actors (Carey et al. 2011; Chae et al. 2020). In the context of SCF, relational capital reflects the trust and commitment within the supply chain relationship, and it can reduce the transaction costs and opportunistic behaviors (Zhang et al. 2015). Structural capital captures the quality and quantity of information exchange, and it can be conceptualized as the social interactions between suppliers and buyers. Cognitive capital represents the shared values and congruent goals between the supplier, buyer, and SCF provider, facilitating the development of shared understandings and sharing each other information during the transaction (Carey et al. 2011).

In the unique context of SCF, to control the financial flow and maximize the benefits, buyers, suppliers, and banks may collaborate more closely under the common goal to facilitate the reduction of financial risks and operation cost (Chakuu et al. 2019; Ma et al. 2020; Wuttke et al. 2013a). Thus, when there is a strong cognitive capital, the supply chain members may reach a consensus of the harmony of interests, develop a strong

relational capital and work more cooperatively to reduce the financial risk and cost in the supply chain.

Besides, social interaction, including interaction behavior, interaction ties, and interaction strength, is considered a significant part of structural capital (Chae et al. 2020; Tsai and Ghoshal 1998). In SCF, the stronger structural capital may further encourage the strengthening the relational capital. Specifically, considering the suppliers tend to be smaller companies that may have difficulties applying for loans from the bank, they always need the credit exchange and guarantee from the buyers (Wuttke et al. 2019). Thus, we propose that:

H1a. *Cognitive capital is positively associated with the relational capital.*

H1b. *Structure capital is positively associated with the relational capital.*

Within SCF, because the buyers and the suppliers are the risk-takers in SCF, relational capital is critical to minimize risk. For suppliers, because buyers in SCF always nominated the banks, the suppliers may not trust an external bank they are not currently doing business with if they not trust buyers and may reduce the willingness to adopt SCF. For buyers, because they need to use their credit rating to guarantee some small suppliers, the risk may be transferred from the supplier to the buyers, the buyer would face a higher risk profile (Wuttke et al. 2013b). Overall, given that relational capital increases the degree of mutual trust that exists between the supply chain members and reduce the expectation of opportunistic behaviors and the need for costly monitoring processes, we pose that:

H2. *Relational capital is positively associated with supply chain finance adoption.*

2.2 Transaction Cost Economics Perspective on SCF Adoption

Transaction cost economics, which was first proposed by Coase (1937) and developed by Williamson (1979), provide an underpinning understanding of companies behaviors and motives about strategy decisions and inter-organization governance (Dekkers et al. 2020). In the following, we focus on how the three primary characteristics related to transactions (i.e., uncertainty, frequency, and asset specificity) may affect the focal companies to adopt SCF (Williamson 1979).

Uncertainty is widely conceded to be a critical characteristic during the transaction process (Williamson 1979), reflecting the risk and the complexity of the transaction. Companies should also deal with the problem caused by the change of financing. Prior research has revealed that economic uncertainty may influence the supply chain companies' profitability and cash and credit transactions (Liu and Cruz 2012). Thus, SCF, a more systematic financing solution that can connect with the change of the whole supply chain, is needed. Thus, we hypothesize that:

H3. *Uncertainty is positively associated with supply chain finance adoption.*

Asset specificity refers to the type of asset with high transfer costs and can only be used in particular transactions (Williamson 1979). If the specific level of asset investment is very high, both parties may get into a bilateral monopoly and may lead to low liquidity. Specifically, considering the value of this capital is difficult to convert the money into other uses, the buyer cannot turn to alternative sources of supply without a hitch. At the same time, the supplier may hard to find another suitable customer after being induced to invest in such specialized physical capital. In this case, both parties are effectively "locked

into" the transaction to a certain degree (Chakuu et al. 2019; Dekkers et al. 2020), which may result in the company's liquidity deteriorates with a long inventory turnover cycle. Because they cannot turn to alternative sources timely to increase liquidity, companies may borrow money from outside, which may influence business continuity and hinder financial performance (Wang et al. 2020). Under this context, SCF could be a potential solution in resolving the problem. Thus, we pose that:

H4. *Asset specificity is positively associated with supply chain finance adoption.*

Frequency, which refers strictly to buyer activity in the market, is considered a significant influence factor during the transaction and can be characterized as one-time, occasional, and recurrent (Williamson 1979). The high frequency may increase of the liquidity requirement for cash flow, information flow and material flow. Under this high-frequency context, a company is more responsive to customers so that the company may spent more cost to verify the information and material, and to process the order (Wang et al. 2020). SCF can facilitate the reduction of financial risk in a supply chain by improving the collaborative cash-to-cash cycle and working capital (Chakuu et al. 2019). Thus, we propose that:

H5. *Frequency of transactions is positively associated with supply chain finance adoption.*

Drawing upon the above discussion, we summarize the research framework in Fig. 1.

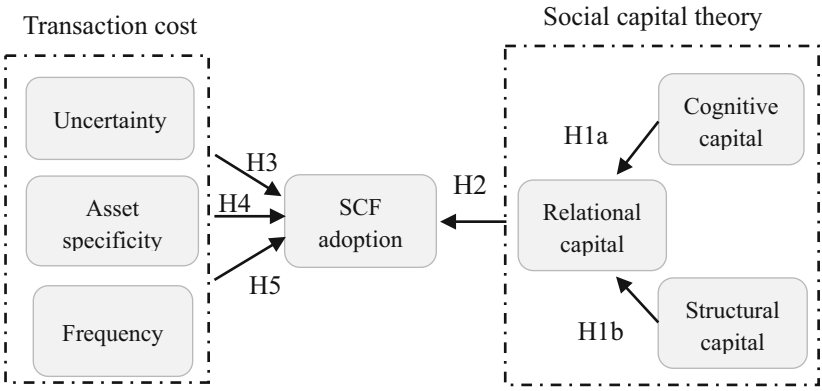

Fig. 1. Theoretical framework

3 Methods

3.1 Data Collection

Our data were sourced from a nationwide survey, namely China Supply Chain Management (Supply Chain Finance) survey. The questionnaires were sent to around 2000 companies in mainland China, most of which already have connections with the bank to guarantee the validity, and finally, 821 questionnaires were returned. Considering the variables covered in this research, the final sample includes 430 valid questionnaires. Table 1 describes the sample characteristics.

Table 1. Sample characteristics.

	Frequency	Percentage (%)
Industry types		
Machinery	67	15.6
Electronics	56	13.0
Retail	28	6.5
Pharmaceutical	66	15.3
Chemical	72	16.7
Coal	31	7.2
Steel	39	9.1
Automobile	33	7.7
Others	38	8.8
Total	430	100.0
Annual sales (million RMB)		
Less than 10	52	12.1
10–50	119	27.7
50–100	70	16.3
100–300	39	9.1
300–500	25	5.8
500–1000	25	5.8
More 1000	100	23.3
Total	430	100.0
Ownership		
State-owned	42	9.8
Collective-owned	12	2.8
Private-owned	182	42.3
Foreign	68	15.8
Share - holding	117	27.2
Others	9	2.0
Total	430	100.0

3.2 Variable Operationalization

Considering that our data is sourced from the China Supply Chain Management (Supply Chain Finance) survey, which is a kind of second-hand data, we use the following conventions to operationalize our variables.

Structural capital. Structural capital depends on the extent to which the buyer and supplier engage in joint events and the state of dependency of a company on its business partners in business (Carey et al. 2011; Choi and Kim 2008). Thus, we operationalize the

structural capital by using the proportion of the purchase amount of the top five suppliers in the total purchase amount of the company.

Cognitive capital. According to prior research, partners' level of symmetry or agreement reflects their shared vision and common understandings (Nahapiet and Ghoshal 1998; Son et al. 2016). Cognitive capital thus can be measured by the duration of the relationship within supply chain members.

Relational capital. Companies may tend to collaborate with someone they trust and develop a longer relationship. We thus operationalize the relational capital through the frequency of company evaluation suppliers on average trust and relationship commitment with customers.

Asset specificity. Because high asset specificity frequently entails large transfer costs, the contexts in which it can be used are usually limited. (Williamson 1979). In this case, we measured the asset specificity using two dimensions: the level of material price fluctuation and the degree of the difficulty of the material itself liquidating.

Uncertainty. Since the uncertainty can be seen as the reflection of the level of risk and the complexity of the transaction, more actions taken in risk management tend to indicate that the companies may control more potential uncertainty (Pellegrino et al. 2019). Therefore, the variable uncertainty is operationalized using the risk management mechanism. Frequency. We operationalize the frequency using the average turnover days of raw material inventory.

SCF adoption. We operationalize the dependent variable SCF adoption using the degree of SCF adoption. Companies were asked about whether they have adopted the SCF services to choose their current financing solutions.

Finally, some control variables in this paper involve company size (measured by numbers of employees), ownership, industry types, total assets (million RMB), financing amount demand and financing purpose (buy raw materials/finished products). Moreover, Table 2 provides descriptive statistics, correlations among factors.

Table 2. Correlation matrix and discriminant validity

	1	2	3	4	5	6	7	8	9
SCF adoption	1.000								
Frequency	−0.159**	1.000							
Asset specificity (slight fluctuation + hard to liquidate)	−0.180**	0.063	1.000						
Asset specificity (large fluctuation + easy to liquidate)	0.310**	−0.024	−0.530**	1.000					
Asset specificity (large fluctuation + hard to liquidate)	−0.104*	0.128**	−0.242**	−0.200**	1.000				
Uncertainty	0.254**	−0.085	−0.064	0.123*	0.043	1.000			
Structural capital	−0.199**	−0.063	0.122*	−0.188**	0.011	−0.111*	1.000		
Cognitive capital	0.040	0.101*	0.034	0.025	−0.053	0.082	−0.058	1.000	
Relational capital	0.112*	0.092	0.004	0.123*	−0.102*	−0.112*	0.028	0.156**	1.000
Mean	2.479	2.807	0.391	0.305	0.084	2.553	2.191	2.412	5.123
Standard deviation	1.311	0.786	0.488	0.461	0.277	0.596	0.859	1.242	1.515

Note: *p < 0.1, **p < 0.05.

4 Results

We adopt hierarchical regression analysis to test the hypotheses. We first conduct a collinearity test by calculating the variance inflation factor (VIF). The result shows that the value of VIF ranging from 1.044 to 1.427. Since all VIF values of variables are well below the maximum acceptable threshold of 3 (Neter et al. 1990), multi-collinearity is not a serious problem in our study. Table 3 summarizes our estimated results. In particular, Model 2 show that both the structural capital and cognitive capital have positively influenced the relational capital. Therefore, our results provide support for H1a and H1b. As for the SCF adoption, Model 5 suggests that the coefficients of relational capital are positively significant, showing that H2 is supported. In model 4, we test the relationships between the three dimensions of transaction cost and SCF adoption. First, to test H3, we relate transaction uncertainty to SCF adoption. Our result shows that companies may be more likely to adopt SCF with the increasing uncertainty. The parameter estimate for uncertainty provides support for H3. Second, with regard to asset specificity, the result is not significant when the material is hard to liquidate and no matter the price fluctuates in a large or slight level, but the result is significant with the characteristics of large price fluctuation and easy to liquidate. Thus, the H4 is supported to some extent. Third, the result of model 4 shows a negative significant between turnover days and SCF adoption, which indicate that the company with a high frequency of raw material turnover may be more likely to adopt SCF. The parameter estimate provides support for this hypothesis. H5 is thus supported as well.

Table 3. Estimated result

	Relationship capital		SCF adoption		
	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	5.028***	4.061***	1.653***	1.134***	0.752
Control variables					
Electronics	−0.615*	−0.459	0.531**	0.706***	0.750***
Steel	0.744**	0.883**	0.722**	0.660**	0.612**
Chemical	−0.265	−0.101	0.080	0.276	0.297
Machinery	−0.236	−0.108	0.495*	0.684***	0.703***
Retail	−0.542	−0.452	0.499	0.625**	0.661**
Coal	0.663*	0.970***	1.084***	1.019***	0.977***
Automobile	−0.028	−0.133	−0.477	−0.071	−0.059
Pharmaceutical	−0.359	−0.247	0.294	0.481*	0.509**
Total asset	−0.072	−0.090*	−0.006	−0.022	−0.018
Company size	−0.009	0.002	0.102**	0.093*	0.091*
State-owned	−0.098	−0.127	0.043	0.131	0.137

(*continued*)

Table 3. (*continued*)

	Relationship capital		SCF adoption		
	Model 1	Model 2	Model 3	Model 4	Model 5
Collective-owned	−1.239***	−1.207***	−0.012	−0.173	−0.082
Private-owned	0.274	0.243	−0.150	−0.009	−0.026
Foreign	0.094	0.041	−0.238	−0.176	−0.179
Loan purpose	0.144	0.226	0.200	0.162	0.151
Loan demand	0.109**	0.100**	0.042	0.052	0.045
Independent variables					
Structural capital		0.227***			
Cognitive capital		0.172***			
Frequency				−0.243***	−0.250***
Asset specificity (slight fluctuation + hard to liquidate)				0.000012	−0.018
Asset specificity (large fluctuation + easy to liquidate)				0.486***	0.478***
Asset specificity (large fluctuation + hard to liquidate)				−0.237	−0.218
Uncertainty				0.367***	0.386***
Relational capital					0.072*
R^2	0.139	0.169	0.175	0.255	0.260
F value	4.181***	4.632***	5.471***	6.634***	6.513***

Note: ***, **, and *represent significance at 0.01, 0.05, and 0.1 level, respectively.

5 Discussion

In this study, we examine the influencing factors that may affect SCF adoption from the theoretical perspective. In light of the companies' core objective of using SCF is to reduce cost and financial risk in the supply chain and maximize the mutual benefits by collaborating with supply chain partners (Chakuu et al. 2019; Ma et al. 2020). We attempt to use social capital and transaction cost economics to highlight the supply chain connections and transaction cost dimensions that may impact SCF adoption.

5.1 Theoretical Implications

Despite the fact that the literature on supply chain finance is rapidly developing, relevant contributions to date have been largely practical. One of the key holes has previously been highlighted as the establishment of more robust theoretical basis (Dekkers et al. 2020). Our research tries to fill the gap by developing a theoretical model based on social capital theory and transaction cost economics to illustrate the relationships and transaction process along with the supply chain's financial flow and help understand the factors that may influence the SCF adoption. Specifically, our result enriches the theoretical understanding in three aspects:

First, we introduce fresh information on the social capital hypothesis. Previous research has looked at the links between three aspects in the setting of social capital. According to some researchers, structural capital and cognitive capital were the antecedents of relational capital. (Carey et al. 2011; Tsai and Ghoshal 1998), while some find that the structural capital is positively associated with the relational capital and cognitive capital (Zhang et al. 2015). We further validate the link using the SCF scenario and discover that structural capital and cognitive capital were the antecedents of relational capital in SCF.

Second, by verifying the ideas in the context of SCF, we contribute to expanding our understanding of transaction cost economics. Uncertainty, asset specificity, and frequency are three essential elements that underpin transaction cost economics and offer crucial variables for hypothesis testing (Inkpen and Tsang 2005). According to our findings, there is a positive association between the three notions and SCF adoption willingness, albeit to varying degrees of significance. This discovery adds to the current SCF research by providing a thorough view of transaction cost economics.

Third, our study is one of the first attempt to test theoretical predictions using a unique data set in the SCF literature. Our empirical investigation illustrates the SCF adoption decision from an academic perspective. By conducting statistical analyses based on credible data, the findings further substantiate that the adoption of SCF is affected by transaction cost (Dekkers et al. 2020) and inter-firm relationships (Caniato et al. 2016). This perspective is echoed by Tseng et al. (2018), who argued the economic attributes and social attributes are two attributes of environmental factors that affect the SCF most critically.

5.2 Practical Implications

Collectively, our results also provide specific, actionable guidance for buyers, suppliers, and SCF providers. The findings can help decision-makers understand the inter-firm cooperation and transaction cost and risk in the SCF process and assist them in judging whether they have to adopt SCF depending on their transaction situations. Before deciding to adopt the SCF, companies should consider the relationship with other supply chain members.

Besides, practitioners should also decide on SCF adoption based on the specific market situation and transaction characteristic. Our findings demonstrate that companies may adopt SCF if the transaction has features about high frequency, asset specificity, and uncertainty. Thus, all three parties, namely, supplier, buyer and SCF provider, should consider the materials' specificity, price fluctuation in the market, and the frequency and uncertainty along with the financial flow.

6 Conclusion

Our research provides an integrated framework of dual theory and tests its influence on SCF adoption using transaction cost economics and social capital theory. First, we investigate whether cognitive capital and structural capital are the antecedents of relational capital in the framework of social capital theory. Second, relational capital may help to

adopt the SCF through its facilitation of cooperation and collaboration. Furthermore, when deciding whether to adopt SCF, we highlight that the practitioners can benefit from understanding the three dimensions of transaction cost economics: uncertainty, frequency, and asset specificity. All of the three dimensions show positive relationships with SCF adoption. Overall, the result of this study makes contributions to SCF literature by revealing the significant environmental influencing factor during the SCF adoption decision from a theoretical perspective.

Even though our study is one of the first to show SCF adoption as an empirical influencing factor based on theoretical knowledge, there are many more promising topics for future investigation. To begin with, the data was only gathered in China, thus our conclusions may not be applicable to other countries. Future research can further examine our results with more data collected from a broader area. Second, although we discussed the three core dimensions of transaction cost, some other factors of transaction cost may affect the result, such as the governance mechanisms, which can be explored further in the future. Third, the cross-sectional data constrained the knowledge of SCF adoption to a superficial level. Future research can look into how these characteristics alter the relationship lifespan because SCF adoption is a dynamic and longitudinal process.

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Sporting Resilience During Covid-19: The Value Co-creation Process on Sport Live-Streaming Platforms

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Abstract. The sports event organisers have rapidly adopted digital technologies (i.e., live streaming) in order to maintain virtual fans' attendances and engagement in the unprecedented times of the Covid-19 crisis. The Sports Live Streaming Platforms (SLSPs) have taken center stage in broadcasting sporting events. However, the value co-creation process in the SLSPs is not clearly understood. In this paper, we aim to unpack the value co-creation process in SLSPs. A case study with China Sport, one of the most representative SLSPs in China, involving 20 in-depth semi-structured interviews was conducted. The study identified 4 types of viewers (professional player viewers, super fans viewers, room managers, and ordinary fans viewers) according to their watching intention and interactive frequency in the SLSPs. The findings show that viewers' values are co-created by both actors (platform, streamers, other viewers, and players)' contributions and viewers' own engagement behaviours. This study extended theoretically the boundary of value co-creation into the context of sport live streaming platforms. Our findings help SLSPs managers and decision makers understand the viewers' segmentation, and the process to encourage value co-creation interactions between actors and streamers so as to facilitate viewers' continual usage.

Keywords: Value co-creation · Engagement behaviour · Sport Resilience · Value networks · Sport live streaming platforms

1 Introduction

In these unprecedented times of the Covid-19 crisis, the lockdown and current social distancing measures across the world have devastated the sports industry. Most major sporting events at international, regional, and national levels have been cancelled, postponed, or played in empty stadiums. The entire sports ecosystem needs new ways to deal with threats to fans' attendance and engagement. Due to the outbreak of Covid-19, fans spending even more time online, the Sports Live streaming Platforms (SLSPs) have taken a canter stage in broadcasting sporting events to innovate the viewing experience and increase connectivity with the sports fan base community.

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With the rapid improvement of the internet and mobile devices technologies, social live-streaming services (SLSSs), a new type of social media, has emerged and grown rapidly all over the world in the last decade. The data of UBS Evidence illustrates that 36% of U.S. Netizens had watched live-streaming in November 2016 and in China, the number of live-streaming users reached 344 million at the end of 2016, which accounts for about half of the total Netizens (Li et al. 2018). Under this context, increasing attention of scholars have been attracted by this rapid growth and wide popularity, which result in the insights about SLSSs in terms of motivations of both users and streamers (Scheibe et al. 2016), watching intention (Chen and Lin 2018), the content of stream (Lu et al. 2018; Friedländer 2017), and reward system (Li et al. 2018) have been generated. However, most of these insights have been gained based on the general live streaming services (without any thematic restriction), which means that the lack of attention and knowledge on topic-specific live streaming services, especially in the sports domain remains underdeveloped. Therefore, the purpose of the current study is to fill this gap, exploring how SLSSs operate in the sports domain and what value can be co-created within this new area.

Different consumption contexts are characterised by the involvement of different actors (e.g., players, fellow viewers, streamers, etc.) with various resources. Consequently, it is critical to understand how the actors influence the viewers' experience of the sporting events on SLSPs. In this article, we integrate the value co-creation concept to explores what is the value co-creation process on SLSPs.

2 Literature Review

2.1 Social Live-Streaming Services

SLSSs is a new type of social media that allows users to broadcast their content (e.g., daily life and talent) in real-time through mobile devices while viewers watch, interact and reward synchronously (Scheibe et al. 2016). Compared with the traditional media, such as mass media, SLSSs is outstanding in three aspects. First, with a live streaming app, users can either view or stream all kinds of live streaming content at anytime and anywhere. Second, SLSSs enables real-time social interaction and communication between streamers and viewers or among viewers synchronously (viewers and streamers) (Chen and Lin 2018; Kim and Kim 2020). The last important feature is the new monetization model. SLSSs allow viewers to send virtual gifts to streamers and buy any goods directly by clicking the links of advertisements. These virtual gifts can be then converted into cash that contributes to most revenues of both streamers and the platforms.

SLSSs can be generally divided into two categories, which are general live streaming services (no thematic restriction) and topic-specific live streaming services (e.g., game and art) (Scheibe et al. 2016). In the study of general SLSSs, previous studies have explored the usage motivation, information behaviour, usage intention on SLSSs. For example, Scheibe et al. (2016) conducted two quantitative studies on YouNow.com and examined the viewers' information production behaviour and information reception behaviour. Friedländer (2017) later observed more than 7,500 streams in the US, Germany, and Japan and found that the main motivations of SLSSs usage are having fun,

reaching certain groups, mitigating boredom, and interaction. Besides, Chen and Lin (2018) studied the usage intention of SLSSs users and noted that flow, entertainment, social interaction, and endorsement have positive relationships with the user's attitude, perceived value, and watching intention.

In terms of topic-specific live-streaming services research, game-related topics are the predominant theme which including viewers' characteristics (Hilvert-Bruce et al. 2018), incentives of different stakeholders and involved technologies (Smith et al. 2013) and the behaviours of streamers and viewers (Qian et al. 2020). Kim and Kim (2020) conduct the first study in terms of sporting events live streams on SLSSs based on uses and gratification theory. Through collecting data from 231 sport SLSSs users, they found that personal integration, social integration, the experience of relaxation and entertainment, and affective gratification positively influence the users' flow experiences (holistic immersion). This study brings initial insights into the sport-specific SLSSs.

2.2 Customer Engagement in Value Co-creation

Vargo and Lusch (2004) first introduced the SDL. It is contrasted with the product-centric view of GDL, which suggests that the value is created via the consumption process. Before that, Prahalad and Ramaswamy (2004) proposed the co-creation concept. They acknowledge that customers and suppliers interact largely collaborate beyond supply-demand relationships. A more complex relationship of the value network was then emphasised in SDL by highlighting that 'the value is always co-created by multiple actors, including the beneficiary' (Vargo and Lusch 2016: 8). Moreover, the actors can only offer value propositions rather than delivering value as there is no value until an offering is used (Lusch and Vargo 2006). Because the value (value-in-use) is co-created by the beneficiary to integrate the value proposition of the service providers with their resources (competencies, knowledge, abilities, and skills) (Akaka et al. 2013).

SDL suggests that interactive consumer experiences co-created with other actors can be interpreted as the act of "engaging" Vargo (2009). In the existing literature, a growth of studies has looked at the customer engagement behaviours on social media platforms (Vale and Fernandes 2018; Hollebeek and Brodie 2016). Social media platforms allow consumers to engage in extensive activities which enabling dynamic and often real-time value co-creation between consumers and firms, as well as consumer-consumer on a large scale. For example, Abeza et al. (2018) also emphasised the customers-firms (clubs-fans) value co-creation on social media as a platform. They point out that the firms can interact and communicate with viewers co-created values, i.e., enriching consumers, humanising brand, venue for voicing, and a hub for consumers (Abeza et al. 2018). In terms of customer-customer value co-creation, Pongsakornrungsilp and Schroeder (2011) applied an approach of netnography and selected the Liverpool Football club – 'This Is Anfield Fan Site' as a case study. They find that the sports fans can be the provider to contribute knowledge, comments, information, and stories to the 'This Is Anfield Fan Site' community. They find that the fans play roles as either provider (more experienced members) or beneficiaries (generally less experienced members) in the community. The experienced fans are working as providers who contributing knowledge, comments, information, and stories while the less experience fans are beneficiaries who acquire these shared values.

However, value co-creation is not limited to the activities of anyone exchange or a dyad of service systems. In SLSSs, value occurs through viewers integrating the resources of a variety of actors, such as streamers, the platforms, players, and other viewers. Therefore, the current study considers broader level analyses to explore how viewers engage with different actors in value co-creation (meso-level).

3 Methodology

In this research, China Sport has been chosen as a case study. China Sport is one of the most prevalent Interactive HD sports live-streaming platforms. It acquired a vast range of competitive sporting events live streaming copyright from sports organisations, including International Table Tennis Federation, Badminton, World Federation, World Professional Billiards, and so forth. In this study, 20 semi-structured interviews have been conducted which ranged from 27 to 67 min for each. A transcription software called Xun Jie text speech converter was employed to transcribe data. However, we proofread every transcribed data again to ensure their accuracy while typesetting them into the same for the sake of further convenience of doing data analysis. An analytical software, Nvivo, was used to do analyse the data. Through coding, comparing, and categorising the whole set of data, key characteristics and patterns were found, which could answer the question proposed in this study.

4 Findings

The data shows value has been co-created through the viewers integrating the value contributions of viewers, platforms, streamers, and players in the sport-specific SLSSs. Meanwhile, different types of viewers' engagement behaviours can be a filter that enable viewers to acquire their unique value-in-use. In the following sections, the findings of the value co-creation process will be illustrated.

4.1 Actors and Value Contributions

4.1.1 Platform

The platform offers a series of contributions to enhance their watching experiences. These contributions include offering a mobile APP, abundant competitions, 360°, and switching angles viewing, a simple and concise interface, and extra content (i.e., pre-match warm-up, inter-match coaching, and post-match interview). Among these contributions, providing a mobile APP is mentioned and praised by almost every interviewee. Viewers are no longer restricted by the place and time, which means they can watch the events whenever and wherever they want as long as they carry their mobile phone with them. As one interviewee explained: In their university, the watching condition is poor. TV cannot be found except in the canteen. Also, carrying the laptop all the time is not convenient. Therefore, Chine Sport APP is the best choice to watch sporting games.

The abundant competition offered by the platform is another contribution that has been acknowledged by the majority of interviewees because of its unique benefit for

them. CCTV5 (China Central Television Sports Channel) only broadcasts the most important matches in big events such as the semi-finals and finals of the Olympic Games, Championships, and World Cup. However, once China sport won the broadcasting copyright, it streams all the events, including Opens, Grand Prix, Leagues, and even domestic games, from group matches to the semi-final and final. Moreover, as a Chinese sport channel, traditional CCTV5 mainly focuses on the broadcast of the matches played by Chinese players, which results in a phenomenon that the matches between two foreign players are hard to happen. In contrast, as there are many live-streaming rooms on the platform, different matches can be live-streamed simultaneously, which gives the right of choice to viewers for choosing their favourite matches freely.

Except for these main widely acknowledged contributions above, respondents also mentioned some other contributions that have benefited them respectively, such as 360° and multi-angle watching, simple and concise interface, and extra content. However, as these contributions were identified individually or in a small group, their benefits may vary for other viewers. Take 360° and switching angles watching as an example, one interviewee described them as a tool that can make him feel as if he is present. However, some interviewees believe that the technologies are not advanced enough.

4.1.2 Streamer

There is little doubt that streamers play an indispensable role in the sport-specific SSLSs. According to the interviewees, streamers' expertise and interactivity are the main factors that contribute to their watching experience.

Just like the commentator in the traditional sports broadcast and TV, the important duty for the streamer is to commentate on the match including introducing players background, the sport's history, and the process of the match. However, unlike traditional sport TV broadcasts where normally have two commentators (the host and the guest) working together to commentate the match, there is only a single streamer in the live streaming room (Li 2008). The streamers place a higher value on playing both the role of the host and the guest to contributes rich information, professional and useful suggestions to viewers. In this case, the level of expertise of the streamers is important. Therefore, the streamers who were professional players are more favourable to viewers. A student from Beijing Sport University described that he would like to choose these former professional players streamers because their comments and opinions are more knowledgeable than other non-professional players streamers. Similarly, another interviewee state that 'these streamers can recognise the good technique and analyse the strategies the players use. So that I can learn a lot when I am watching.'

The interactivity of streamers is another crucial contribution to the experience of SLSPs viewers. Streamers interact with viewers through a series of activities such as vocal communication and real-time messages. They react to the viewers' messages in real-time to care about the audience's expectations and address the audience's requirements. The interactive communication makes the viewers feel that the streamer is approachable. Meanwhile, the viewers are free to send their thoughts and questions via real-time messages. One interviewee emphasises it by stating that: "I could only be a quiet viewer when watching events on TV and commentators' comments are for

the public viewers only. However, in China Sport, streamers sometimes selected my questions and specifically answer them for me […]; I feel I am being noticed.

4.1.3 Fellow Viewers

Although viewers are the main beneficiaries of the platform, they also offer their contributions to the community. The viewers are embedded in the live streaming process to cheer for their teams or to criticise opponents through interacting with streamers and other viewers in the form of posting real-time messages (Fan et al. 2018) or virtual gifts (Scheibe et al. 2016). These real-time messages are shown on the open viewer chat. They are automatically animated over the stream screen, which is called Danmu (Fan et al. 2018).In the context of watching a sporting event on-site, other fans' and spectators' behaviours (e.g., singing battle chants) contribute to the atmospherics at a sports stadium 21. In SLSPs, these real-time messages and virtual gifts are important components of the live streaming room atmosphere. Moreover, answering questions is not the priority of streamers on SLSPs. Instead, the viewers are also able to answer other viewers' questions which are related to techniques, strategies, scores, and so on. Therefore, the viewers can contribute to other viewers by providing knowledge through interactions.

4.1.4 Players

The final actor in this value co-creation process is players. Although they are not on the platform and cannot directly interact with other actors, their performance is an indispensable factor in shaping viewers' experience. According to around 70% of the interviewees, their viewing experiences would be fluctuated according to how good was their favourite players performing. For instance, one interviewee who is a fan of Xin Xu and Zhendong Fan mentioned: 'I would be very happy and excited if Xin Xu and Zhendong Fan have had a good performance and won the matches. However, if they had not performed normally and lost the match, I would feel sad.'

4.2 Viewer Engagement and Perceived Value

The data reveals that viewers have different engagement behaviours and interaction frequencies, which is related to their professional table tennis background and passion for table tennis. Accordingly, the viewers are divided into two main categories, professional player viewers and amateur viewers.

4.2.1 Professional Player Viewers

The professional player viewer is the first viewer type that was identified. They refer to the viewers who are professional players or retired professional players of provincial teams and beyond. This type of viewer is mainly focusing on watching the game and rarely interacts with other viewers and streamers. Although they rarely participate in the quiz and send real-time messages and virtual gifts occasionally, doing these activities may distract their attention. The viewing motivation of professional player viewers is to learn advanced and useful techniques from the players. As one interviewee explained:

'I just want to focus on watching the competitions and to see if there is anything I can learn from the players. I normally watch the game in the horizontal view with zooming in the screen to against distractions.'

4.2.2 Amateur Viewers

Another type of viewers that are identified from the data is amateur viewers. Compared with professional player viewers, they have more engagement behaviours. Amateur viewers are further classified into another three categories, which are ordinary fans and super fans, and room managers.

Ordinary fans could be defined as the viewers who like table tennis as much as or even less than other sports. This type of viewer does not bring strong and clear purposes to watch the game. The major motivation for watching is entertainment. They perceive watching table tennis as an entertainment activity, which can be used to kill the time in their leisure moments. As one interviewee stated that she might follow other viewers to sending real-time messages to cheer players up. In addition, acquiring knowledge and skills is another motivation. However, as they have a relatedly low level of knowledge in table tennis, they focus more on the general understanding of this sport rather than learning something for their usage.

Super fans are the viewers who are obsessed with table tennis, viewing it as the most important sport and an indispensable part of their life. Super fans participated in every activity in the live-streaming room, including sending real-time messages and virtual gifts, quizzing, voting, and drawing. At the same time, their interactive frequency is much higher than the professional players and ordinary fans. In extreme cases, in order to have fun and interact with streamers, some viewers are willing to recharge money to buy and send gifts. These fans tend to acquire a sense of belonging and fans identification when they feel like a part of their loved players' fans communities and cheer up for them.

Room managers can be seen as working viewers who not only watch the game for themselves but are also in charge of managing the environment of the streaming room for streamers. Their interactive frequency is much higher than other viewers. One of the room managers used the word "countless" to describe the number of his interactions in one match with the streamers and other viewers. Moreover, room managers are selected by streamers who are knowledgeable in terms of table tennis information and expertise as they are expected to answer the questions proposed by different viewers. The key responsibility for room managers is to harmonise the language environment of the room in order to provide viewers with a harmonious viewing atmosphere. To achieve this purpose, room managers can mute anyone who is misbehaved and even kick someone out of the streaming room.

5 Discussion and Conclusion

This study has revealed the value co-creation process between different actors (the platform, streamers, viewers, and players) and viewers on the SLSPs. These findings have enriched the understanding of the meso-level value co-creation within SLSPs. In the SLSPs co-creation process, the platform, streamers, players, and viewers are the four

actors who provide a set of unique contributions to viewers watching experiences. The sports live streaming platforms play a vital role as they provide a platform for different actors to collaboratively co-create value (see Fig. 1).

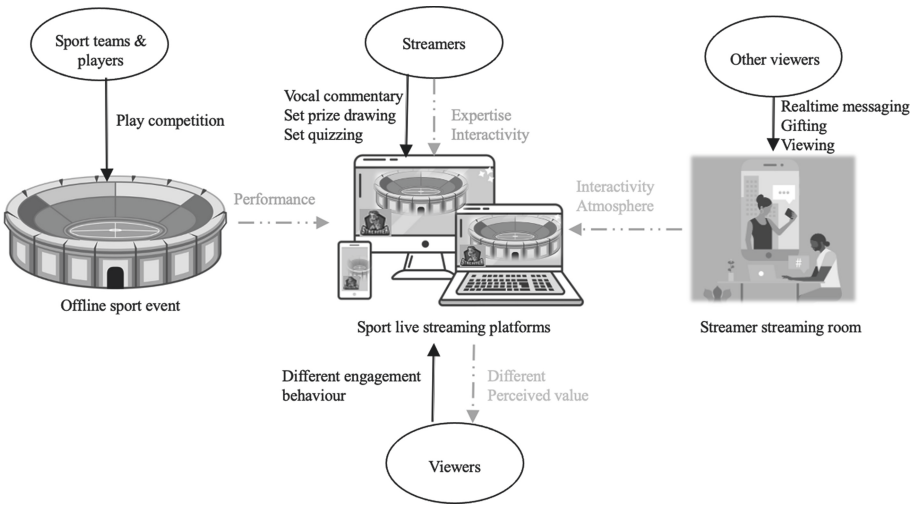

Fig. 1. Value flow of Sport live streaming platform (adapted from Liu et al. 2022).

This study found that viewers' perceived values are influenced by their own engagement behaviours and their distinct motivations. For professional player viewers, they prefer watching matches quietly with limited interaction so that they can fully focus their attention on the expertise perspective of players' performance. Thus, they would acquire more epistemic values as their motivation is learning. The Amateur viewers have relatively more positive interactions. They not only want to acquire knowledge but also have fun and make friends by watching sports event in SLSPs.

Based on this research, SLSPs managers could understand viewers by observing their engagement frequencies, so that they could elaborate on different actors to maximise the actors' contributions. Moreover, as knowledge and information acquisition are the main requirements for almost every type of viewer, managers could pay more attention to providing knowledge. For example, more qualified and professional streamers can be enrolled into the platform to provide more professional commentary. Another way could be increasing the professional knowledge and skills of streamers through training so that the quality of streamers could be improved, which will play a key role in customer retention.

6 Limitations and Future Research

Although this study has offered many insights into the value co-creation process in sports live-streaming platforms, making contributions for both academic field and business practices, it is undeniable that there is a limitation. The researcher only adopted in-depth

interviews as a research method. Therefore, future studies can adopt quantitative research methods to examine the distinctive perceived value of different viewers. Besides, other sports and counties can be used as research case studies so that a more comprehensive understanding of the value co-creation of sport live-streaming services can be generated.

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Leveraging Supply Chain Digitalization Through Supply Chain Responsiveness, Resilience, and Restoration

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Abstract. This study aims to examine how supply chain digitalization (SCD) affects supply chain responsiveness, resilience, and restoration (3Rs) and supply chain performance. Further, this study explores the moderating role of pandemic impact of the COVID-19. Based on survey data from 215 firms in China, the hypothesized relationships were tested using a SPSS macro program (i.e., PROCESS regression analysis). The results show that SCD enhances supply chain 3Rs, and the supply chain 3Rs positively mediate the relationships between supply chain digitalization SCD and supply chain performance. Further, the mediating effects are strengthened under a high degree of pandemic impact during the COVID-19.

Keywords: Supply chain digitalization · Supply chain responsiveness · Supply chain resilience · Supply chain restoration · Supply chain performance

1 Introduction

The COVID-19 pandemic has posed huge threats to global supply chains. According to Fortune [1], 94% of the top 1000 firms were heavily affected by supply chain disruptions during this outbreak. Such sudden shock has aroused firms to pay more attention on building supply chain responsiveness, resilience, and restoration (3Rs) to survive in the difficult times [2, 3]. Likewise, van Hoek and Lacity [4] also urge scholars to investigate how managers address the challenges posed by disruption risks as the existing research has not fully realized its potential to understand supply chain risk management capabilities yet.

The supply chain 3Rs are the abilities of supply chains to plan for, respond to, and recover from disruptions in a timely and cost-effective manner. Among the approaches proposed by supply chain experts to enhance resilience and develop recovery plans, supply chain digitalization (SCD) has received much attention recently [4]. Previous studies have found that firms can benefit from developing digitalization to gain competitive advantage [5]. It has been suggested that digitalized supply chains serve to increase information visibility and optimize inter-organizational logistics through end-to-end real-time information access, integration, and control [6, 7]. However, most of the existing research on digitalization is rooted in conventional business operating context,

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few have explored the underlying mechanism of digitalization affecting performance from the supply chain risk management perspective, especially during the crisis time.

To address this gap, this study draws on organizational information processing theory (OIPT) [8, 9] to empirically explore supply chain 3Rs as the underlying mechanism through which SCD contributes to improved supply chain performance. We further examine how the influence mechanism of SCD affecting supply chain performance would be contingent upon pandemic impact.

2 Theoretical Background and Literature Review

2.1 Organizational Information Processing Theory

The central logic of OIPT is that firms must effectively collect and process information when performing tasks with great uncertainty [8–10]. To address the uncertainty and eventually achieve organizational effectiveness, organizations should fit their information processing capabilities to the information processing requirement [11]. Information processing capabilities are defined as the abilities to reconfigure resources and technical capital that facilitate information gathering, transformation, communication, and storage [8, 12, 13].

Past studies have identified digital information systems as important ways to enhance the information processing capabilities. In this study, we conceptualize SCD as an effective information processing capability which serves as an information architecture for the information flow along the supply chains. Further, the OIPT also reasons that despite uncertainties/disruptions in the environment, organizations should develop capacity buffers and build a stabilization mechanism that incorporates resources and capabilities to manage unexpected business uncertainty and thus improve performance [5, 8, 14]. In this study, we suggest that the supply chain 3Rs are information intensive process and represent higher-order information processing capabilities which can help firms to utilize and transform the collected data and make effective decisions.

Therefore, drawing on OIPT, we propose that in the context of disruption impact during the COVID-19 pandemic, SCD, representing primary information processing capabilities, enables firms to gather and collect data in real time and promote intensive-information processing mechanisms (i.e., supply chain 3Rs), which contributes to enhanced supply chain performance. The OIPT provides a holistic theoretical base to build a solid research framework for SCD, supply chain 3Rs, and supply chain performance under the disruption impact.

2.2 Supply Chain Digitalization (SCD)

SCD is reshaping business ecosystems and changing the ways of interaction between upstream and downstream stakeholders. From the OIPT perspective, SCD creates increased information processing capabilities through strengthening data collection, storage, big data analysis and implementation [15]. It can release tremendous potential to form super-perceptive, intelligent decision-making, and rapid implementation ability, especially when facing supply chain disruptions [16]. While the value of the SCD has

been recognized in the prior studies (such as speed, visibility, connectivity, transparency, real-time inventory, etc.), it is still not clear how the adoption of SCD affects supply chain performance when faced devasting catastrophes, especially ones such as the largest-scale supply chain disruptions of the COVID-19 pandemic.

2.3 Supply Chain Responsiveness, Resilience, and Restoration (3Rs)

The outbreak of COVID-19 has put the supply chain risk management capabilities the priority of managers [17, 18]. Supply chain risk management is a multi-faceted process, including aspects of proactive planning, quick recovery, and sustainable growth. Accordingly, the 3Rs represent the abilities of supply chains to proactive planning before disruptions, quick recovery during disruptions, and the sustainable growth after disruptions. Specifically, supply chain responsiveness involves the ability of proactive planning, so that the supply chain can respond quickly and accurately to the short-term changes of customer demands and market needs [19–21]. Supply chain resilience concerns the ability to ensure continuity of SC operations and recover quickly from the disruptions caused by external disasters to the original operating level in the damage repair stage [22]. Supply chain restoration refers to the ability to restart supply chain after disruptions and redesign/reconfigure the supply chain to meet new demands under/after external disasters [23].

3 Theoretical Model and Hypotheses Development

3.1 Theoretical Model

Based on OIPT, we develop a conceptual model addressing the relationships among SCD, supply chain 3Rs, supply chain performance, and pandemic impact (see Fig. 1).

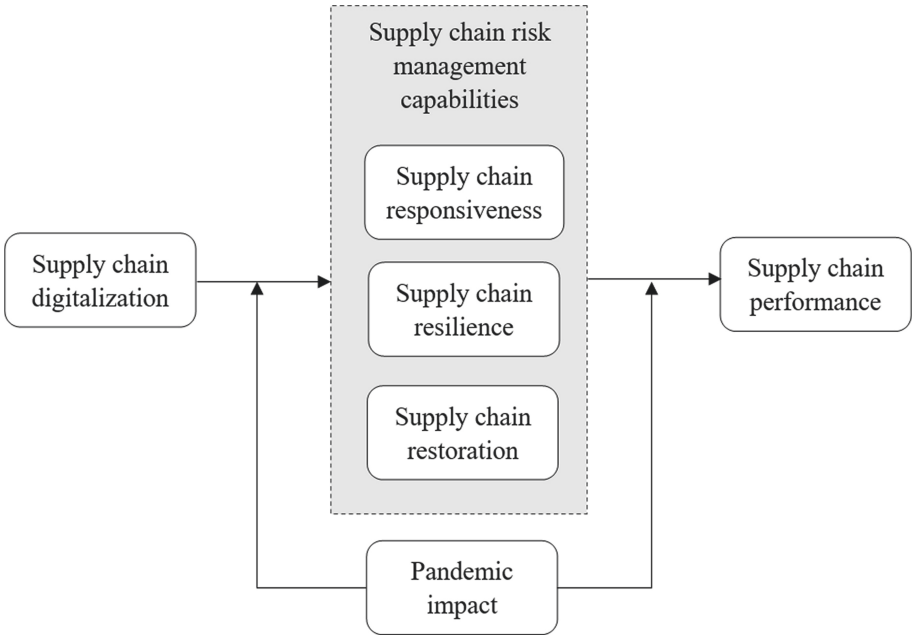

Fig. 1. Conceptual model.

3.2 Hypotheses Development

3.2.1 The Relationships between SCD and Supply Chain 3Rs

The digitalization of the supply chain is enabled by data interaction and it brings new patterns of supply chain risk management with the continuous integration and deepening of advanced technologies and supply chain structure [24]. From the OIPT perspective, supply chains are information-processing systems [8, 14]. Digitalization represents the information processing capabilities of the supply chain and provides the information infrastructure. It can support supply chain 3Rs through connectivity, aggregation, and screening functions, respectively. SCD accelerates the speed of information collection and expands the capacity of information processing, which shortens the distance of information access among the supply chain members. In this way, supply chain managers can quickly perceive the scope of impacts and damage of crisis events, thus improving supply chain 3Rs. Accordingly, we propose the following hypothesis:

Hypothesis 1. *SCD positively influences supply chain (a) responsiveness, (b) resilience, and (c) restoration.*

3.2.2 The Mediating Roles of Supply Chain 3Rs

Building on OIPT, this study proposes that supply chain 3Rs act as underlying mechanism which mediates the relationship between SCD and supply chain performance. Previous literature has highlighted the strategic value of SCD in improving operational efficiency and integrating value chains in terms of high speed, intelligence, transparency, visualization, and scalability [7]. However, recent studies show that solely investing in digitalization along supply chains are not sufficient to achieve desirable performance [16]. Organizations can reap the benefits of digitalization only when they develop necessary capabilities to utilize and capitalize on the collected data [25]. In other words, firms need to update supply chain structure and develop more comprehensive risk management capabilities to sense, shape and seize opportunities through using digital technologies and data effectively, and create and capture supply chain performance in new ways. The digital information systems are considered as the lower-order resource capabilities that generate and collect fragmented data and create a profound ground for building higher-order capabilities, such as supply chain risk management capabilities [5, 26]. Particularly, supply chain 3Rs imply more information-intensive process and further information processing capabilities. The 3Rs provide firms with available assets across supply chain partners, as well as sharing and processing information collected through digital information systems to ensure the normal operations and improve supply chain performance during the crisis. Therefore, we argue that deploying supply chain 3Rs capabilities can help firms leverage the value of SCD. Accordingly, we propose the following hypotheses:

Hypothesis 2. *Supply chain (a) responsiveness, (b) resilience, and (c) restoration mediates the relationship between SCD and supply chain performance.*

3.2.3 The Moderating Role of Pandemic Impact

The disruption impacts during the COVID-19 pandemic has been widely identified as a contextual factor that influence supply chain operations [2, 4]. As the disruption impact increases, firms need to obtain more accurate and sufficient external information to quickly predict change and reduce uncertainty. The value of digitalization is magnified in this context as digitalization infrastructure incorporating supply chain partners can play a more effective role in connecting, aggregating, and screening for recovery and rebound of supply chain operations than those that do not. Therefore, when firms are affected by the supply chain disruption during the COVID-19 heavily, they tend to extend the application of SCD into the process of supply chain risk management to integrate information from both suppliers and customers and establish a relatively stable mechanism.

Moreover, under the impacts of supply chain disruptions, firms tend to establish 3R supply chains to better activate, reconfigure, and transform critical resource endowment. The higher-order information processing capabilities are matched with higher information processing requirements, ultimately achieving the improved supply chain performance [5]. The recent evidence indicates that the relationships between supply chain risks management capabilities and supply chain performance strengthens with the scale of pandemic impact [14], which provides a strong basis for the arguments made in this study. Consequently, the following moderated-mediation hypotheses are proposed in this study.

Hypothesis 3. *The pandemic impact positively moderates the indirect effect of SCD on supply chain performance, such that this indirect effect is stronger with higher degree of pandemic impact.*

4 Research Methodology

4.1 Sampling and Data Collection

The research model was tested using web-based survey data in China in 2021. First, a stratified sampling method was adopted to identify 600 firms from the potential sample pool of Yellow Pages of China Telecom. Senior managers and supply chain managers were targeted for this study. Finally, 215 valid questionnaires were received.

4.2 Measures

To measure SCD, we comprehensively considered the scales of Xue et al. [27] and Xue [28]. Supply chain responsiveness were measured in line with the definitions in the mainstream supply chain literature [29]. The measurements of the supply chain resilience were adopted from Elbaz and Ruel [30]. Supply chain restoration was developed and adapted from Essuman et al. [31]. Based on insights from Belhadi et al. [5] and Srinivasan and Swink [32], identified four items were used to capture supply chain performance. The measurement of pandemic impact was drawn from El Baz and Ruel [30]. A Likert

scale with seven points was used to measure each of the items, in which 5 indicates strongly agree and 1 indicates strongly disagree. Respondents were required to indicate their degree of recognition regarding the statements. We also controlled for ownership type, firm age, and development stage. Scholars have indicated that ownership type may influence supply chain activities and performance [33]. This study used dummy variables for ownership types. Firm age and development stage have often been used as control variables in previous studies.

5 Results

5.1 Measurement Validation and Construct Development

Content validity was verified as the measurement constructs were strongly supported by theories and practice developed in previous studies, and it was also verified in pre-tests. The results of the overall exploratory factor analysis (EFA) indicate that the factor loading of each item on its corresponding construct was greater than 0.6, while the cross loadings on other constructs were less than 0.4. This provides comforting evidence of convergent and discriminant validity for the whole measurement model.

Confirmatory factor analysis (CFA) was used to verify the reliability and convergent validity of the whole measurement (Table 1). The factor loadings of the items range from 0.740 to 0.987, with all above the 0.7 threshold. Cronbach's alphas for the constructs were above the 0.70 threshold recommended by Nunnally and Bernstein [34], and the composite reliability (C.R.) values all reached the recommended 0.7 threshold [34, 35]. The average variance extracted (AVE) values of the constructs also reached the 0.5 threshold recommended by Fornell and Larcker [36].

Table 1. Construct reliability and validity.

Item	Factor loading	AVE	CR	Cronbach's alpha
Supply chain digitalization		0.761	0.927	0.983
SCD1	0.972			
SCD 2	0.969			
SCD 3	0.973			
SCD 4	0.987			
Supply chain responsiveness		0.644	0.878	0.919
SCRESP1	0.837			
SCRESP2	0.899			
SCRESP3	0.932			
SCRESP4	0.918			
Supply chain resilience		0.665	0.888	0.932
SCRESI1	0.874			
SCRESI2	0.940			
SCRESI 3	0.918			

(*continued*)

Table 1. (*continued*)

Item	Factor loading	AVE	CR	Cronbach's alpha
SCRESI 4	0.915			
Supply chain restoration		0.704	0.905	0.954
SCREST1	0.946			
SCREST 2	0.905			
SCREST 3	0.959			
SCREST 4	0.941			
Supply chain performance		0.618	0.865	0.899
SCP1	0.740			
SCP 2	0.925			
SCP 3	0.933			
SCP 4	0.903			
Pandemic impact		0.516	0.984	0.918
PI1	0.923			
PI2	0.935			
PI3	0.924			

Table 2 shows the correlation coefficients of the constructs, with numbers on the diagonal representing the arithmetic square root of each construct's AVE. The arithmetic square root of each construct's AVE was greater than its correlation coefficients with the other constructs, indicating adequate discriminant validity [36]. In general, the results shown in Table 1 and Table 2 support the measurement model.

Table 2. Mean, standard deviations, and correlations

Variables	Mean	SD	1	2	3	4	5	6
1.Supply chain digitalization	2.64	0.86	**0.873**					
2.Supply chain responsiveness	3.17	0.80	0.418***	**0.802**				
3.Supply chain resilience	3.22	0.66	0.539***	0.493***	**0.815**			
4.Supply chain restoration	3.31	0.70	0.488***	0.537***	0.517***	**0.839**		
5.Supply chain performance	3.08	0.62	0.484***	0.394***	0.507***	0.437***	**0.786**	
6.Pandemic impact	3.42	0.90	0.229**	0.287***	-0.068	-0.036	-0.013	**0.718**

(Note: N = 215. The diagonal elements (in bold) are the square roots of the AVE values. Off-diagonal elements are the correlations among constructs in the model; +p <0.10, *p < 0.05, **p < 0.01, ***p < 0.001)

5.2 Hypotheses Testing

This study used the PROCESS proposed by (Hayes 2017) to validate the hypotheses. The results are shown in Table 3. To test hypotheses 1a, 1b, 1c, 2a, 2b, 2c, we built the mediation model using "Model 4" in PROCESS. Controlling for the firm size, firm age, development stages, and ownership, SCD positively influences supply chain responsiveness ($\beta = 0.40$, $t = 6.54$, and $p = 0.00$), supply chain resilience ($\beta = 0.39$, $t = 8.22$, and $p = 0.00$), and supply chain restoration ($\beta = 0.39$, $t = 7.61$, and $p = 0.00$). Therefore, H1a, H1b, and H1c were strongly supported. H2a, H2b, and H2c tested the mediation effects of supply chain 3Rs on the relationship between SCD and supply chain performance. The results in Table 4 showed that the indirect effects of SCD on supply chain performance through supply chain responsiveness ($\beta = 0.07$), supply chain resilience ($\beta = 0.18$), and supply chain restoration ($\beta = 0.09$) were all significant. Therefore, H2a, H2b, and H2c were supported in this study.

To test H3, PROCESS macro in SPSS with a bootstrapping analysis on default 5000 resamples and 95% CI were used. The regression results were shown in panel A and panel B of Table 5 and 6. The results indicated that the interaction effect between SCD and pandemic impact had a positive effect on supply chain responsiveness ($\beta = 0.20$, $t = 3.47$, and $p = 0.00$), supply chain resilience ($\beta = 0.17$, $t = 3.92$, and $p = 0.00$), and supply chain restoration ($\beta = 0.13$, $t = 2.68$, and $p = 0.01$). Similarly, the interaction term between pandemic impact and supply chain 3Rs had significant and positive impact on supply chain performance, with the $\beta = 0.06$, $t = 1.23$, and $p = 0.22$ for supply chain responsiveness, $\beta = 0.11$, $t = 2.30$, and $p = 0.02$ for supply chain resilience, and $\beta = 0.16$, $t = 3.15$, and $p = 0.00$ for supply chain restoration. The regression results of the conditional indirect influence of SCD on supply chain performance through supply chain 3Rs are reported in Table 7. The findings indicated that the mediation effects of supply chain 3Rs on the relationship between SCD and supply chain performance was stronger when pandemic impact was higher. Therefore, H3 was also supported in this study.

Table 3. Regression results for H1a, H1b, and H1c

Variables	Supply chain responsiveness			Supply chain resilience			Supply chain restoration		
	β	T	p	B	T	p	β	T	p
Constant	2.25	8.28	**0.00**	2.02	9.69	0.00	2.13	9.39	0.00
Firm size	0.07	0.81	**0.42**	0.08	1.23	0.22	0.10	1.42	0.16
Firm age	−0.07	−1.01	**0.31**	−0.02	−0.33	0.75	−0.02	−0.27	0.79
Development stage1	−0.07	−0.37	**0.71**	0.03	0.20	0.84	0.04	0.25	0.81
Development stage2	−0.20	−1.08	**0.28**	0.11	0.73	0.46	−0.01	−0.06	0.95
Development stage3	−0.05	−0.30	**0.77**	0.22	1.69	0.09	0.18	1.25	0.21
Ownership	−0.23	−1.15	**0.25**	0.04	0.25	0.81	−0.12	−0.73	0.46
SCD	0.40	6.54	**0.00**	0.39	8.22	0.00	0.39	7.61	0.00
R^2	0.19			0.31			0.26		
F	8.02***			13.19***			10.40***		

(Notes: *p < 0.05,**p < 0.01,***p < 0.001).

Table 4. Regression results for H2a, H2b, and H2c

Variables	Supply chain performance			Supply chain performance			Supply chain performance		
	β	T	p	β	T	p	β	T	p
Constant	1.83	8.00	0.00	1.32	6.06	0.00	1.75	7.41	0.00
Firm size	−0.03	−0.54	0.59	−0.06	−1.01	0.31	−0.04	−0.71	0.48
Firm age	0.03	0.65	0.52	0.03	0.61	0.54	0.02	0.47	0.64
Development stage1	−0.13	−0.97	0.33	−0.16	−1.27	0.20	−0.15	−1.14	0.26
Development stage2	−0.19	−1.40	0.16	− 0.27	−2.20	0.03	−0.22	−1.66	0.10
Development stage3	0.04	0.28	0.78	−0.07	−0.64	0.52	−0.01	−0.12	0.91
Ownership	−0.09	−0.60	0.55	−0.15	−1.10	0.27	−0.10	−0.69	0.49
SCD	0.28	5.64	0.00	0.17	3.70	0.00	0.26	5.15	0.00
SCRESP	0.18	3.53	0.00						
SCRESI				0.45	7.45	0.00			
SCREST							0.23	3.78	0.00
R^2	0.30			0.42			0.31		
F	10.92***			18.17***			11.22***		
Indirect effect	0.07			0.18		z	0.09		
95%CI	[0.03, 0.12]			[0.11, 0.26]			[0.04, 0.16]		

(Notes: *p < 0.05, **p < 0.01, ***p < 0.001).

Table 5. Regression results for moderation effect of pandemic impact (Panel A)

Variables	Supply chain responsiveness			Supply chain resilience			Supply chain restoration		
	β	T	p	β	T	p	β	T	p
Constant	3.11	5.47	0.00	3.75	8.41	0.00	3.44	6.90	0.00
Firm size	0.14	1.64	0.10	0.09	1.43	0.16	0.11	1.55	0.12
Firm age	−0.09	−1.40	0.16	−0.04	−0.82	0.41	−0.03	−0.60	0.55
Development stage1	−0.01	−0.07	0.95	0.01	0.01	0.98	0.02	0.11	0.91
Development stage2	−0.19	−1.08	0.28	0.06	0.42	0.67	−0.04	−0.29	0.77
Development stage3	0.01	0.06	0.95	0.17	1.33	0.18	0.14	0.99	0.32
Ownership	−0.14	−0.73	0.47	0.08	0.52	0.60	−0.09	−0.55	0.58
SCD	−0.26	−1.39	0.17	−0.17	−1.10	0.27	−0.03	−0.19	0.85
PI	− 0.28	−1.82	0.07	− 0.52	−4.34	0.00	−0.39	−2.93	0.00
SCD*PI	0.20	3.47	0.00	0.17	3.92	0.00	0.13	2.68	0.01
R^2	0.29			0.37			0.29	z	
F	9.26***			13.23**			9.30***		

(Notes: *p < 0.05, **p < 0.01, ***p < 0.001).

Table 6. Regression results for moderation effect of pandemic impact (Panel B)

Variables	Supply chain performance			Supply chain performance			Supply chain performance		
	β	T	p	β	T	p	β	T	p
Constant	2.67	5.14	0.00	2.67	4.32	0.00	3.81	5.71	0.00
Firm size	− 0.04	−0.77	0.45	−0.04	−0.72	0.47	−0.04	−0.62	0.53
Firm age	0.03	0.59	0.56	0.02	0.35	0.73	0.01	0.13	0.90
Development stage1	−0.13	−0.98	0.33	−0.16	−1.31	0.19	−0.20	−1.53	0.12
Development stage2	−0.19	−1.41	0.16	−0.26	−2.11	0.04	−0.27	−1.99	0.05
Development stage3	0.02	0.18	0.86	−0.05	−0.45	0.65	−0.05	−0.44	0.66
Ownership	−0.08	−0.57	0.57	−0.13	−0.96	0.34	−0.05	−0.38	0.71
SCD	0.27	5.51	0.00	0.17	3.68	0.00	0.25	4.91	0.00
SCRESP	0.02	0.12	0.90						
SCRESI				0.05	0.25	0.80			
SCREST							−0.32	−1.75	0.08
PI	−0.27	−1.86	0.06	−0.36	−2.33	0.02	−0.59	−3.29	0.00
SCRESP *PI	0.06	1.23	0.22						
SCRESI*PI				0.11	2.30	0.02			
SCREST*PI							0.16	3.15	0.00
R^2	0.32			0.43			0.34		
F	9.62***			15.33***			10.45***		

(Notes: *p < 0.05, **p < 0.01, ***p < 0.001).

Table 7. Conditional indirect effect of supply chain digitalization on supply chain performance at different levels of pandemic impact

Mediators	Condition of pandemic impact	Indirect effect	Bootstrapped SE	95%CI
Supply chain responsiveness	Low (−1SD)	0.04	0.02	[0.01, 0.09]
	Mean	0.09	0.02	[0.05, 0.14]
	High (+1SD)	0.15	0.05	[0.07, 0.25]
Supply chain resilience	Low (−1SD)	0.09	0.04	[0.02, 0.18]
	Mean	0.18	0.04	[0.11, 0.27]
	High (+1SD)	0.30	0.07	[0.17, 0.43]
Supply chain restoration	Low (−1SD)	0.03	0.03	[−0.03, 0.09]
	Mean	0.10	0.03	[0.05, 0.17]
	High (+1SD)	0.21	0.05	[0.11, 0.32]

6 Discussion and Conclusions

6.1 Theoretical Implications

Based on the OIPT, we propose and examine the mediation effects of supply chain 3Rs and the moderation effect of pandemic impact during the COVID-19. The empirical results contribute to literature of supply chain management in the digital age from the following three aspects.

First, this study finds that SCD is positively associated with supply chain 3Rs. Past research suggests that SCD involves information generation and collection processes, but the existing literature lacks an understanding of the role of SCD in achieving supply chain risk management [37]. The findings enrich the existing literature of SCD, and respond to the calls of Seyedghorban et al. [7] and Appio et al. [37] to explore how digitalization can enhance supply chain risk management capabilities. Our results contribute to a better understanding of the integration of the advanced SCD and its significant effect on firms' supply chain 3Rs capabilities development.

Second, this study proposes and investigates the mediating roles of supply chain 3Rs serving as the underlying mechanisms through which SCD affects supply chain performance. The increasingly frequent supply chain disruptions have led to calls for more empirical research on supply chain 3Rs to help firms survive through the difficult times. In this study, we clarify supply chain risk management capabilities from three different aspects, that is responsiveness, resilience, and restoration. The empirical findings extend the existing research of the supply chain 3Rs and identify the 3Rs as the mediating roles which explain why investment in SCD is likely to improve supply chain performance.

Finally, this study indicates that pandemic impact positively moderates the indirect effect of SCD on supply chain performance through supply chain 3Rs. To the best of our knowledge, empirical research on the pandemic impact as a moderating factor in the field of supply chain management is limited. Our results reveal that, when suffering from the COVID-19 pandemic, firms should not only rely on the information collected by the digitalization infrastructure but also build higher-order information processing capabilities and stabilization mechanisms, i.e., supply chain 3Rs, to utilize and transform the collected information, thereby realizing higher supply chain performance. Overall, SCD and supply chain 3Rs play a more critical role during the COVID-19 pandemic.

6.2 Practical Implications

Our empirical results also provide insightful practical implications. Digitalization is promoting firms to update supply chain management strategies and practices. Firms are thus suggested to apply digital supply chain information systems to achieve the sustainable development of supply chains. It should be noted that supply chain management activities in the current turbulent business environment are highly information-intensive. Firms can only gain a competitive advantage if they have access to adequate, accurate, and real-time information. SCD is destined to be one of the most important choices for firms to succeed in supply chain management, especially under the ongoing impact of supply chain disruptions during the pandemic.

Our results further imply that companies should integrate the adoption of SCD into supply chain risk management processes and build supply chain 3Rs capabilities. Previous literature has highlighted the significant value of supply chain risk management capabilities in dealing with the disruption events [38, 39]. This study indicates that supply chain 3Rs play crucial roles in achieving supply chain performance during the crisis.

6.3 Limitations and Future Research

The following are the limitations of this research and the future research directions. First, the data in this study was only obtained from China. Although the outbreak of COVID-19 sweeps through global supply chains, the impact pattern may differ across each country. Therefore, further research is suggested to examine whether the conclusion in this study is applicable to other countries' supply chains. Moreover, we used cross-sectional data to analyze the relationships, and further longitudinal studies are called for to verify the causal relationships dynamically over time. Finally, we only examined the impact of SCD on the supply chain performance. Other aspects of performance, such as financial performance, innovation performance, etc. can be considered in the future research.

Appendix. Measurement Items

Supply Chain Digitalization

(1) The proportion of suppliers that our firm transacts with and collects real-time information from through digital supply chain systems, such as the Internet of Things, artificial intelligence (AI), cloud computing, and big data analytics, etc.
(2) The proportion of transaction volume and activities that our firm conducts with our suppliers through digital supply chain systems, such as the Internet of Things, artificial intelligence (AI), cloud computing, and big data analytics, etc.
(3) The proportion of customers that our firm transacts with and collects real-time information from through digital supply chain systems, such as the Internet of Things, artificial intelligence (AI), cloud computing, and big data analytics, etc.
(4) The proportion of transaction volume and activities that our firm conducts with our customers through digital supply chain systems, such as the Internet of Things, artificial intelligence (AI), cloud computing, and big data analytics, etc.

Supply Chain Responsiveness

(1) Our supply chain can make full preparations and effectively handle the difficult nonstandard orders.
(2) Our supply chain can make full preparations and quickly meet special customer specification.

(3) Our supply chain can make full preparations and rapidly adjust production capacity in response to changes in customer demand.
(4) Our supply chain can introduce large numbers of product improvement quickly to deal with the unforeseen demands.

Supply Chain Resilience

(1) Material flow would be quickly recovered.
(2) It would not take long for our supply chains to recover normal operating performance.
(3) The supply chain would easily recover to its original state.
(4) Supply chain disruptions would be dealt with quickly.

Supply Chain Restoration

(1) Our supply chain can restore operations and grow to a more desirable state quickly and effectively when faced with supply chain disruption.
(2) Our supply chain can redesign the structure to a more desirable state quickly and effectively when faced with supply chain disruptions.
(3) Our supply chain can restart operations to a more desirable state reliably when faced with supply chain disruption.
(4) Our supply chain can transform the customer value to a more desirable state easily when faced with supply chain disruption.

Supply Chain Performance

(1) The costs of per unit of goods and service are lower than our competitors.
(2) Our supply chain can deliver goods and service more punctually than our competitors.
(3) Our supply chain can deliver goods and service more reliably than our competitors.
(4) Our supply chain has a shorter lead time for order fulfillment than our competitors.

Pandemic Impact

(1) The extent of the impact of the pandemic on the supply chain's overall operating efficiency.
(2) The extent of the impact of the pandemic on the customers' order fulfillment.
(3) The extent of the impact of the pandemic on the procurement from suppliers.

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An Investigation into the Impact of Digitalisation on Open Innovation via Supply Chain Relationship Capital

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Abstract. Open innovation and digitalisation are prevalent practices in modern age, and it is widely believed that the former can be better supported by the latter, due to the innovative and collaborative nature of some of digital technologies. However, our understanding of theorising and delineating their relationship in extended supply chain networks is lacking in existing literature. Using technology affordance theory, this study identifies three types of digital affordances, that is, affordance for value co-creation, affordance for relationship building, and affordance for strategic learning, and develops a conceptual framework by integrating with three inter-related areas to shed new light onto the digitally enabled open innovation in supply chain relationships. Our findings indicate that digital affordances positively affect supply chain relationship capital, and then increased supply chain relationship capital can mitigate barriers and challenges associated with open innovation, thus increasing their occurrence and success rate.

1 Introduction

Today's intensive competition significantly incentivises firms to pursue innovation, enabling firms to grow and prosper. One prominent phenomenon related to innovation is open innovation, which uses purposive knowledge inflows and outflows to expedite innovation and commercialise external innovation (Chesbrough et al. 2006, Chen et al. 2011, Chesbrough and Bogers 2014). This paradigm considers Research and Development (R&D) as an open system, and assumes that valuable ideas can be sourced internally and externally. Innovation can then be available to market via external channels, from inside or outside the firm. One telling example is that Procter and Gamble (P&G) stipulate to obtain 50% of the products and technologies from outside the firm (Huston and Sakkab 2006). These sources include, amongst others, suppliers, universities, and consumers. As a particular form of co-creation, open innovation can be facilitated using digital technologies (Loureiro et al. 2020). For instance, depending on its collaborative digital platform, Nike works on process and product innovation along with its suppliers (Shen et al. 2021).

At the same time, the past decade has witnessed the increasing interest in open innovation from academic and practitioners alike. Briefly, there are studies looking at

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trade-offs of open innovation (e.g., Foege et al. 2019, Lauritzen and Karafyllia 2019, Ritala and Stefan 2021), sources of knowledge and factors in open innovation (e.g., Billington and Davidson 2013, Mubarak and Petraite 2020, Kafouros and Forsans 2012), and the impact of open innovation on firm performance (e.g., Wang et al. 2015, Hameed et al. 2021, Ebersberger et al. 2021, Stefan and Bengtsson 2017). There are also studies pointing out that the digital supply chain can promote the open innovation by including suppliers and users in the product development (Reeves et al. 2011, Chavez et al. 2017). Recent studies such as Dahlander et al. (2021) noted that technological trends raise new questions in open innovation domain. According to the scholars, technologies play an important role in open innovation as the technologies have advanced to generate and analyse large quantities of data, mediate diverse interaction, automate decision making and expand knowledge search. Nevertheless, contributions on theorising how and why open innovation could be facilitated with the increasing adoption of digitalisation are limited.

In the meantime, it is worth noting that with the pervasiveness of digitalisation in the business landscape, the way firms do business and build their relationship with partners accordingly changes (Handfield 2019). For manufacturers, they have benefitted from the transparency to all manufacturing factories due to the integration of computer network, data integration, and analytics (Lee 2015). It enables manufacturers to enhance their supply chain relationships (hereafter referred to as SCR) with other entities to co-create in integrated platforms (Tian et al. 2021). Above changes the feature of SCR from a transactional approach towards a value co-creation model (Xu et al. 2018). Against this background, how digitalisation could empower open innovation is a significant and trendy topic, as supply chain partners recognise the increasing importance of a value co-creation model in the digital economy. To address above-mentioned gap and investigate the phenomenon of interest, the intriguing research question we intend to explore is how does digitalisation affect open innovation through reshaping SCR? This investigation deserves further research attention. On one hand, digitalisation paves the way towards digital data translation into knowledge (Barney et al. 2001) and increased transparency and effective decision making (Ness et al. 2015). On the other hand, the pre-conditions do not guarantee the success of open innovation when various supply chain stakeholders are involved.

To disentangle the above research question, literature review of three concepts were conducted, and their interrelations were untangled from the theoretical lens of technology affordance theory and social capital theory. Affordance theory is extensively utilised to explore the role of particular technological artefacts in organisational contexts. Meanwhile, with affordance perspective, users, their intentions and capabilities when dealing with the material properties and features of technological artefacts are also taken into account (Lehrer et al. 2018, Du et al. 2019, Krancher et al. 2018, Dremel et al. 2020). To put it differently, even though with the same digital artifacts, different users may perceive distinct affordances from the use. In the meantime, recent studies have pointed out that lower-order or basic affordances could lead to higher-order affordances (ibid). The concept of social capital has attracted increasing attention in the buyer-supplier relationship domain. It is because social capital can provide a valuable and rich viewpoint to explain and theorise the nature and characteristics of cooperation and connections in the

relationship (Krause et al. 2007, Carey et al. 2011, Roden and Lawson 2014). In addition, social capital can explain and predict multiple important behaviours and outcomes in the relationships due to the accumulated goodwill between buyer and supplier (Villena et al. 2011, Lawson et al. 2008).

In this study, digital affordance stems from technology affordance, which can be defined as action potential or possibilities to users when they interact with modern digital technologies, such as the Internet of things, social media, big data analytics in particular circumstances (Vial 2019, Markus and Silver 2008, Gibson 2014). It has been widely recognised that digitalisation has made organisations more collaborative with their stakeholders (e.g., customers and suppliers etc.). For instance, with the establishment of an integrated platform, manufacturers can enhance their SCR with other firms for value co-creation (Tian et al. 2021). By taking advantage of digital affordance, digital technologies provide numerous opportunities to rethink how to manage supply chain relations, data and knowledge management, and new ways of connecting potential customers and partners. Consequently, strategic SCR can be developed and open innovation with external collaborators can be facilitated, which represents increasing value in today's highly competitive and turbulent business environment. Specifically, in line with technology affordance theory, three types of digital affordances are identified herein: affordance for value co-creation, affordance for relationship building, and affordance for strategic learning.

These three types of digital affordances identified herein are seen as higher-order affordances, which could be actualised with the lower-order affordances. For instance, business analytics affordances can be lower-order affordances, which creates favourable conditions to realise higher-order decision making affordances (Cao and Duan 2015). Affordance for value co-creation refers to as digital affordances that provides individuals opportunities to cocreate value with others through accessing and harnessing external knowledge and resources. Affordance for relationship building denotes that this affordance allows firms to develop and maintain business relationships in supply chain networks mediated by various digital channels. Affordances for strategic learning account to empowering individuals the capabilities to learn from external sources and transform data and knowledge etc. into actionable intelligence.

Though a technology-mediated business contexts through digital affordance provides a fruitful breeding ground for firms to achieve their goals, research efforts on the effect of digitalisation on firms' open innovation initiatives and their outcomes are scanty. As such, we attempt to integrate with relevant scholarship to elucidate how firms could build SCR capital with digital technologies in their pursuit of open innovation initiatives. In other words, we contribute to social capital theory by including relationship capital with open innovation in digitalised business setting and form new relationships among them. In a nutshell, our study offers novel theoretical understanding by connecting three interrelated research streams and produces a conceptual framework to explain the digitally enabled open innovation phenomenon.

This study extends the literature in three aspects. Firstly, we have pointed out that digitalisation driven by a multitude of innovative digital technologies can create three kinds of affordances and they could be positively related to the creation of SCR capital. After this, a conceptual framework of open innovation is developed, which incorporates

SCR capital as a driver. Third, the interconnections are developed by linking relationship capital in the supply chain context to digitalisation and open innovation, therefore, extending the research discourse on social capital. In addition, managerial implications are offered to practitioners alike. The findings could enrich their managerial knowledge of innovation performance by tapping into their SCR capital and carrying out open innovation initiatives in their digitalisation trajectories. By developing a deep understanding of the three interrelated constructs, we responded to Doh et al's (2019) call for research on management phenomena due to the fundamental changes in current business environment brought by technological and societal trends, such as artificial intelligence, digitalisation, open innovation and globalisation. And it is also responding to the call of Chesbrough and Bogers (2014) and Bogers et al. (2017) for more research on the context-dependency of open innovation.

2 Research Propositions

In terms of the effect of affordance for value co-creation, according to the Babu et al. (2020) "value co-creation represents the collaboration amongst a range of firms and their stakeholders (i.e., actors) in developing successful innovations, design and developing products, and identifying new business opportunities" (p. 16). With this type of digital affordance, participants can devote certain amount of information and knowledge to the transactions (Storbacka et al. 2016). Furthermore, such interactions amongst various stakeholders form the basis for innovations to be diffused to broader business communities (Windrum et al. 2016). Arguably, this digital affordance allows for constant interactions, resource integration amongst stakeholders, and customers could become a valuable source of value creation in the supply chain, and thus reshapes buyer-supplier relationships. This argument is in line with Zhang and Xiao (2020), who suggested that to effectively understand and meet customer needs, customers can be involved as a role of Data Analyst rather than mere data providers, this is especially suitable in the B2B business context given the complexities and uncertainties of customer problems. These practices associated with relationships could create social capital value (Lombardo and Cabiddu 2017, Martineau and Arsel 2017). Therefore, we present the proposition below.

Proposition 1: *Affordance for value co-creation positively affects SCR capital.*

In terms of the effect of affordance for relationship building, firms could widen and enhance potential and existing stakeholder relationships to help with their strategic goals. For example, Kohtamäki et al. (2019) highlights the need for interorganisational collaboration to develop smart autonomous ecosystems due to the existence of smart product-service systems. Besides, supply chain structures are found to be modified. Dalenogare et al. (2018) provided the evidence that digital technologies could generate heaps of data, and can play a role in building internal (vertical integration) and external (horizontal integration) connections. It is believed that these collaborative opportunities are essential for stakeholders and firms to carry out coordinated conversations, which in turn serve as a major contributor to the development of collective wisdom and thinking. Hence, we present the following proposition.

Proposition 2: *Affordance for relationship building positively affects SCR capital.*

As regards the effect of affordance for strategic learning, it implies that firms can be empowered to access and accumulate knowledge resources and convert such assets into strategic behaviour and actions. On one hand, digital technologies such as cloud computing can reduce the experimentation costs. On the other hand, to extract more value from digitalisation, firms are encouraged to convert data, experiences and other strategic assets into the organisational fabric. A good example is that firms can enrich their understanding of supplier and buyer behaviours and their across-organisational relations when business intelligence is combined with the use of traditional ERP system. As such, the following proposition is developed.

Proposition 3: *Affordance for strategic learning positively affects SCR capital.*

Scholars have highlighted the value of interfirm relationship in collaborative innovation; however, they tend to overlook of role of digitalisation in related research discourse. When supply chain entities increase their collaboration level and the implementation of digitalisation on the firm and their supply chain level, a data sharing system with security and openness across firm boundaries can engender open innovation (Bär et al. 2018). It is also observed by these scholars that firms will prefer open innovation and engage in it when they could obtain new data sources or partner with new entities.

Meanwhile, despite the value of open innovation in the supply chain context, notable challenges exist. To be specific, four primary barriers are identified in the existing literature. They are 1) different technologies adopted by the entities, especially in the case involving suppliers and clients (Peitz and Shin 2013); 2) the difficulty to develop trust-based relationships among supply chain partners (Zimmermann et al. 2016); 3) certain supplier-client contracts that produce negative impact on innovation performance (Wang et al. 2011); 4) unsuccessful attempts for focal firms to integrate knowledge (Narasimhan and Narayanan 2013). We argue that relationship capital can help to mitigate these challenges, increase the occurrence and success rate of open innovation. For example, with increased SCR capital among partners, trust and goodwill will be salient in their relationships. Thereby, two propositions are presented.

Proposition 4a: *SCR capital positively affects the occurrence and success of OI.*

Proposition 4b: *The relation between SCR capital and OI performance could be moderated by the maturity level of digitalisation.*

In sum, the conceptual framework (see Fig. 1) is developed to show how digitalisation exerts an impact on open innovation via SCR capital. This work contributes to literature on social capital perspective by exploring the relationship that exists between digital affordances of innovative technologies and SCR capital. The above propositions clearly delineate SCR capital can be created via the use of digital technologies, and then increased SCR capital mitigates the barriers and challenges encountered in collaborative innovations within the supply chain network. As a result, it could be reasonably assumed that occurrences and the success of open innovation can be promoted.

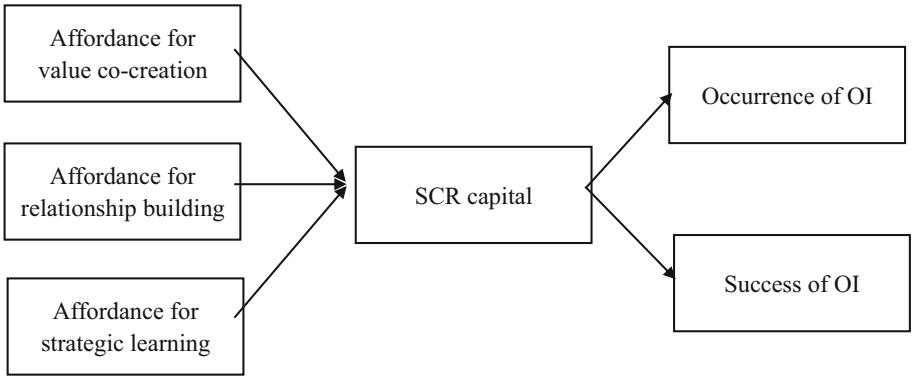

Fig. 1. Conceptual framework

3 Conclusion

To conclude, we provide a holistic picture of the inter-related, yet not thoroughly covered research domains, looking at the interplay between digitalisation, social capital, and open innovation. We interpret the role of digitalisation from technology affordance perspective and propose three types of digital affordances that can be beneficial to create relationship capital as firms engage in open innovation activities in an extended supply chain network. The main contribution of this work is to propose a conceptual framework through the lens of affordance theory and social capital theory. The study presents affordance for value co-creation, affordance for relationship building, and affordance for strategic learning. The findings point out that digital affordances positively affect SCR capital, which can further increase the open innovation occurrence and success, during which the maturity level of digitalisation could moderate this process.

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Are Corporate Social Responsibility (CSR) Disclosure High Performers Authentic? - Perspective from Supply Chain Cash Conversion Cycle (CCC)

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Abstract. Although with significant momentum in quantity for over ten years, Chinese firms' CSR disclosures have been criticised as low comparability, content quality and reliability. The situation reveals that Chinese CSR disclosure may be in an institutionalised box-ticking fashion, and consequently, the questionable CSR authenticity. Thus, this study tries to empirically consider whether CSR disclosure high performers are authentic and really responsible supply chain members. The study defines the supply chain egocentrism index, calculated as the ratio of the Focal firm's cash conversion cycle (CCC_{FF}) to the sum of Suppliers' CCC (CCC_S) and Customers' CCC (CCC_C), as the proxy for the extent of the firm's CSR inauthenticity. It shows the focal firm's egocentrism in winning finance advantages by suppressing other supply chain stakeholders' welfare. Four quadrants of CSR authenticity are identified based on the discrepancy between CSR disclosure score and the egocentrism index: questionable authenticity, grey zone, authentic CSR and silent saint. By comparing features between firms in different quadrants, the study provides a new angle to view the relationship between CSR ratings and corporate features considering CSR authenticity and supply chain network settings. The preliminary result shows that firms located in the first quadrant with questionable authenticity are statistically larger in firm size, especially than truly CSR authentic firms in the third quadrant and forth quadrant. The higher tendency of possibly abused CSR marketing for larger firms calls for a more substantial evaluation and related research on the CSR process performance and authenticity.

Keywords: Corporate Social Responsibility · CSR authenticity · Supply chain finance · Cash conversion cycle

1 Introduction

As one of the most heated research topics during recent decades, CSR (i.e. Corporate Social Responsibility) can be well-acknowledged difficult to define due to the broad,

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complex and diverse nature of an area [1]. Aguinis [2] proposed a widely adopted academic definition: "*context-specific organisational actions and policies that take into account stakeholders' expectations and the triple bottom line of economic, social, and environmental performance*." [3–5]. Based on that, CSR can be regarded as social relationships the organisation constructed to communicate with different stakeholders according to the different institutional environments. While the world is still experiencing the aftershocks of COVID-19, research on CSR calls for the shift on conceptualising CSR from an individual to a societal one and redefining business's social responsibilities from a "systemic perspective" [6]. Extant studies on CSR in supply chain management emphasise the consideration of triple bottom line on a chain base [7] and show that mutual trust and reciprocity with upper- and down-stream partners nurtured by focal firm's CSR engagement will improve long-term relationship and supply chain performance [8–11].

While research processes had been made in addressing all kinds of CSR-related topics [1], the consideration of CSR authenticity tends to be relatively neglected [12]. To fill this gap, we borrowed the supply chain finance factor: Cash Conversion Cycle (CCC), which stands for days that a firm takes to convert its inventory into cash flows; and constructed the focal firm egocentrism index to show the focal firm's egocentric extent and the possible imbalance power distribution along the supply chain. The longer the focal firm's CCC days, relatively to its first layer suppliers and customers, the higher the possibility of winning finance advantages by suppressing their most closed supply chain stakeholders' welfare. Thus, the study would like to explore questions like how can we determine the authenticity of a firm's CSR behaviour? Whether CSR disclosure high performers are authentic and truly responsible supply chain members? Do the firms that veil their CSR authenticity share some similarities?

China is an ideal focus to explore the issues of interest because of its very different political institutions and its increasingly global importance in recent years [13–15]. Authorities like the China Securities Regulatory Commission (i.e., CSRC), Shanghai Stock Exchange (i.e., SSE) and Shenzhen Stock Exchange (i.e., SZSE) have issued progressive guidelines and initiatives continuously since 2006. However, the consequent significant momentum in CSR reports quantity tends to be an institutionalised response [16, 17], as Chinese firms' CSR disclosures have been criticised as low comparability, content quality and reliability. The situation reveals that Chinese firms' CSR disclosure may be in an institutionalised box-ticking fashion, and consequently, their CSR authenticity should be questioned.

With the help of the focal firm egocentrism index, the study constructed the CSR Rating – Supply chain egocentrism index matrix as a conceptual model and identified four quadrants of firm CSR authenticity based on the discrepancy between these two axes: questionable authenticity, grey zone, authentic CSR and silent saint.

The ANOVA result shows that, among firms located in four quadrants, there is statistically significant differences for firm size in terms of revenue, total assets or the number of employees, which means firms located in the first quadrant (questionable authenticity that with a higher level of CSR rating and a higher level of egocentrism) are statistically larger in size, especially than truly CSR authentic firms in the third quadrant.

The preliminary result of this study shows the possibly abused CSR marketing, especially for firms in a larger size, which calls for a more substantial evaluation and related research on the CSR process performance and authenticity. With the help of the matrix,

the study may provide strategic aspects for business actors to mitigate the painstaking trade-off between economic target and implementation of responsible supply chain management, provide suggestions in promoting firms' CSR authenticity and restoring their credibility among supply chain stakeholders. The research may also provide some practical tools for governments and stock exchanges to consult on promoting responsible supply chain and the social accountability environment regulations or guidelines in the future.

2 Literature Review

2.1 The Institutionalised CSR Disclosure in China

The literature search shows mainstreams of CSR strategy conceptual lenses including stakeholder theory, institutional theory and legitimacy theory, are well discussed in consideration of the antecedents and outcomes of CSR, firm strategy implementations and theoretical framework as well [18–20]. For CSR disclosure specifically, the widely used signaling theory provides a perspective for firms' motivation to issue CSR reports and the like, especially voluntarily, to send their ethical nature to the target audience [21, 22].

Defining CSR can be well-acknowledged difficult due to its broad, complex and diverse nature in terms of conceptual contents, stakeholder parties and structure [1]. However, CSR's essence-be responsible for and pay back the society - is never new to a Chinese businessman [23–25], like the Taoism's idea of "*harmonious between nature and human society*" is rooted deeply in the Chinese culture and well-captured by national policies and rubrics [26] that implemented till today. Although being accused of diverting from the traditional moral and focusing on the sole economic target [26, 27], the Chinese business environment had actively adopted and responded to official initiatives by the ever-increasing CSR reports since 2006 (Fig. 1.).

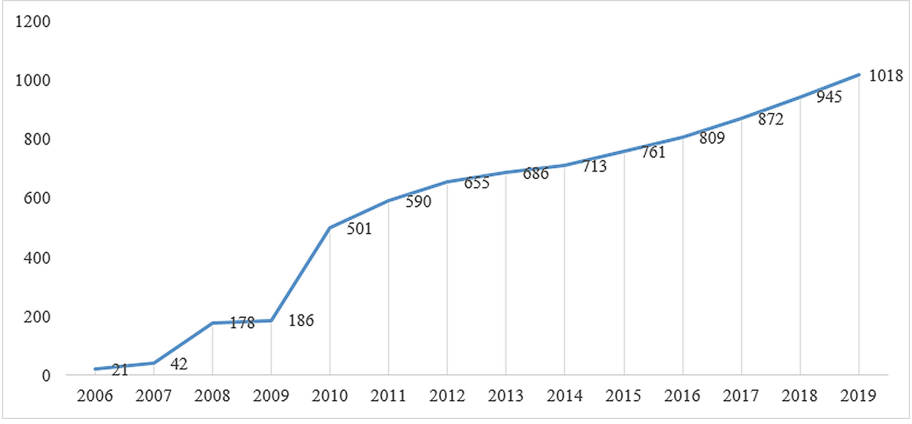

Fig. 1. The number of listed firm issued CSR reports each year during 2006–2019. (Data source: CSMAR: China listed firm's corporate social responsibility research database).

Due to the "soft" or implicit coercive pressure of promoting CSR disclosure from CSRC, SSE and SZSE, which reflected by avoiding terms like "regulations" or "policies" in most CSR disclosure initiatives; Instead, the frequently used terms are "guidelines", "opinions", "should", "encouraged" and "recommended practices" [16]. Although mandatory CSR reporting initiatives for certain firms are issued, not yet one non-compliance behaviour has received formal stipulated sanction [28]. Compared with the significant momentum in quantity, Chinese firms' CSR disclosure quality has been suffered from criticisms like lacking assurance by authorities, the avoidance of negative events and the repeats of monotonous summary and bromidic boast [27–30].

The proliferation in quantity while relatively low in quality for Chinese firm's CSR disclosure together show that Chinese firms' CSR disclosure tends to be an institutional pressure [17, 31] and maybe in "a box-ticking fashion" [32].

2.2 The Decoupling of CSR Talking and Walking

Predicted by the institutional theory, decoupling can result from corporates adopting institutionalised management practices like CSR, which means "what the firm says/looks" may not be coupled with "what the firm does" [33]. The existence of business misconducts, or CSiR (Corporate Social Irresponsibility), leads to increased amounts of finer-grained CSR analysis in recent years [34–36].

Delmas and Burbano [37] systematically reflected the decoupling of these two dimensions using a typology that categorised firms into four quadrants according to their environmental performance and communication. Under this typology, silent green means the firm with actual high environmental performance but keeps a low communication level. In contrast, a firm is greenwashing means it disseminates fraudulent information to cultivate its responsible image. The firm with high-high performance and communication can be called "vocal green", and Silent Brown with low-low performance and communication.

The decoupling of "walking" and "talking" leads to suspicion about the firm's CSR authenticity [16]. The definition normally means how real or genuine a firm's CSR practices are [12, 18]. Two mainstream measurements for CSR authenticity in existing literature are concluded here as the perceived authenticity and the represented authenticity.

The perceived CSR authenticity ("CSR talking") refers to the audience evaluation of CSR authenticity based on the publicly available information provided but also maybe "manipulated" by the firm itself [38]. For example, the perception of CSR authenticity by customers [12], employees [39] or other stakeholders [40]. Marquis and Qian [16] used the CSR overall score issued by the third party (Rankins) and the disclosure coverage as the measurement of "CSR Substantiveness" can be a mixed-up of the perceived authenticity with the substantive one. Because the perceived CSR authenticity relates closely to the ways of disclosure [38, 41]; with the possibility that the message/practice can be *real* (authentic), but the firm fails to deliver it effectively and causes the disclosure to seem implausible for the audience or the other way around: highly effective disclosure and wording may cover the inauthentic message and still be perceived as credible for the audience without sufficient information. Thus, the increasing number of CSR disclosure may also increase the risk of "greenwashing" instead of substantiating responsible actions [42–44].

The material CSR authenticity ("CSR walking") concluded by this study has widely appeared as the firms' actual/substantive behaviours or practices as the reflections of CSR intention and authenticity. Like the scandals of corporate social irresponsibility (i.e. CSiR) [34], charitable giving [45] and financial adjustments like tax aggressiveness or earning management [35, 36, 46].

This study defines CSR authenticity as the consistency between the firm's perceived CSR and material CSR, emphasising the detection of possible oversell or strategic silence [47] of what the firm actually did. The existence of decoupling and questions about the CSR authenticity reflect certain disorders in several societal layers, like the institutional voids [48, 49], immature business environment and the unified market recognition [50], and the opportunism of corporate symbolic CSR disclosure [37, 38, 44], which leads to profound negative effects on social accountability and confidence on CSR [37], and for the firm itself credibility along the supply chain.

2.3 The Typology of CSR Authenticity

Cash conversion cycle (i.e., CCC) is a term that reflects a firm's liquidity or repayment capability with the nature of transforming forms of capital along the supply chain [51], see Fig. 2. from Wetzel and Hofmann [52], which made it an ideal index to consider partner relationships in terms of working capital management and network analysis along the supply chain [52]. Multiple studies about a firm's inter-organisational opportunism will be detrimental to the interests of partners and harm exchange performance [53, 54], studies also showed that collaborative practices in working capital management along value chain, a more balanced supply chain position, for instance, will be beneficial for supply chain financial performance and long term relationship [55, 56].

The study defines the supply chain egocentrism index, calculated as the ratio of the focal firm's CCC (CCC_{FF}) to the sum of Suppliers' CCC (CCC_S) and Customers' CCC (CCC_C), as the proxy for the extent of the firm's CSR inauthenticity. It shows the focal firm's egocentrism in winning finance advantages by suppressing the most closed supply chain stakeholders' welfare.

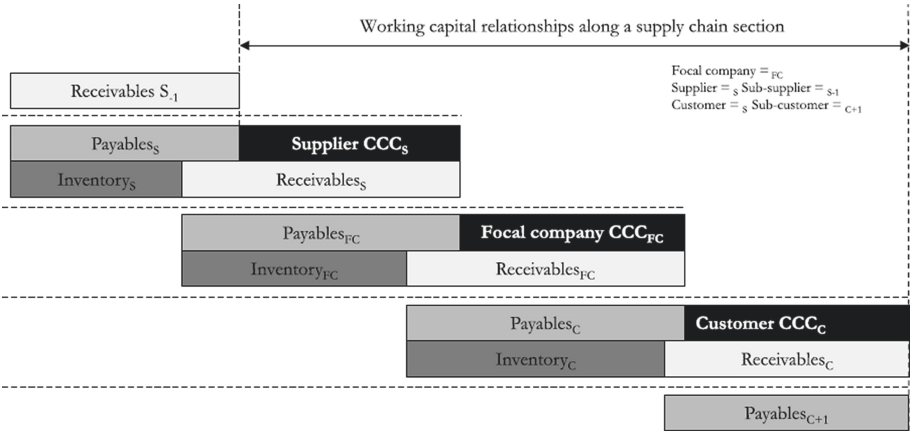

Fig. 2. Supply chain finance-oriented perspective on working capital assets. (Source: Wetzel and Hofmann [52] p. 367)

Based on the idea of firms' typology based on environmental performance and communication proposed by Delmas and Burbano [37], this paper proposed the CSR authenticity typology for Chinese listed firms. Four configurations of CSR authenticity are identified based on the discrepancy between the perceived CSR authenticity and the material CSR authenticity: questionable authenticity, grey zone, authentic CSR and silent saint, see Fig. 3.

CSR Disclosure Score / Firm Egocentrism	High (Above average industrial level)	Low (Below average industrial level)
High (Above average industrial level)	I. **Questionable authenticity** (Questionable motivation for issuing CSR report)	II. **Grey Zone** (Call for more strict governance watch-out)
Low (Below average industrial level)	III. **Authentic CSR** (Doing good and also being good at delivering it)	IV. **Silent Saint** (The enterprise is doing good but does not disclose it effectively)

Fig. 3. The CSR rating – supply chain egocentrism index matrix for CSR authenticity.

The typology can help categorise and analyse firms' authenticity according to the CSR rating level (low-high) and egocentrism level (low-high). When a firm is perceived as a CSR outperformer and tends to suppress its suppliers and customers than its peers, its CSR authenticity should be questioned. And for firm with a relatively low egocentrism index but with a low CSR disclosure quality, the decoupling situation may be due to the firm's inability to deliver its CSR practices to the public. And firms with high quality of CSR report and considerable supply chain responsibility (in terms of working capital) can be regarded as firms with CSR authenticity. The most noteworthy quadrant that calls for more scrutiny is firms with low CSR disclosure quality and also possible supplier partners working capital suppressing behaviour.

The consideration of the supply chain egocentrism index compared with the industry average as benchmarks, the matrix can provide a more fine-grained aspect of firms' governance, which may call for a more substantial evaluation and related research on the CSR process performance and authenticity.

3 Methodology

3.1 Method

The Analysis of Variance (ANOVA), together with *Post hoc* test have been conducting research using various focus groups, identifying and comparing the differences between

groups [57]. In this preliminary study, ANOVA and *Post hoc* test will be conducted to find the shared features of firms located in the same quadrant.

3.2 Measurements

The Perceived CSR Authenticity. Our goal is to examine the consistency between the firm's perceived CSR and material CSR, and the former can be the CSR score provided by the third party. In this study, we collected Rankins CSR ratings (RKS CSR Report Score) of firms listed in Shanghai or Shenzhen Stock Exchange in 2019. Rankins is a Chinese independent rating agency who provides CSR ratings for firms since 2008. Widely used and validated in the past Chinese CSR researches, to name but a few: [28, 31, 58, 59], RKS CSR rating system is regarded as integrated GRI guidelines with China-specific CSR elements [16, 17]. According to the RKS CSR rating methodology[1], the final RKS CSR ratings ranges from 0 to 100 and appears as a weighted score of three dimensions: strategically macrocosm, report content and disclosure techniques that solely according to the CSR reports revealed by firms on their initiatives, which is perfect for serving this study's purpose, especially compared to the CSMAR CSR score which is limited to the CSR report content coverage of a firm.

The Material CSR Authenticity. The calculation of CCC is the sum of days sales outstanding (DSO) and days inventory held (DIH) minus the days payables outstanding (DPO) [51, 60], details can be seen as the following equation.

$$\begin{aligned} CCC_i &= DSO + DIH - DPO \\ &= \left(\frac{Account\ Receivables}{Sales}\right) \times 365 + \left(\frac{Inventory}{Sales}\right) \times 365 - \left(\frac{Account\ Payable}{Sales}\right) \times 365 \\ &= \frac{Account\ Receivables + Inventory - Account\ Payable}{Sales} \times 365 \end{aligned} \tag{1}$$

The boundary for collecting supply chain relationships information and data is limited to the five most important suppliers and customers according to the SPLC data from the Bloomberg Terminal. The consideration of determining the boundary includes both the data availability and analysis feasibility; according to the current guideline[2] on the publicly listed firm accounting disclosure, Chinese firms are not required to disclose their supply chain partners' names and the specific quantified value of their relationships. With the help of three different but complementary sources: company disclosure, mathematically derived and algorithmically derived data, Bloomberg SPLC data has its proprietary quantified information on supply chain network more than any other database. However, the amount of information on average is rather limited in terms of relationship chains in number and relationship values in percentage (see Table 1); extending the network boundary will further decrease the sample size. In such context, weighted averages for

[1] http://www.rksratings.cn/ueditor/php/upload/file/20201101/1604217870886834.pdf.

[2] Standards for the Contents and Formats of Information Disclosure by Companies Offering Securities to the Public No. 2 - Contents and Formats of Annual Reports (2014 Revision), available at: http://www.csrc.gov.cn/pub/csrc_en/laws/overRule/Announcement/201508/t20150816_282862.html.

suppliers and customers CCC, see Eq. (2) and (3), will be used to take the relative importance of each partner and decrease the marginal utility of every additional partnership included [52].

Table 1. Sample focal firm's relationship values in percentage.

	Top 5 Suppliers counted for focal firm's %COGS in 2019	Top 5 Customers counted for focal firm's %Revenue in 2019
Mean	10.22%	17.76%
Min	0.22%	0.45%
Max	73.05%	78.74%
SD	10.22%	17.76%
Sample size	42	

$$WCCCs = \frac{\sum_{i=1}^{n} \%\ COGS_{S_i} \times CCC_{S_i}}{\sum_{i=1}^{n} \%\ COGS_{S_i}} \tag{2}$$

$$WCCCc = \frac{\sum_{i=1}^{n} \%\ Revenue_{C_i} \times CCC_{C_i}}{\sum_{i=1}^{n} \%\ Revenue_{C_i}} \tag{3}$$

The calculation of supply chain focal firm egocentrism index (i.e. *FFEI*) using focal firm's cash conversion cycle (CCC_{FF}), the weighted top 5 Suppliers' CCC ($WCCC_S$) and the weighted top 5 Customers' CCC ($WCCC_C$), can be seen as follows:

$$Focal\ Firm\ Egocentrism\ Index = \frac{CCC_{FF}}{(WCCC_S + WCCC_C)} \tag{4}$$

Firm Size. The first firm feature will be compared in this preliminary study is firm size. Referring to the literature, firm size is measured in different indexes like total assets [61], number of employees [62] and revenue [62, 63]. We used the natural logarithm of revenue as the measurement of firm size, and natural logarithm of employees and total assets are alternative measurements. The overview of variable measurements can be seen in Table 2.

Table 2. Overview of variables

Factor	Variable	Description	Data source
Firm size	lnRev	Defines a focal company's size, in terms of natural logarithm of Revenue	Bloomberg
	lnPPL	Defines a focal company's size, in terms of natural logarithm of Number of employees	Bloomberg
	lnTA	Defines a focal company's size, in terms of natural logarithm of Total assets	Bloomberg
CSR score	CSR rating	Defines the perceived firm's CSR authenticity by the outside audiences	RKS 2019 CSR report score

(*continued*)

Table 2. (*continued*)

Factor	Variable	Description	Data source
CCC	CCC_{FF}	Defines the cash conversion cycle of the focal firm	Bloomberg
	$WCCC_C$	Defines the weighted cash conversion cycle of the focal firm top 5 customers according to the descending order of revenue in percentage	Bloomberg
	$WCCC_S$	Defines the weighted cash conversion cycle of the focal firm top 5 suppliers according to the descending order of COGS in percentage	Bloomberg
Egocentrism index	*FFEI*	Proxy variable for focal firm's egocentrism, defined as CCC_{FF} to the sum of $WCCC_S$ and $WCCC_C$	Calculation

3.3 Sample Selection and Data Collection

Sampling Process. The sample criteria for selecting focal firms of this study including (i) public listed firm with 2019 RKS CSR rating available, (ii) located in industries that have manufacturing and distribution partnerships with suppliers and customers, in this paper, firms listed in the Financial industry, Real estate industry & culture, sports and entertainment industry according to CSRC industrial classification have been omitted, and (iii) with enough supply chain relationships information and data available. The detailed sampling process can be seen in the following table (Table 3).

Table 3. Focal firm sample selection and industry distribution.

Sample selection process	Total
Firms with RKS CSR ratings in 2019 available	942
Firms listed in financial industry, Real estate industry & culture, sports and entertainment industry (CSRC)	(191)
Less than 5 suppliers & customers data available	(701)
Missing at least one factor's value in the fiscal year 2019	(7)
Firm located in one single industry	(1)
Final sample	42
Industry	Sample size
Mining industry	4
Manufacturing industry	27
Industry of electric power, heat, gas and water production and supply	2
Wholesale and retail industry	6
Industry of information transmission, software and information technology services	3
Total	42

The Calculation of WCCC. The suppliers' exposure is based on the descending order of costs of goods sold (COGS in percentage) for a focal firm, which means the procurement amount in weight of the focal firm paid to its suppliers. And accordingly, the exposure of customers is based on the descending order of revenue (in percentage) for a focal firm, which means the sales volume in weight of the focal firm got from its customers. In Bloomberg SPLC data, the relationship value between upper- and downstream companies can be calculated and cross-validated as:

$$\begin{aligned} \textit{Relationship value} &= \%\textit{Revenue} \times \textit{Upperstream company revenue} \\ &= \%\textit{COGS} \times \textit{Downstream company costs} \end{aligned} \tag{5}$$

Although Bloomberg SPLC data also provides two other kinds of relationship types: the total selling, general, and administrative expenses (SG&A), and the total capital expenditures (CAPEX), focal firms' supply chain relationships categorised into these two kinds are omitted to guarantee the only the manufacturing and distribution-related costs along the supply chain used in this study [52]. Thus, each focal firm has top five suppliers and top five customers for a focal firm. Each supplier/customer's and focal firm's CCC data, as well as its accounting data, are collected from the Bloomberg fiscal annual data.

According to the data collected, there are several firms' CCC is negative, the account payable days (DPO) are longer than operating cycle days (DSO + DIH), which means a firm's suppliers and customers are dominant sources of its working capital [64]. Although it seems ideal to lower the working capital costs from a single company perspective [64], negative CCC tends to signal the unbalanced working capital distribution along the supply chain, which not only hurts the supply chain but also brings impacts on the firm itself adversely [65]. In this case, only the focal firm's negative CCCs have been transformed into its absolute value in the egocentrism index calculation to present its meaning better. A summary of CCC statistics is shown in Table 4.

Table 4. Summary of CCC statistics.

Industry	CSR rating		CCC_{FF}		$WCCC_C$		$WCCC_S$	
	(Min, Max)	Mean	(Min, Max)	Mean	(Min, Max)	Mean	(Min, Max)	Mean
Mining industry	(35.23, 74.49)	61.18	(−48.90, 9.0172)	−10.05	(−18.60, 25.024)	1.62	(−3.653, 43.272)	21.75
Manufacturing industry	(27.44, 87.00)	54.38	(−28.33, 171.64)	64.12	(−28.82, 405.74)	91.86	(−33.13, 220.60)	43.16
Industry of electric power, heat, gas and water production and supply	(39.49, 64.04)	51.76	(−17.83, −12.95)	−15.40	(−6.98, 35.982)	14.50	(−45.18, −28.84)	−37.02

(*continued*)

Table 4. (*continued*)

Industry	CSR rating		CCC_{FF}		$WCCC_C$		$WCCC_S$	
	(Min, Max)	Mean	(Min, Max)	Mean	(Min, Max)	Mean	(Min, Max)	Mean
Wholesale and retail industry	(36.53, 62.38)	46.04	(18.72, 167.98)	73.92	(20.41, 148.17)	65.47	(37.48, 145.01)	76.17
Industry of information transmission, software and information technology services	(23.14, 39.67)	33.58	(80.25, 86.68)	83.05	(71.10, 152.32)	112.12	(−281.50, 57.226)	−76.58
Total	(23.14, 87.00)	52.23	(−48.90, 171.64)	56.02	(−28.82, 405.74)	77.26	(−281.50, 220.60)	33.47

Descriptive Analysis. Among all the sample firms, firms in manufacturing industry took for more than half of the total sample size. As for the CSR rating, the mining industry average rating is higher than other industries and the total sample mean. According to the discrepancy between CSR disclosure score and the egocentrism index, sample firms are assigned into four quadrants (descriptions see Table 5).

Table 5. Description of firm size measures for firms in different quadrants

Quadrant	Sample size	Firm size					
		lnRev		lnPPL		lnTA	
		(Min, Max)	Mean	(Min, Max)	Mean	(Min, Max)	Mean
I	6	(10.89, 14.88)	12.22	(9.58, 12.90)	11.40	(10.90, 14.38)	12.12
II	16	(8.86, 14.73)	11.41	(8.43, 13.04)	10.61	(9.27, 14.82)	11.98
III	9	(7.513, 12.72)	9.88	(7.36, 11.82)	9.59	(8.617, 12.60)	10.28
IV	11	(9.128, 12.20)	10.91	(7.98, 11.51)	9.61	(9.285, 12.31)	10.70
Whole sample	42	(7.51, 14.88)	11.07	(7.37, 13.04)	10.24	(8.62, 14.82)	11.30

4 Result and Discussion

The one-way ANOVA test was conducted to compare the factors chosen for firms located in different quadrants. There was a significant effect on firms' size, using revenue as measurement, located in different quadrants at the $p < .05$ level ($F = 4.484$, $p = 0.009$).

Due to the unequal sample size in quadrants [57], we used the Tukey HSD test method for *Post hoc* comparisons. The ANOVA result can be seen in Fig. 4. The comparisons between firm size indicated that the mean value for firms located in the first quadrant ($M = 12.222$, $SD = 1.465$) and second quadrant ($M = 11.412$, $SD = 1.362$) were significantly larger than the firms located in the third quadrant ($M = 9.876$, $SD = 1.594$). However,

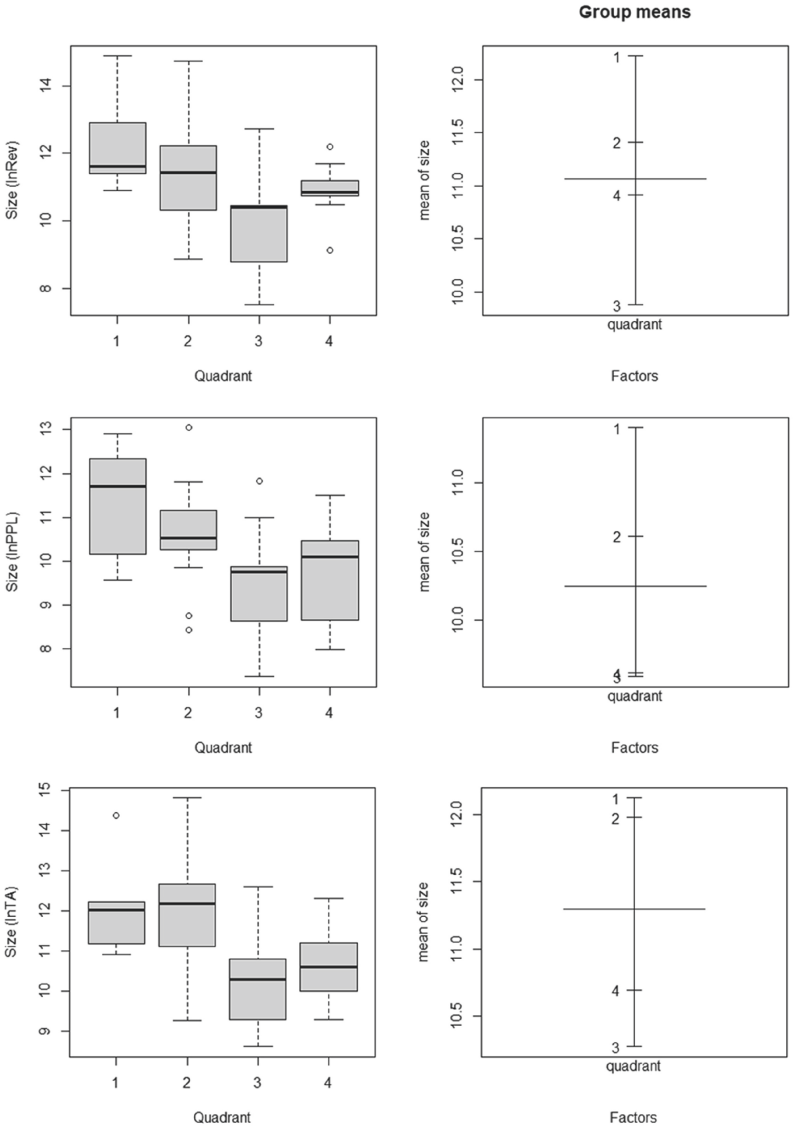

Fig. 4. ANOVA test for firm size

the firms in the first quadrant did not significantly differ in size from firms in the second and fourth quadrant (M = 10.914, SD = 0.771).

We also changed the number of employees and total assets as the alternative measures for firm size as robustness tests, and the results remain the same: firms located in the first quadrant are larger in size than firms in the third quadrant (See Table 6.).

Table 6. ANOVA results and Tukey HSD test *Post hoc* analysis for firm size.

Dependent variable: size	Passed the test for normal distribution	Passed the test for equal variance	ANOVA *p*-value	Quadrants compared	Mean difference value	*SE*
Revenue	Yes	Yes	0.009	1–2	0.810	0.625
				1–3	2.346***	0.688
				1–4	1.308	0.663
				2–3	1.537***	0.544
				2–4	0.498	0.512
				3–4	-1.038	0.587
Number of employees	Yes	Yes	0.011	1–2	0.789	0.575
				1–3	1.813***	0.633
				1–4	1.787***	0.609
				2–3	1.024	0.500
				2–4	0.998	0.470
				3–4	-0.026	0.540
Total assets	Yes	Yes	0.002	1–2	0.145	0.566
				1–3	1.848***	0.623
				1–4	1.427	0.600
				2–3	1.704***	0.493
				2–4	1.282***	0.463
				3–4	-0.421	0.532

*** Significant at .05 level

5 Conclusion

Whereas most Chinese CSR studies applied single-company perspective and also tend to focus solely on whether its payoff in the financial/accounting aspects and the trade-off mentality [50, 66–68], we considered the Chinese firms' CSR authenticity with consideration of supply chain network settings. With the help of the CCC factor from supply chain finance, we constructed the Supply chain egocentrism index as the measurement for firm's CSR authenticity and then a typology to divide firms into four quadrants:

questionable authenticity, grey zone, authentic CSR and silent saint based on a firm's CSR rating (as the perceived CSR talking) and the Supply chain egocentrism index (as the material CSR walking).

The result shows that firms with larger sizes have a higher tendency of decoupling CSR talking and saying: they tend to have relatively higher value of supply chain egocentrism index, a measurement of suppressing supply chain partners' working capital, and CSR rating, a measurement of outsiders' perception on the CSR reports they issued. Thus, their CSR authenticity should be questioned because CSR talking can be one of the possible ways to cover their CSR inauthenticity. This situation is even more significant when comparing firms located in Quadrant I to firms in Quadrant III and IV with higher possibility of authentic CSR. The possible reason may be larger size firms attracted more attention from outside stakeholders, like the government or media. Higher visibility [69] brings higher expectations to these firms while they are not yet or able to doing something good, without enough supervision or clear standard, audience may be distracted by information firms delivered, at the same time, manipulated.

To sum up, the preliminary study is only a first step in analysing CSR authenticity beyond the traditional single-company perspective and represents a starting point for several further studies. Like expending time period, refine the measurements for CSR authenticity, and identify more firm features to compare.

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Customer Integration in the Era of Digital Transformation: Evidence from Third-Party Logistics Firms in China

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Abstract. Integration with client firms is the most important external relationship for third-party logistics (3PL) firms. Based on information processing theory, a conceptual model was developed to explore the mechanism of how customer integration contributes to 3PL firms' performance via differentiation and low-cost advantages, and the moderating effects of information technologies were examined in relation to the trend of digital transformation. Survey data were collected from 235 3PL firms in China and analyzed using structural equation modeling. The results show that customer integration is positively related to the performance of 3PL firms, which is mediated by differentiation and low-cost advantages. In addition, information acquisition technologies and information processing technologies significantly moderate the effect of customer integration on differentiation advantages. These findings help to address the challenges faced by 3PL firms in the context of digital transformation and add to the literature on customer integration and logistics information technologies.

Keywords: Customer integration · Information acquisition technologies · Information processing technologies · Differentiation advantages · Low-cost advantages

1 Introduction

The need to improve logistics quality and customization capabilities has urged third-party logistics (3PL) firms to strengthen their collaborative networks and the integration with client firms is the most important external relationship for third-party logistics (3PL) firms [1–3]. Previous studies have confirmed that customer integration helps to improve a firm's competitive advantages and performance [4, 5], yet there is a limited understanding on the mechanism of how performance is improved by customer integration, especially in the logistics industry, which is rapidly growing in digital economies [6, 7]. The trend of digital transformation entails closer integration and interaction with customers to improve customer experience and reduce costs [8]. As such, the effects of customer integration on differentiation and low-cost advantages and financial performance in 3PL firms need to be further investigated.

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In the context of digital transformation, the traditional customer relationship faces challenges in two main areas [9]. First, logistics data are massive, unstructured and scattered, which poses great challenges to data acquisition and sharing [10]. Second, there is often a lack of stability and trust in partnerships between 3PL firms and client firms [3, 11]. Studies have shown that the collaboration of supply chain partners increasingly rely upon information technologies [12], and that improving information processing capabilities is essential to deal with the above challenges the risks and uncertainties in customer integration [13, 14]. On the basis of information processing theory, we argue that increased investment in information technologies for integration with client firms is linked to a higher level of dynamic information processing capabilities. As such, this study builds a holistic model to investigate the effects of customer integration on 3PL firm performance via differentiation and low-cost advantages, which is moderated by information technologies, namely information acquisition technologies (IAT) and information processing technologies (IPT).

2 Literature Review and Hypotheses Development

2.1 Customer Integration and Competitive Advantages in 3PL Firms

For 3PL firms, external integration includes customer integration and logistics collaborator integration [3]. This paper focuses on customer integration, the formation of strategic alliances with client firms, which involves collaboration in the pursuit of a common vision [15, 16]. SCM studies and practice have repeatedly shown that customer integration is conducive to performance improvement [3, 17]. However, customer integration in 3PL firms, especially the mechanism of its impact on firm performance, has received insufficient attention.

From a strategic management perspective, we consider competitive advantages in two dimensions: differentiation advantages and low-cost advantages [18–20]. "Differentiation advantages" here refers to a 3PL firm's ability to differentiate its services from those of its major competitors in terms of quality, delivery speed and flexibility. "Low-cost advantages" here refers to a 3PL firm's ability to provide lower service costs and prices compared with its major competitors.

2.2 Information Technologies and Information Processing Theory

Information processing theory is centered on information processing requirements and information processing capability [21] and stresses that an organization's efficiency in acquiring and processing related information is critical to its success in a highly uncertain and volatile market [22, 23]. Recent studies have increasingly emphasized the significance of information technologies to SCM through the lens of information processing theory [24]. As such, we incorporate information technologies into the model of customer integration and competitive advantages. We consider two types of information technologies, IAT and IPT [2, 25], because massive data are collected by IAT and then stored and processed by IPT. We argue that information technologies can help 3PL firms strengthen their information processing capabilities during their integration with client firms, thereby improving service quality and reducing costs [26, 27].

2.3 Research Model and Hypotheses

Based on information processing theory, a conceptual model is developed. (see Fig. 1).

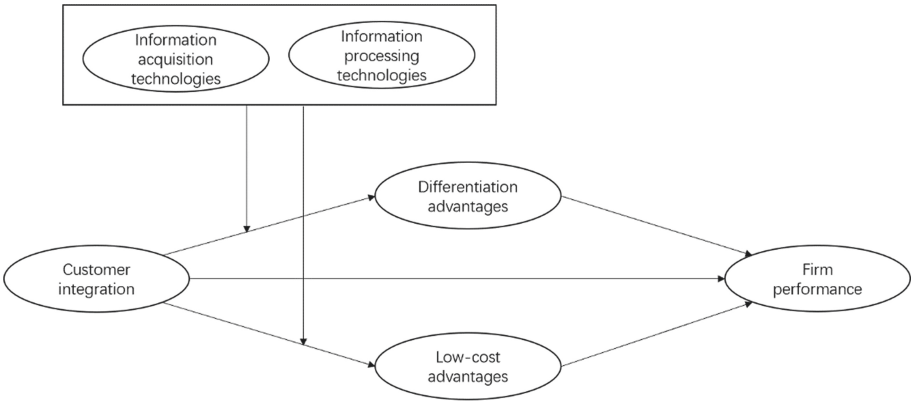

Fig. 1. Conceptual model.

Customer Integration and Firm Performance

The SCM literature has shown that customer integration is positively related to financial performance [15, 28]. The major benefits include reducing resource waste [29], improving efficiency [30] and providing more flexible solutions [31]. By integrating with client firms, 3PL firms can acquire more information about dynamic demands, operations processes and strategic targets [32, 33]. In addition, technology-sharing and risk-sharing with client firms increases 3PL firms' access to advanced technologies and shared values, while reducing economic risks [34]. Hence, we hypothesize as follows:

Hypothesis 1: *Customer integration in 3PL firms is positively related to firm performance.*

The Mediation Effects of Differentiation Advantages and Low-Cost Advantages

Excellent business performance is usually attributed to a firm's ability to transform key resources into core competitive advantages [35]. Competitive advantages are thus an important link between customer integration and firm performance. Previous studies have found that differentiated service are one of the main outcomes of customer integration. Zhao et al. [36] confirmed that customer integration helps firms to discover customer preferences and revise delivery plans, which increases customer satisfaction. Flynn, Huo and Zhao [6] argued that downstream integration with customers generates opportunities for information sharing and collaborative processes, which are positively associated with service quality and response speed. For 3PL firms, customer integration promotes information sharing, joint planning and coordinated operations between the two sides [37]. The benefits include duplication reduction, the flexibility needed to accommodate changes, rapid responses to obstacles and emergencies and ultimately an increase in firm performance [38, 39]. Hence, we hypothesize as follows:

Hypothesis 2a: *Differentiation advantages positively mediates the relationship between customer integration and firm performance.*

By integrating with client firms, 3PL firms can greatly reduce work redundancy and the overallocation of resources, which results in lower costs, such as inventory costs and stockout costs [4, 40, 41]. Liu and Lai [7] indicated that the external integration capabilities of 3PL firms are positively linked with quarter on quarter growth and operating profit margins through cost saving. In-depth integration and shared values with client firms help 3PL firms to manage costs effectively and avoid duplication and resource waste. Therefore, the level and efficiency of customer integration may be positively correlated with the achievement of low-cost advantages, which offer opportunities for 3PL firms to enhance their financial performance [42]. Therefore, we hypothesize as follows:

Hypothesis 2b: *Low-cost advantages positively mediates the relationship between customer integration and firm performance.*

Low cost is seen as the most dependable strategy for 3PL firms to quickly occupy the market, but it rarely functions for long [32]. 3PL firms need to establish differentiation advantages to gain a solid market position in the long run [43]. It is therefore reasonable to expect that the mediation effect of differentiation advantages is stronger than that of low-cost advantages. Indeed, the positive impact of customer integration on differentiation advantages have been consistently recognized, but there have been mixed findings regarding the impact on costs when conditions change. For example, Visser [44] found that logistics firms' specific investment in information systems increased the risks of dependence and spillover in the course of transactions, and that increased coordination and flexibility costs were inevitable with the pursuit of greater external integration [45]. We thus propose the following hypothesis:

Hypothesis 2c: *The mediation effect of differentiation advantages was stronger than the mediation effect of low-cost advantages.*

The Moderation Effects of Information Technologies

Heterogeneity has long been a huge obstacle to the interaction between 3PL firms and client firms in logistics outsourcing activities [46]. IAT and IPT standardize data formats and transmission processes, thus enabling 3PL firms and client firms to input, exchange, monitor and trace the entire logistics process on a unified platform and making decentralized decision-making possible [47, 48]. Hence, various logistics resources can be effectively integrated to alleviate problems caused by heterogeneity in the process of integration, thereby improving delivery efficiency and quality [7, 49]. Even more importantly, by enabling efficient information flow between 3PL firms and client firms, fickle client-specific services can be addressed optimally [50]. Moreover, IAT and IPT improve process visibility and service responsiveness, through which 3PL firms can formulate compatible processes and norms with client firms to strengthen mutual trust and reduce opportunistic tendencies [51, 52]. Therefore, we propose the following hypothesis:

Hypothesis 3: *(a) IAT and (b) IPT positively moderate the relationship between customer integration and 3PL firm's differentiation advantages.*

The benefits of customer integration are also strengthened by the adoption of information technologies from the perspective of cost reduction. First, front-end information acquisition that relies on IAT can provide 3PL firms with more accurate information, and effective feedback during the integration can be used to reduce the risks of speculation and distrust [53]. In this regard, technologies make the integration between 3PL firms and client firms more transparent and effective, thus reducing operational duplication

and resource waste [54]. Second, IPT implemented in 3PL firms can consolidate orders from a wide range of client firms to achieve economies of scale and scope. By expanding the width and depth of integration, costs and resource scarcity can be greatly reduced [55, 56]. Therefore, we propose the following hypothesis:

Hypothesis 4: *(a) IAT and (b) IPT positively moderate the relationship between customer integration and 3PL firm's low-cost advantage.*

3 Research Methodology

3.1 Sampling and Data Collection

The research model was tested using survey data collected from 23 main cities in China from 2017 to 2018. First, a stratified sampling method was adopted to identify 690 3PL firms by city. The sampling pool comprised all logistics companies in the A-level directory of China Federation of Logistics & Purchasing (CFLP). Senior managers and operations managers were targeted for this study. Finally, 235 valid questionnaires were received.

3.2 Measures

To measure customer integration, we comprehensively considered the scales of Liu and Lee [3], Zhao, Feng [15], and Wang, and Islami et al. [19]. Low-cost and differentiation advantages were measured in line with the definitions in the mainstream OM literature [7, 9, 57]. We used financial performance as our measure of firm performance, assessing firm efficiency and effectiveness mainly through sales and turnover growth, market share and investment return [19, 58]. A 7-point Likert scale was used, in which 1 meant "strongly disagree" and 7 meant "strongly agree."

The adoption of information technologies by 3PL firms was assessed through IAT and IPT. Drawing on previous studies, they were measured by the extent to which the main technologies were embedded and well functioned in the whole logistics service process [17, 59]. By reviewing the literature on the taxonomy of modern logistics technologies [58, 60, 61] and learning about the latest technology frontiers, we covered the main technologies applied in logistics industry, including Internet of Thing (IoT), automation, big data and information management systems. Among them, IoT and automation devices are mainly used to improve the efficiency and accuracy of information acquisition, while big data and information management systems are mainly used for information processing and joint management. Thus, we evaluate the adoption of IAT through IoT and automation and evaluate the adoption of IPT through big data and information management systems. These two constructs are formative and items were also measured by a seven-point Likert scale ranging from 1 to 7.

4 Results

4.1 Measurement Validation and Construct Development

In this study, a partial least squares (PLS) method of structural equation modeling (SEM) was used to test the research hypotheses. Analyses were performed in Smart PLS software (3.2.8 version).

Content validity was verified as the measurement constructs were strongly supported by theories and practice developed in previous studies, and it was also verified in pre-tests. The results of the overall exploratory factor analysis (EFA) indicate that the factor loading of each item on its corresponding construct was greater than 0.5, while the cross loadings on other constructs were less than 0.4. This provides comforting evidence of convergent and discriminant validity for the whole measurement model [62]. The EFA results show that only one factor could be extracted from each construct with an eigenvalue greater than one and that more than 50% of variance was explained, further indicating the convergent validity of the measurement [63]. Moreover, the fitting indexes of the six-factor measurement model were obviously better than those of the alternative models, confirming that the proposed measurement constructs were reasonable and valid.

Confirmatory factor analysis (CFA) was used to verify the reliability and convergent validity of the whole measurement (Table 1). The factor loadings of the items range from 0.748 to 0.924, with all above the 0.7 threshold recommended by Fornell and Larcker [64]. Cronbach's alphas for the constructs were above the 0.70 threshold recommended by Nunnally and Bernstein [65], and the composite reliability (C.R.) values all reached the recommended 0.7 threshold [65, 66]. The average variance extracted (AVE) values of the constructs also reached the 0.5 threshold recommended by Fornell and Larcker [64].

Table 1. Construct reliability and validity.

Construct and items	Factor loadings	Cronbach's alpha	C.R	AVE
Customer integration (CI)		0.823	0.880	0.648
CI1	0.748			
CI2	0.753			
CI3	0.838			
CI4	0.874			
Differentiation advantages (DA)		0.827	0.896	0.743
TA	0.844			
QA	0.900			
FA	0.839			
Low-cost advantage (LCA)		0.867	0.908	0.713
PA1	0.904			
PA2	0.838			
PA3	0.781			
PA4	0.851			
Financial performance (FP)		0.903	0.932	0.774
FP1	0.924			
FP2	0.876			
FP3	0.860			
FP4	0.856			

Table 2 shows the correlation coefficients of the constructs, with numbers on the diagonal representing the arithmetic square root of each construct's AVE. The arithmetic square root of each construct's AVE was greater than its correlation coefficients with the other constructs, indicating adequate discriminant validity [64]. In general, the results shown in Table 1 and Table 2 support the measurement model.

Table 2. Convergent validity and discriminant validity.

Constructs	CI	DA	LCA	FP	IAT	IPT
Customer integration (CI)	0.805					
Differentiation advantages (DA)	0.455	0.862				
Low-cost advantages (LCA)	0.283	0.370	0.845			
Financial performance (FP)	0.333	0.289	0.297	0.879		
Information acquisition technology (IAT)	0.365	0.173	0.121	0.176		
Information processing technology (IPT)	0.339	0.185	0.195	0.261	0.482	

Note: Arithmetic square root of AVE is on the diagonal

4.2 Structural Model and Hypotheses Testing

The results of structural model are shown in Table 3. When IAT was the moderator, the model explained 23.3% of the variance in differentiation advantages, 7.6% of the variance in low-cost advantages, and 11.8% of the variance in firm performance. When IPT was the moderator, the model explained 21.4% of the variance in differentiation advantages, 7.6% of the variance in low-cost advantages, and 11.8% of the variance in firm performance. Goodness of fit (GoF) widely serves as the baseline value for validating a PLS model. The GoF values were 0.3200 and 0.3128 when IAT and IPT were moderators respectively, exceeding the cut-off value of 0.25 for medium effect sizes of R^2. Therefore, our model had a satisfactory model fit [67].

Table 3. Results of the hypotheses testing.

Paths	Path coefficients	t-value	Outcomes
H1: CI → FP	0.336****	5.384	Supported
H2a: CI → DA → FP	0.094***	2.492	Supported
H2b: CI → LCA → FP	0.062***	2.783	Supported
H2c: (CI → DA → FP)- (CI → LCA → FP)	0.032****	50.935	Supported
H3a: moderating effect of IAT (CI-DA)	0.213***	2.937	Supported
H3b: moderating effect of IPT (CI-DA)	0.141*	1.828	Supported
H4a: moderating effect of IAT (CI-LCA)	0.063	0.825	Unsupported
H4b: moderating effect of IPT (CI-LCA)	0.047	0.652	Unsupported

* $p < 0.01$; ** $p < 0.05$; *** $p < 0.01$, *** *$p < 0.001$

The direct effect of customer integration on firm performance was significantly positive ($\beta = 0.336$, $p < 0.001$); hence, H1 was supported. Next, the mediating effects were tested, and the results were also significantly positive ($\beta = 0.094$, $p < 0.01$ when mediated by differentiation advantages; $\beta = 0.062$, $p < 0.01$ when mediated by low-cost advantages), supporting H2a and H2b. As predicted, the mediating effect of differentiation advantages was stronger than that of low-cost advantages (the difference was 0.032, $p < 0.001$. Therefore, H2c was supported.

Finally, the moderating effects were tested. First, IAT and IPT positively moderated the relationship between 3PL firms' customer integration and differentiation advantages, with a coefficient of 0.213 ($p < 0.01$) for IAT and 0.141 ($p < 0.1$) for IPT. Hence, H3a and H3b were supported. The moderating effects of IAT and IPT are shown in Fig. 2 and Fig. 3, respectively. Second, the moderation effects of IAT and IPT were not significant, with a coefficient of 0.063 ($p = 0.409$) for IAT and 0.047 ($p = 0.519$) for IPT. Hence, H4a and H4b were not supported.

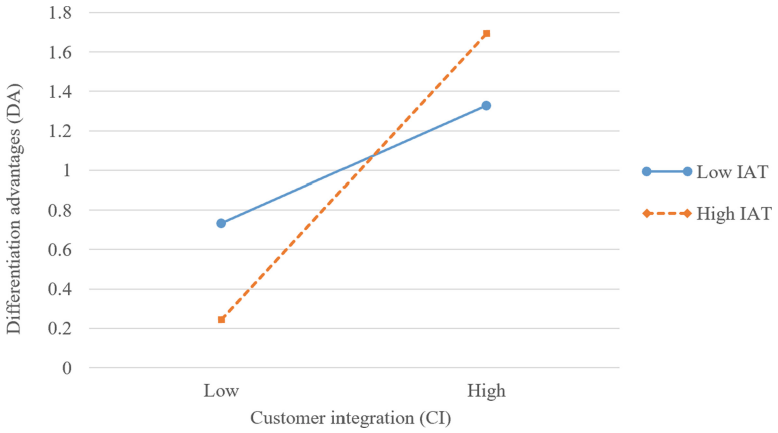

Fig. 2. Moderating effect of IAT.

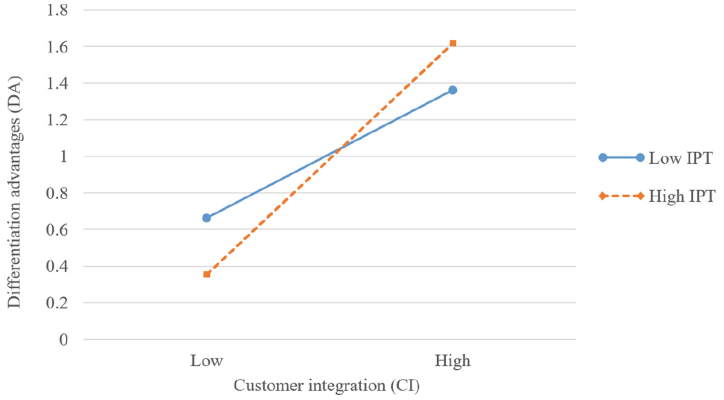

Fig. 3. Moderating effect of IPT.

5 Discussion

Drawing on information processing theory and focusing on 3PL firms, this study models the influence of customer integration on firm performance through differentiation and low-cost advantages and tests the moderating effects of IAT and IPT. Integrating with client firms can improve a 3PL firm's performance by providing differentiated services or reducing logistics costs. Faced with huge amounts of information and growing customer demand, we argue that IAT and IPT are effective in reducing information distortion and improving response speed in the integration with client firms. As such, by applying dynamic information processing capabilities, the advantages of customer integration for differentiation and low-cost advantages can be further emphasized. Thus, this study makes three main theoretical contributions.

First, it provides empirical evidence that customer integration enhances low-cost and differentiation advantages and, in turn improves firm performance. By focusing on these two competitive advantages, this study proposes an overarching framework to aid comprehension of the mechanism by which firm performance is improved by customer integration. Furthermore, our study shows that the mediating effect of differentiation advantages is stronger than that of low-cost advantages. The difference between mediation effects suggests that 3PL firms should pay more attention to the impact of external integration on differentiation (vs. low-cost) advantages.

Second, this study emphasizes the moderating role of information technologies in the relationships between customer integration and differentiation and low-cost advantages based on information processing theory. The strategic deployment of information technologies for customer integration are vital to respond to the high uncertainty and volatility of the contemporary dynamic market. By nurturing dynamic information processing capabilities, the final value is created (Teece and Leih 2016; Wilden and Gudergan 2015). This also offers new insights into digital transformation.

However, our findings indicate that IAT and IPT do not significantly moderate the effect of customer integration on low-cost advantages. This may be explained by the productivity paradox and transaction costs. Technological development and increasing scope of integration may incur new transaction costs for 3PL firms (Hong, Son, and Menachof 2010). This, in turn, might have a negative effect on the development of low-cost advantages. The impact of information technologies on performance is complex, and more knowledge is needed to explore their association in different strategic emphases.

6 Conclusion

This paper evaluates the relationships between customer integration, differentiation/low-cost advantages and firm performance. It also explores the moderating effects of information technologies on the relationship between customer integration and differentiation/low-cost advantages through the theoretical lens of information processing theory. An IT-enabled customer integration approach is likely to be effective in achieving digital transformation. The results confirm that these two competitive advantages can mediate the effect of customer integration on firm performance, but the moderating effects of IAT and IPT only exist for differentiation advantages. Overall, this

paper fills gaps in the literature regarding the customer integration of 3PL firms in the digital era and provides theoretical support for 3PL firms' decision to adopt information technologies.

Managerially, this paper offers practical insights into supply chain integration and logistics management in 3PL firms. First, 3PL firms should focus on integration with client firms in areas relating to differentiation, such as accurate ordering, quick delivery and customized services. Second, this paper stresses the importance of information technologies in 3PL firms' integration with client firms. Managers must be aware of customers' increasingly high expectations and the associated risks and costs in logistics delivery. The deployment of information technologies in the supply chain should be accelerated to capitalize on the advantages of supply chain integration and improve 3PL firms' dynamic information processing capabilities and continuous competitive advantages in today's changeable business environment.

Although this study provides valuable insights into customer integration in the context of 3PL, it has some limitations that provide opportunities for future research. First, this study surveyed more than 200 large 3PL firms in China using random sampling, but the sample did not cover small 3PL firms and start-ups. Future studies should pay more attention to customer integration and technology adoption in smaller 3PL firms or start-ups. Second, this research discusses how 3PL firms can take advantage of customer integration and information technologies to improve their competitive advantages and firm performance; however, contextual factors are also influential. Future studies should consider more environmental factors.

Appendix. Measurement Items

Customer Integration (CI)

CI1: We have high level of information exchange with main client firms through information networks.
CI2: Major client firms can use our system to track the status of goods.
CI3: We share key information such as demand forecasts with main client firms.
CI4: We share information with main client firms about the plans and capabilities of the services we provide.

Differentiation Advantages (DA)

Time Advantages (TA)

TA1: Our delivery is faster.
TA2: Our delivery is more punctual.
TA3: Our delivery is more reliable (no wrong delivery, no damage).

Quality Advantages (QA)

QA1: Our customers are more satisfied.
QA2: Our response to customer inquiries is much faster.
QA3: Our response to customer claims and complaints is much faster.

Flexibility Advantages (FA)

FA1: We are more responsive to customer urgent orders.
FA2: We are more responsive to changes in customer demand.
FA3: We are more flexible to customers' special requirements.

Price Advantages (PA)

PA1: Our logistics costs are lower.
PA2: Our service costs are lower.
PA3: Our service prices are lower.
PA4: We have cost advantage overall.

Financial Performance (FP)

FP1: Average growth rate of turnover over the past two years.
FP2: Average growth rate of market share over the past two years.
FP3: Average growth rate of return on sales over the past two years.
FP4: Average growth rate of return on investment over the past two years.

Information Acquisition Technology (IAT)

IAT1: We have widely adopted Internet of Things technologies in operational activities.
IAT2: We have widely used automation devices in operational activities.

Information Processing Technology (IPT)

IPT1: We have widely adopted information management systems in operational activities.
IPT1: We have widely used big data technologies in operational activities.

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Is Balanced Working Capital a Good Strategy for Supply Chain Financial Collaboration?

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Abstract. Current supply chain finance studies focus on the financing channel of firms, but how the capital flows within the supply chain remains to be discussed. Because of the power distance between trading partners, large strong firms tend to utilize its bargaining power to gain favorable terms, so the capital that small firms obtain through SCF solutions flow back to large powerful firms again. This study puts forward the strategy of the balanced working capital distribution among trading partners and empirically investigates its impact on the performance of both supply chain and trading members.

Keywords: Supply chain finance · Working capital management · Cash conversion cycle

1 Introduction

In the last decade, technological improvement and innovations in finance industry has significantly reduced transaction costs and mitigated the information asymmetry problem in the capital market. New ways of financing, such like Supply Chain Finance (SCF) among others, have effectively alleviate the financing difficulties for firms, especially Small and Median Size Enterprises (SMEs). SCF is defined as an optimizing method that the companies in a supply chain to create value inter-organizationally though the financial flow, aiming to improve the efficiency of capital utilisation along the supply chain and to fill in short-term liquidity gaps in particular (Hofmann 2005). SCF has drawn increasing attentions from academics, industries, as well as governments. More firms and financial institutions are proactively adopting SCF solutions, such as reverse factoring and dynamic discounting (Martin and Hofmann 2019).

Majority of studies on the SCF focus on the financing channel of firms, but how supply chain members operate with the capital within the supply chain remains to be discussed. Financing is only one part of the SCF, and it is not comprehensive to isolate financing from operations (Hofmann 2005). Therefore, this study tends to delve further into the use of financial resources in supply chain after the capital pours in. Finance theories suggest that firms tend to pay payables late and collect receivables early. Because of the power distance within the supply chain, large strong firms tend to utilize bargaining power to gain favorable terms and weak small firms accommodate themselves and compromise

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on unfair trading terms (Fabbri and Klapper 2016, Crook and Combs 2007). Therefore, the capital that small and weak firms obtain through SCF solutions flow back to large powerful firms again. The dilemma that SMEs make effortful attempt to finance while losing capital to powerful firms at the same time would negate the benefits from adopting SCF solution and result in the inefficient operation of the whole supply chain.

As the receivables of the upstream contributes to the payables of the downstream in the supply chain, financial relationship between trading partners is reflected through the working capital. It is necessary to take the reactions of both upstream and downstream into consideration from a holistic view when making decision on working capital management (WCM). This study uses the balanced degree of working capital distribution to indicate the liquidity and efficiency level among supply chain members, and whether firms in supply chain are not squeezed by unfair trading term. Triadic supply chains are constructed for panel data analysis. Our results show that when the working capital level is balanced distributed among trading partners, both supply chains and firms obtain a better performance.

2 Literature Review and Hypotheses Development

Working capital management studies mainly discuss the optimization, determinants and environment impact from single firm perspective, without considering the growing interdependency between firms. Traditional working capital management suggest that the firm should either adopt conservative working capital strategy or aggressive working capital strategy (Altaf and Ahmad 2019). Recent studies on working capital management start to emphasize this trade-off between liquidity and profitability, and suggest the relationship between working capital level and firm performance is a concaved (Wetzel and Hofmann 2019, Altaf and Ahmad 2019, Baos-Caballero et al. 2014).

However, firms are not isolated in the market but interdependent with each other. Firms are no longer content with waste eliminating between departments internally, but minimizing the waste between firms externally (Stemmler 2002). The rise of supply chain finance brings urge firms to review working capital management strategies from a holistic view. Individual profit optimization may be hurtful to the joint benefits of the entire supply chain and firms should support and nurture each other in a supply chain instead of compressing for local benefit (Lee and Rhee 2011). Supply chain finance-oriented management allows customers and suppliers to share demand risk and profit at trading partners' advantages in financial resources. Therefore, firms not only need to consider the trade-off between liquidity and profitability, but also need to take the other firms' behavior into consideration (Barratt 2004).

The distribution of working capital among trading partners may reflect more information: fairness of trading terms, distance of operation efficiency and difference of liquidity level. Balanced working capital distribution indicates that the trading terms are fair in supply chain (Grosse-Ruyken et al. 2011). The unfair trading terms can aggravate the difference of working capital level between trading partners. Balanced working capital distribution in supply chains implies fairly distributed working capital for each member and no short board firm with particularly server liquidity problem compering with their own industrial peers. Moreover, as working capital metrics also give a view of

the company's operating efficiency, firms working capital difference also indicates the efficiency distance in operation and management (Wang 2019). To ensure the flexibility and responsiveness of the supply chain, trading partners need to incorporate tightly to achieve a suitable working capital distribution that works for all members, which also enhance the stability and robustness of the supply chain structure (Grosse-Ruyken et al. 2011). It ensures the quick turnover of all members in the supply chain, which enables supply chain members to utilize capital efficiently and respond quickly to the market demand (Protopappa-Sieke and Seifert 2017). Based on these arguments, we propose that inter-organizational working capital management and balanced working capital distribution is essential in supply chains, which is able to improve supply chain performance. Therefore, the first hypothesis is: Balanced working capital distribution is positively correlated to the supply chain performance.

However, whether all supply chain members are benefited from the balanced working capital distribution remains moot. Various studies have confirmed that the use of trade credit is determined by the bargaining power of the firm that steams from the resources that the firm has and to what extend other firm rely on these resources (Mateut and Chevapatrakul 2018, Crook and Combs 2007, Kim and Henderson 2015). Firms that have high bargaining power are normally large, profitable and financially strong and they may utilize bargaining power to gain favorable terms from trading partners (Fabbri and Klapper 2016, Crook and Combs 2007). Meanwhile, less powerful suppliers and customers accommodate themselves and compromise on trading terms. The supply chain collaboration indicates that powerful firms need to give up their monopoly rents and take the liquidity of trading partners into consider when making working capital decisions in order to avoid supply chain disruption. On the other hand, all supply chain members can enjoy the cost saving and efficiency improvement through collaborative supply chain management. Therefore, the second hypothesis is: Balanced working capital distribution is positively related to the performance of all trading members.

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3 Data and Variable Construction

All firms involved in empirical investigation are North American listed firms. The main reason to choose North American firms as observations is the data availability and accuracy. Data including firm relationship and financial information used in this study is collected from Compustat and SEC 10-k annual reports. "Fundamentals Annual" contains information of Income Statement, Balance Sheet and Statement of Cash Flows since 1950. SEC 10-k annual reports are used to double check and fill the missing value. Monetary based values are inflation adjusted and measured in US dollars.

In order to understand the overall performance measure of the whole supply chain, we constructed a triadic supply chain based on the disclosed information on focal firm's major customers. Customer information is available in "Segments (Non-Historical) – Customer" on an annual basis Over 137,000 records of customer relationship are provided since 2013. The construction process are as follows:

Table 1. Firm level variables.

Variable name	Acronym	Measurement	Expt sign
Firm ROA	$adjROA_{j,t}$	$ROA_{j,t} = \frac{NetIncome_{j,t}}{AssetTotal_{j,t}}$; $adjROA_{j,t} = ROA_{j,t} - medianROA_{j,t}$ The ability of firms to generate outcomes using the total assets comparing to industry median level	/
Firm Tobin's Q	$adjTobinsQ_{j,t}$	$TobinsQ_{j,t} = \frac{DebtMarketvalue_{j,t}+Equity_{j,t}}{AssetTotal_{j,t}}$; $adjTobinsQ_{j,t} = TobinsQ_{j,t} - medianTobinsQ_{j,t}$ Market value of assets to book value of assets ratio	/
Cash Conversion Cycle	$adjccc_{j,t}$	$ccc_{j,t} = \frac{Inventory_{j,t}}{COGS_{j,t}} * 365 + \frac{Receivables_{j,t}}{Sales_{j,t}} * 365 - \frac{Payables_{j,t}}{COGS_{j,t}} * 365$; adj$ccc_{j,t} = ccc_{j,t} - medianccc_{j,t}$ The number of days that cash is collected from a sale after the firm pays for the production materials	+
Net Working Capital	$adjnwc\_sale_{j,t}$	$nwc\_sale_{j,t} = (Inventory_{j,t} + Receivables_{j,t} - Payables_{j,t})/Sales_{j,t}$; adj$nwc_sale_{j,t} = nwc_sale_{j,t} - mediannwc_sale_{j,t}$ Difference between firm non-cash current asset and short-term obligation	+
Firm Size	$adjSize_{j,t}$	$Size_{j,t} = ln(Sales_{j,t})$; $adjSize_{j,t} = ln(Sales_{j,t} - mediansale_{j,t})$ Natural log of firm total sales.	+
Firm Tangible Ratio	$adjTangible_{j,t}$	$Tangible_{j,t} = \frac{PP\&E_{j,t}}{AssetTotal_{j,t}}$; $adjTangible_{j,t} = Tangible_{j,t} - medianTangible_{j,t}$ The ratio of net property plant and equipment over total assets.	+/-
Firm Leverage Ratio	$adjLeverage_{j,t}$	$Leverage_{j,t} = \frac{DebtTotal_{j,t}}{EquityTotal_{j,t}}$; $adjLeverage_{j,t} = Leverage_{j,t} - medianLeverage_{j,t}$ Firm financial leverage, calculated as total debt over total equity.	-
Firm Age	$adjAge_{j,t}$	Time from the IPO or Compute the years of accounting data available in Compustat is regarded as firm age.	+
Firm Cash Flow Ratio	$adjCashflow_{j,t}$	$Cashflow_{j,t} = \frac{Income_{j,t}+Depreciation_{j,t}}{AssetTotal_{j,t}}$; $adjCashflow_{j,t} = Cashflow_{j,t} - medianCashflow_{j,t}$ Firm cash flow ratio, calculated as income plus depreciation and amortization over total asset	+

As the database only provides customer names or abbreviated names without unique identification code, data organizing start from identifying reported customers with unique GVKEY codes. The matching process includes fuzzy matching and manual matching. In the end, 12,077 pairs of supplier-customer are identified. These supplier-customer pairs are then merged to form three-firm supply chains or triadic supply chains. In total, 2415 triadic supply chains are obtained with 6459 observations. If the same customer was reported again but not in consecutive years, it is assumed the relationship of principle customer and the focal firm is stable in this interval. Under this assumption, 2431 chains with 6722 observations are constructed during 2013 to 2020 in total. The firms are classified into 10 industries according to Global Industry Classification Standards (GICS). Financials, utilities and real estate firms are not considered and omitted in this study, as these firms usually have very unique capital structures. After cleasing the chains that has incomplete financial information and chains that only appear once, and further winsorizing observations of main variables to one percent tail to deal with outliers, 840 chains are constructed in the end.

As for empirical investigation, all firm level variables will be industry median adjusted according to GICS-2-digit category to control for industry specific factor. Firm level metrics are constructed as the deviation from its industry median level. Chain level metrics are constructed as the deviation from the weighted average of the component firm's industry median level. Financial performance will be measured by Return on Asset (ROA) and Tobin's Q, which are widely adopted to capture the firm outcome at aggregate level (Kim and Ivey 2015, Aktas et al. 2012, Wetzel and Hofmann 2019).

ROA is an accounting proxy for short-term financial performance, while Tobin's Q is a market-based proxy for long-term financial performance (Altaf and Ahmad 2019). ROA effectively measures how firms generate returns using the assets (Wagner et al. 2012), while the Tobin's Q indicates the expected profitability by comparing the market value and book value. The detailed calculations of firm level variables are exhibited in Table 1.

Working capital is measured by both monetary-based measurement, Net Working Capital (NWC), and time-based measurement, Cash Conversion Cycle (CCC). NWC measures how much firm current asset that firm has after pay off the short-term obligations. Following Hill et al. (2010) and Afrifa (2016), we focus on the non-cash working capital, which can reduce the impact of cash holding on the result and highlight the operational effect (Hill et al. 2010). On the other hand, CCC is introduced to measure the time interval between cash inflow and cash outflow (Gitman 1974). NWC can underline the capital cost incurred in holding excess current asset over current liability. Meanwhile, CCC is generated from three turnover ratios and can evaluate the firm operational efficiency. Therefore, the difference in NWC reflects the cost differentials between firms, while the difference in CCC indicates the efficiency differentials in operation management.

To quantify the proposed argument of balanced working capital distribution among firms of a supply chain, logarithmic sum of squared deviations of industry median adjusted firm CCC/NWC level from the average industry median adjusted CCC/NWC level of the supply chain members are calculated, following Wetzel and Hofmann (2019). As firms in a supply chain may be from different industries, direct comparison on the absolute level of working capital may subject to industry heterogeneity, the balance working capital measure used in this study essentially measures the degree of balance in terms of firms' deviation from their own industrial peers' normal working capital holding. Detailed definitions are shown in Table 2.

To test for differentials in benefit of balanced working capital distributions to firms with different financial positions, firm financial condition dummy, Constraint_(j,t), is generated based on firm net cash flow ratio. Cash flow of the firm reflects whether the firm has comparative advantage in the obtaining capital at a lower cost (Randall and Farris 2009). Afrifa (2016) finds that the adequate cash flow can promote the performance of working capital management as it can be a cheap financing source. Moreover, Chou et al. (2014) and Hill et al. (2010) also find that firms with high cash flow are able to attract more investment. Cash flow ratio is calculated as income plus depreciation and amortization over total asset. Because the cash flow ratio has a highly similar calculation as dependent variable ROA does, the dummy variable of cash flow ratio is more suitable than the numerical measurement.

Firm performance is also controlled by the following variables: firm age, firm size, leverage ratio and tangible ratio. We measure and define all firm level variables in Table 1. Meanwhile, the aggregate variables are constructed to control supply chain characteristics: supply chain sales concentration, collaborating length, supply chain size, leverage ratio and market-to-book ratio. The detailed information of chain level variables is in Table 2. Collaboration duration and sales concentration is used to measure how tight

Table 2. Chain level variables.

Variable name	Acronym	Measurement
Chain ROA	$chainROA_{i,t}$	$chainROA_{i,t} = \frac{\sum_{j=1}^{j=3} NetIncome_{j,t}}{\sum_{j=1}^{j=3} AssetTotal_{j,t}} - \sum_{j=1}^{j=3} (medianROA_{j,t} \times \frac{Asset_{j,t}}{\sum_{j=1}^{j=3} Asset_{j,t}})$ Chain aggregate ROA minus asset weighted average industry median ROA of three trading members
Chain Tobin's Q	$chainTobinsQ_{i,t}$	$chainTobinsQ_{i,t} = \frac{\sum_{j=1}^{j=3} (DebtMarketvalue_{j,t} + Equity_{j,t})}{\sum_{j=1}^{j=3} AssetTotal_{j,t}} - \sum_{j=1}^{j=3} (medianTobinsQ_{j,t} \times \frac{Asset_{j,t}}{\sum_{j=1}^{j=3} Asset_{j,t}})$ Chain aggregate Tobin's Q minus asset weighted average industry median Tobin's Q of three trading members
balance degree of CCC	$balccc_{i,t}$	$balccc_{i,t} = \ln \sum_{j=1}^{j=3} (ccc_{j,t} - \frac{\sum_{j=1}^{j=3} ccc_{j,t}}{3})^2$ Logarithmic sum of squared deviations from the average CCC in supply chain
balance degree of NWC	$balnwc_{i,t}$	$balnwc_{i,t} = \ln \sum_{j=1}^{j=3} (nwc/sales_{j,t} - \frac{\sum_{j=1}^{j=3} nwc/sales_{j,t}}{3})^2$ Logarithmic sum of squared deviations from the average NWC-sales ratio in supply chain
Duration	$duration_{i,t}$	Length of trading years: years that customer is reported
Sales concentration	$concentration_{i,t}$	$concentration_{i,t} = \frac{sales\ beween\ j=1\ and\ j=2}{total\ sales_{j=1}} \times \frac{sales\ beween\ j=2\ and\ j=3}{total\ sales_{j=2}}$ The product of sales proportion between firms to total sales
Chain Size	$ChainSize_{i,t}$	$ChainSize_{i,t} = ln(\sum_{j=1}^{j=3} adjSales_{j,t})$ Natural log of supply chain total sales.
Chain Leverage	$chainLeverage_{i,t}$	$chainLeverage_{i,t} = \sum_{j=1}^{j=3} (Leverage_{j,t} \times \frac{Equity_{j,t}}{\sum_{j=1}^{j=3} Equity_{j,t}})$ Equity weighted average industry median adjusted leverage ratio.
Chain Market to Book Ratio	$chainMBR_{i,t}$	$chainMBR_{i,t} = \sum_{j=1}^{j=3} (MBR_{j,t} \times \frac{Sales_{j,t}}{\sum_{j=1}^{j=3} Sales_{j,t}})$ Sales weighted average industry median adjusted market-to-book ratio.

the relationship between trading partners. Supply chain aggregate leverage ratio, market-to-book ratio and supply chain size are constructed as the aggregated value. The industry median value of the supply chain level metrics is calculated as the denominator weighted average of supply chain members' industry median values.

Figure 1 plots the trends of median values of variables during the sample period. Tobin's Q is rather stable during this time. Median value of Chain ROA is increasing and median values of unbalanced degree have the opposite trend during this time. NWC also has a clear increasing trend. Firms are divided into financially constrained group (read line) and healthy group (yellow line) based on the cash flow ratio. Financially healthy firms have better performance than the constrained firms regarding ROA and Tobin's Q. Both groups have a slight rise in ROA but a significant decrease in Tobin's Q. Moreover, the median values of median adjusted CCC and NWC of financially healthy firms have been decreasing, while those of constrained firms have been increasing during this period, which fits the bargaining theory in trade credit.

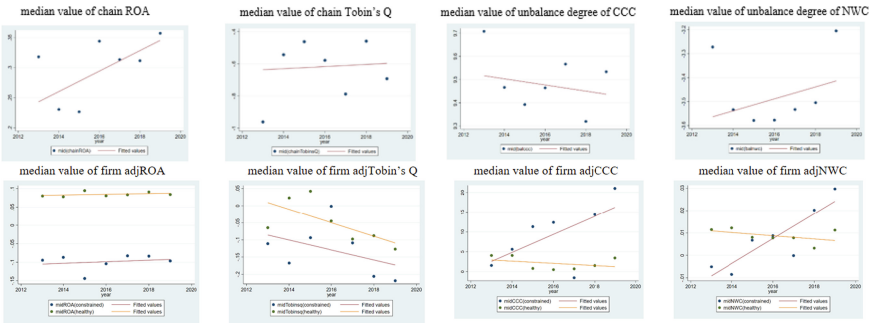

Fig. 1. Median values of variables.

4 Empirical Investigation and Results

This study starts with a supply chain level analysis and then conduct a firm level test. In Model 1, $ChainPerformance_{i,t}$ is the dependent variable to estimate supply chain financial performance, which consisted of ROA and Tobin's Q. Unbalanced degree of working capital $balccc_{i,t}$ and $balnwc_{i,t}$ measure the distribution of CCC and NWC among trading members. Lagged value are used for independent variables to alleviate endogeneity problem. The dataset used in this study is a panel data set. The results of LM test and Hausman test suggest that fixed effect model should be adopted. Similar test applies to NWC as well.

$$\begin{aligned} ChainPerformance_{i,t} &= \beta_0 + \beta_1 balccc_{i,t-1} + \beta_2 duration_{i,t-1} \\ &+ \beta_3 concentration_{i,t-1} + \beta_4 chainSize_{i,t-1} + \beta_5 chainLeverage_{i,t-1} \\ &+ \beta_6 chainMBR_{i,t-1} + \beta_7 GDP_t + \varepsilon \end{aligned} \tag{1}$$

Model 2 will investigate whether all members are benefited from this balanced CCC or NWC in general. ROA and Tobin's Q of firm j from Chain i at time t is noted as $adjPeformance_{j,t}$. Hypothesis 2 supports the idea that firms are able to benefit from fair trading terms and efficient supply chain management. Therefore, coefficient of $balccc_{i,t}$, β_1, is expected to be negative. Interaction terms in Model 3 between balance degree of working capital distribution and financial condition dummy, $balccc_{i,t-1} \times Constraint_{j,t}$, present the different impact of balanced working capital distribution on performance of firms in different financial condition. Similar test applies to NWC as well.

$$\begin{aligned} adjPerformance_{j,t} &= \beta_0 + \beta_1 balccc_{i,t-1} + \beta_2 duration_{i,t-1} + \beta_3 adjccc_{j,t-1} \\ &+ \beta_4 adjccc^2_{j,t-1} + \beta_5 adjLeverage_{j,t-1} + \beta_6 adjTangible_{j,t-1} + \beta_7 Size_{j,t-1} \\ &+ \beta_8 Age_{j,t} + \varepsilon \end{aligned} \tag{2}$$

$$\begin{aligned} adjPerformance_{j,t} &= \beta_0 + \beta_1 balccc_{i,t-1} + \beta_2 duration_{i,t-1} + \beta_3 adjccc_{j,t-1} \\ &+ \beta_4 adjccc^2_{j,t-1} + \beta_5 adjLeverage_{j,t-1} + \beta_6 adjTangible_{j,t-1} + \beta_7 Size_{j,t-1} \\ &+ \beta_8 Age_{j,t} + \beta_9 balccc_{j,t-1} \times Constraint_{j,t} + \varepsilon \end{aligned} \tag{3}$$

Table 3. Supply chain performance and working capital distribution.

Variables	(1) $chainROA_{i,t}$	(2) $chainROA_{i,t}$	(3) $chainTobinsQ_{i,t}$	(4) $chainTobinsQ_{i,t}$
$balccc_{i,t-1}$	-0.00342**		-0.00696	
	(-2.356)		(-0.627)	
$balnwc_{i,t-1}$		0.000354		-0.0240**
		(0.302)		(0.0110)
$concentration_{i,t-1}$	0.0267	0.0319	0.0265	0.0888
	(0.655)	(0.830)	(0.0647)	(0.397)
$chainSize_{i,t-1}$	0.0910***	0.0941***	-0.801***	-0.820***
	(6.637)	(6.836)	(-4.033)	(0.196)
$chainLeverage_{i,t-1}$	-0.0191**	-0.0198**	-0.00938	-0.00860
	(-2.511)	(-2.545)	(-0.958)	(0.00946)
$chainMBR_{i,t-1}$	0.00301**	0.00310**		
	(2.485)	(2.504)		
$duration_{i,t}$	0.00818***	0.00818***	-0.00135	-0.000548
	(6.394)	(6.272)	(-0.0956)	(0.0140)
$GDPgrowth_{t-1}$	-0.0779***	-0.0777***	0.0402***	0.0353***
	(-21.80)	(-21.37)	(2.943)	(0.0137)
Constant	-0.729***	-0.799***	9.095***	9.173***
	(-4.391)	(-4.916)	(3.878)	(2.322)
Observations	1,491	1,488	1,564	1,561
R-squared	0.498	0.496	0.114	0.118
No. of chains	630	626	668	664

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3 exhibits the result of empirical tests of Model 1and 2 which exams the relationship between unbalance degree of working capital distribution and financial performance of the whole supply chain through fixed effect model. The unbalanced degree of CCC is significantly and negatively correlated to the chain ROA and the unbalanced degree of NWC is significantly and negatively correlated to the chain Tobin's Q, which rejects the null hypothesis of H1. The results suggest that the supply chain whose CCC is balanced distributed among trading members has superior ROA, and the supply chain whose NWC is balanced distributed among trading members has superior Tobin's Q. The results also agree with the idea that fair trading terms between members are beneficial to the overall chain performance, as stable and uninterrupted supply chains are expected to bring advantage into full play (Grosse-Ruyken et al. 2011, Cao et al. 2010).

Table 4 provides the results of Model 2 and 3. Overall, unbalanced CCC and NWC distributions have no significant correlation with firm ROA or Tobin's Q. By adding the interaction term of firm financial condition and working capital distribution, correlations between firm performance and working capital distribution are discussed separately for financially constrained and healthy firms. The relationship between unbalanced CCC distribution and firm ROA is straightforward and significant at 5 percent. Together with interaction terms, the coefficient of unbalance degree of financially constraint firms is

Table 4. Firm performance and working capital distribution.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	$adjROA_{j,t}$	$adjROA_{j,t}$	$adjTobinQ_{j,t}$	$adjTobinQ_{j,t}$	$adjROA_{j,t}$	$adjROA_{j,t}$	$adjTobinQ_{j,t}$	$adjTobinQ_{j,t}$
$balccc_{i,t}$	-0.00463	-0.0113**	-0.00895	-0.00408				
	(0.00303)	(0.00455)	(0.0217)	(0.0309)				
$balnwc_{i,t-1}$					0.000358	0.0160	0.00912	0.00900
					(0.00492)	(0.0114)	(0.0357)	(0.0626)
$duration_{i,t}$	-0.00434	-0.00225	-0.0392	-0.0403	-0.00739**	-0.00447	-0.0393	-0.0429
	(0.00324)	(0.00296)	(0.0319)	(0.0318)	(0.00367)	(0.00325)	(0.0279)	(0.0283)
$adjccc_{j,t}$	0.000602***	0.000478***	-0.00143	-0.00137				
	(0.000189)	(0.000143)	(0.00154)	(0.00156)				
$adjccc_{j,t}{}^2$	-0.0102**	-0.00839***	0.00300	0.00206				
	(0.00426)	(0.00312)	(0.0372)	(0.0374)				
$adjnwc_{j,t}$					-0.0367	-0.00845	0.520	0.469
					(0.0900)	(0.0715)	(0.605)	(0.598)
$adjnwc_{j,t}{}^2$					-32.87	-86.93	-2,355	-2,253
					(348.5)	(270.6)	(2,736)	(2,721)
$adjLeverage_{j,t}$	-0.000270	-0.000275	0.000694	0.000686	-5.53e-05	-0.000236*	-0.000503	-0.000127
	(0.000332)	(0.000245)	(0.000938)	(0.000912)	(0.000187)	(0.000140)	(0.00122)	(0.00126)
$adjAge_{j,t}$	0.00662***	0.00639***	-0.0306	-0.0305	0.00750**	0.00702**	-0.0187	-0.0180
	(0.00240)	(0.00221)	(0.0240)	(0.0241)	(0.00312)	(0.00277)	(0.0284)	(0.0281)
$adjSize_{j,t}$	0.00491	0.00744	-0.393***	-0.395***	-0.0167	-0.0106	-0.584***	-0.597***
	(0.0141)	(0.0123)	(0.148)	(0.148)	(0.0160)	(0.0134)	(0.156)	(0.157)
$adjTang_{j,t}$	-0.0692	-0.0909	-0.361	-0.350	0.00800	-0.0429	-0.320	-0.238
	(0.0728)	(0.0684)	(0.534)	(0.537)	(0.101)	(0.0992)	(0.512)	(0.515)
$Constraint_{j,t}$		0.101***		-0.0396		0.178***		-0.359**
		(0.0300)		(0.155)		(0.0368)		(0.164)
$balccc_{i,t} \times Constraint_{j,t}$		0.0101**		-0.00717				
		(0.00411)		(0.0261)				
$balnwc_{i,t} \times Constraint_{j,t}$						-0.0151		-0.00877
						(0.0115)		(0.0545)
Constant	0.0181	-0.0842	3.819***	3.862***	0.132	-0.0337	4.930***	5.267***
	(0.105)	(0.0931)	(1.093)	(1.121)	(0.123)	(0.100)	(1.204)	(1.246)
Observations		1,313	1,297	1,297	1,427	1,427	1,377	1,377
R-squared	0.059	0.273	0.049	0.050	0.017	0.209	0.091	0.099
No of Firms	542	542	536	536	571	571	553	553

Standard error in parentheses
*** p<0.01, ** p<0.05, * p<0.1

-0.0113 and it of financially healthy firms is -0.0012. It indicates that both financially constraint firms and financially healthy firms are benefited from balanced working capital distribution, but the impact of working capital distribution on financially constrained firm is much larger than it on financially healthy firms. However, the results of NWC distribution are not significant in these tests. It indicates that there is no direct relationship between NWC distribution and financial performance. Moreover, results regarding Tobin's Q are all insignificant. It is possible that the working capital distribution does not affect the market-based performance of the firm.

5 Conclusion

The current capital market situation underlines the importance of working capital management. As the market is more and more integrated and the rise of supply chain management, the interdependence between firms cannot be ignored. Although there are studies focusing on the firm working capital management, the investigation on working capital management from supply chain perspective is still scarce. Supply chain studies mainly adopt theoretical modelling or quantitative method through survey and interviews. There are supply chain finance studies that use secondary empirical data to test the relationship between supply chain relationship and focal firm performance, despite of the fact that supply chain finance strategy is made inter-organizationally and impact on other trading members in the supply chain has to be taken into consideration. These studies jump to the conclusion of SCF collaboration can improve firm performance, but still need a deeper investigation to verify that SCF strategy is made out of the whole supply chain's interest, which eventually benefit firms. To fill these two research gaps, this study use North America listed firm data to empirically test the impact of SCF oriented working capital strategy on the performance of both the overall supply chain and individual firms in the chain.

This study has several potential contributions. To our best knowledge, this study is the first study to use principal customer information to form triadic supply chains and empirically test the impact of working capital distribution on chain level performance. Secondly, this study makes theoretical contribution to the effective working capital distribution in supply chain. Balanced working capital distribution is emphasized in this study as a proxy of SCF collaboration. It indicates the fair trading terms and adequate liquidity level among trading partners in the supply chain. Moreover, the result of this study contributes to the debt of whether firms are benefited from the supply chain collaboration. This study divides trading partners into financially constraint and financially healthy firms and discuss the impact of balanced working capital distribution on performance of these two groups of firms separately.

The result of this study shows that balanced CCC distribution as a SCF oriented working capital strategy has positive impact on the ROA of the whole supply chain. Moreover, the balanced CCC distribution also improve the ROA of the financially constrained firms as they are benefited from the fair trading terms and liquidity provided by trading members through supply chain financial collaboration. Though financially healthy firms give up monopolistic rents and provide liquidity to constraint trading partners, they are also benefited from the balanced working capital distribution, as they are also able to enjoy the cost saving and efficiency improvement resulted from the supply chain collaboration.

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